Design and Development of A Smart Military Robot for Surveillance and Explosive Handling

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Abstract: *The Design and Development of a Smart Military Robot for Surveillance and Explosive Handling focuses on creating an intelligent unmanned ground vehicle (UGV) capable of operating in hazardous and high-risk environments. The system is built around the Raspberry Pi microcontroller, which serves as the main processing and control unit. The robot is designed to assist defense and security forces in surveillance, reconnaissance, and suspicious object handling operations while minimizing human exposure to danger.*

The Raspberry Pi enables real-time video streaming, wireless communication, sensor data processing, and remote operation through a web or mobile interface. The robot integrates a night vision camera for continuous monitoring, ultrasonic sensors for obstacle detection, a metal detector sensor for identifying potential explosive materials, and a robotic arm controlled by servo motors for safe handling of suspicious objects. GPS integration allows real-time location tracking, improving situational awareness during field deployment.

The proposed system offers a cost-effective, efficient, and reliable solution for military surveillance and explosive handling tasks. By combining embedded systems, IoT communication, and robotic mechanisms, the smart military robot enhances operational safety, reduces human casualties, and improves mission efficiency in critical defense applications..

Keywords*: Smart Military Robot, Raspberry Pi, Surveillance System, Explosive Detection, Unmanned Ground Vehicle (UGV), Robotic Arm, Metal Detector Sensor, IoT, Wireless Communication, Night Vision Camera, Defense Robotics*

I. INTRODUCTION

The rapid advancement of technology has significantly transformed modern military and defense systems, shifting the focus toward automation, intelligence, and enhanced safety measures. In contemporary warfare, surveillance and reconnaissance play a crucial role in gathering real-time information, assessing threats, and supporting strategic decision-making. However, traditional surveillance methods often require direct human involvement, exposing soldiers to extreme dangers such as ambushes, landmines, improvised explosive devices (IEDs), and chemical hazards. These challenges have driven global research efforts toward the development of robotic systems capable of performing surveillance and explosive handling tasks in hostile environments while minimizing risks to human life [1], [2].

Military robots have emerged as an effective solution to address the limitations of manual surveillance and bomb detection techniques. These robots are designed to operate in unpredictable and hazardous terrains, providing real-time data without requiring the physical presence of defense personnel. The integration of embedded systems, wireless communication, and advanced sensor technologies enables such robotic platforms to detect threats, monitor surroundings, and transmit critical information to remote control stations. Research has shown that robotic surveillance systems significantly improve situational awareness and response time during military operations, making them indispensable tools in modern defense strategies [3], [4].

One of the most important aspects of a military surveillance robot is real-time visual monitoring. Live video streaming allows operators to remotely observe battlefield conditions, identify suspicious activities, and plan appropriate actions

without exposing soldiers to danger. Camera modules integrated with microcontrollers and wireless networks have been widely used to transmit real-time video feeds over secure cloud platforms. Recent studies emphasize that IoT-based video surveillance systems enhance operational flexibility by enabling access to live footage from any location, thereby supporting faster and more informed decision-making in critical situations [5], [6].

In addition to visual surveillance, explosive and landmine detection is a major concern in military and border security operations. Hidden explosives pose severe threats not only to soldiers but also to civilians in conflict-prone regions. Metal detectors integrated into mobile robotic platforms have proven effective in identifying buried metallic objects such as landmines and unexploded ordnance. By detecting such threats at an early stage, robotic systems help prevent accidental detonations and reduce casualties. Several researchers have highlighted the effectiveness of robotic metal detection systems in enhancing safety during bomb disposal and reconnaissance missions [7], [8].

Environmental hazards such as toxic gases, smoke, and chemical leaks further complicate military operations, particularly in enclosed or damaged structures. Exposure to hazardous gases can cause severe injuries or fatalities within a short period. Gas sensors integrated into surveillance robots provide early detection of harmful substances, allowing timely alerts and preventive actions. Studies indicate that combining gas detection with robotic surveillance significantly improves hazard assessment and emergency response capabilities, especially in war zones and disaster-affected areas [9], [10].

Accurate location tracking is another critical requirement for military robots operating in remote or unfamiliar territories. Global Positioning System (GPS) technology enables continuous tracking of the robot's position, facilitating navigation, mission coordination, and recovery if communication is lost. GPS-enabled robotic systems allow commanders to monitor movement patterns and deploy resources more efficiently. Research demonstrates that the integration of GPS with surveillance robots enhances operational reliability and supports real-time mission planning in dynamic battlefield conditions [11], [12].

The use of low-power, high-performance microcontrollers has played a key role in the development of compact and efficient military robots. One such widely adopted controller is the ESP32, developed by Espressif Systems. The ESP32 is a dual-core 32-bit microcontroller with integrated Wi-Fi and Bluetooth capabilities, making it highly suitable for IoT-based defense applications. It supports multiple communication protocols such as UART, SPI, I2C, and PWM, allowing seamless integration with cameras, metal detectors, gas sensors, GPS modules, and motor drivers. Its low power consumption, real-time processing capability, and built-in encryption features enhance secure data transmission in military environments. Furthermore, the ESP32 supports over-the-air (OTA) firmware updates, enabling remote system upgrades without physical access to the robot. Several studies have highlighted the suitability of ESP32-based systems for real-time surveillance and defense-oriented applications due to their cost-effectiveness, scalability, and reliable wireless performance [13], [14].

In addition to microcontrollers, single-board computers such as the Raspberry Pi, developed by the Raspberry Pi Foundation, play a significant role in advanced military robotic systems. The Raspberry Pi offers higher computational capability compared to traditional microcontrollers, enabling complex tasks such as high-resolution video processing, image recognition, artificial intelligence implementation, and secure data encryption. With support for Linux-based operating systems, multiple USB interfaces, HDMI output, and CSI camera connectivity, it allows seamless integration of camera modules for real-time HD streaming and on-board image processing. Its compatibility with Python and other high-level programming languages simplifies the implementation of machine learning algorithms and autonomous navigation systems. Due to its affordability, compact design, and powerful processing capabilities, the Raspberry Pi has become a preferred platform for research and prototype development of intelligent surveillance robots.

Mobility and terrain adaptability are essential features of a military surveillance robot. Uneven surfaces, debris, sand, and rugged landscapes are common in battlefield environments. A robust locomotion system using DC motors and motor drivers ensures smooth movement and maneuverability under such conditions. Research indicates that four-wheel drive robotic platforms offer better stability and traction, making them suitable for military reconnaissance and explosive handling operations in challenging terrains [15].

Another important consideration in military robot design is modularity and future scalability. A modular architecture allows additional components such as robotic arms, advanced sensors, artificial intelligence modules, or autonomous navigation systems to be integrated without redesigning the entire system. This flexibility ensures that the robot can evolve with changing defense requirements and technological advancements. Literature emphasizes that modular robotic platforms significantly reduce development costs while extending the operational lifespan of defense systems [16].

In recent years, increasing geopolitical tensions and the growing demand for indigenous defense technologies have further strengthened the need for smart military robots. Developing cost-effective, locally manufactured robotic systems aligns with national initiatives aimed at technological self-reliance and defense modernization. The design and development of a smart military robot for surveillance and explosive handling not only contribute to soldier safety but also represent a step toward intelligent, automated, and resilient defense infrastructure capable of addressing future security challenges [17].

PROBLEM STATEMENT

Military and security personnel are frequently required to operate in hostile and high-risk environments such as border areas, terrorist-affected zones, and locations suspected of containing explosive devices. Conducting surveillance and handling suspicious objects manually exposes soldiers and bomb disposal squads to life-threatening dangers. Conventional surveillance methods often lack real-time monitoring, mobility in rough terrains, and safe mechanisms for explosive handling.

Existing bomb disposal and surveillance robots are often expensive, complex, and not easily deployable for small-scale defense units. Additionally, limited communication range, lack of integrated sensor systems, and insufficient real-time data processing reduce operational efficiency in critical missions.

OBJECTIVE

- To design and develop a smart robotic system capable of operating in hazardous and sensitive military environments.
- To implement Raspberry Pi as the main controller for processing sensor data, controlling actuators, and managing wireless communication.
- To enable real-time video surveillance using a camera module for continuous monitoring of remote or dangerous locations.
- To integrate obstacle detection mechanisms using ultrasonic sensors to ensure safe navigation.
- To incorporate a metal detection sensor for identifying suspicious metallic objects that may indicate explosive devices.

II. LITERATURE SURVEY

1. Design And Development of Multipurpose Robot for Military Spying and Patrolling

Authors: Mamta Koban, Vinayak Hinge, Yashwant Vyapari, Atharva Wadake
Year: 2022
Publication: International Journal of Creative Research Thoughts (IJCRT)
Journal Details: Volume 10, Issue 9, September 2022, ISSN: 2320-2882
Summary: This paper presents the development of an RF-based spy robot equipped with a wireless camera for military surveillance applications. The system utilizes Bluetooth, Wi-Fi, and ZigBee technology for wireless control and data transmission. The robot employs a Raspberry Pi as its main processing unit along with multiple sensors including metal detectors, ultrasonic sensors, and GSM modules for tracking. The hardware implementation uses Arduino for programming, with Python scripts controlling the robotic functions. The robot is designed to autonomously enter enemy territory, gather intelligence through its camera system, and transmit encrypted data back to operators. Key features include night vision capabilities, real-time monitoring, and Android application-based control. The authors emphasize

the robot's potential applications in border monitoring, landmine detection, and tracking foreign unit movements, while noting limitations such as battery dependency and vulnerability of the camera system.

2. Design and Develop of a Communication Module for A Military Surveillance Robot

Authors: Shoeb Ahmed Tanjim, Shaqran Bin Saleh, Md. Muhtasim Fuad, M. Akhtaruzzaman

Year: 2022

Publication: The MIST Journal of Computer Science and Engineering

Journal Details: CSE Technical Paper, 01(01), 2022, Military Institute of Science and Technology (MIST)

Summary: This research focuses specifically on developing a real-time communication module for military surveillance robots using Line of Sight (LOS) technology. The system architecture consists of two main components: the surveillance robot module and the remote control base station. The robot utilizes Raspberry Pi 3 as its central processing unit, with a NoIR camera for video capture, USB microphone for audio input, GPS module for location tracking, and IMU sensors for orientation data. The communication is established through omnidirectional and directional antennas operating at 2.4GHz frequency. The base station features a touchscreen display showing live video feed, audio visualization, IMU readings, and GPS coordinates, with joystick control for robot navigation. The system demonstrated effective performance within a 200-600 meter range, with grayscale video transmission proving most bandwidth-efficient. The research methodology included extensive testing of video quality at different resolutions and bandwidth requirements, making it a comprehensive study of communication challenges in hostile environments.

3. *Long-Duration Inspection of GNSS-Denied Environments with a Tethered UAV-UGV Marsupial System*

Authors: Simón Martínez-Rozas, David Alejo, José Javier Carpio, Fernando Caballero, Luis Merino

Year: 2025

Publication: *Drones*, Volume 9, Issue 11 (MDPI), 765, DOI:10.3390/drones9110765

Summary:

This paper presents a novel **tethered marsupial robotic system** combining an Unmanned Ground Vehicle (UGV) with an Unmanned Aerial Vehicle (UAV) to perform **long-duration inspection tasks**, especially in **GNSS-denied environments** (where GPS signals are unavailable). The UGV carries high-capacity batteries and supplies power through a cable to an attached UAV, enabling extended mission duration without relying solely on the UAV's limited battery life. The system uses **off-the-shelf hardware and open-source software (ROS)** for localization, navigation, and mission coordination.

4. Smart Surveillance Robot For Military Applications Using Iot

Authors: K. Ravikiran, J. Ajay Kumar Reddy, J. Harika, Dr. B. Swapna Rani

Year: 2023

Publication: International Journal of Creative Research Thoughts (IJCRT)

Journal Details: Volume 11, Issue 4, April 2023, ISSN: 2320-2882

Summary: This research presents an IoT-based smart surveillance robot utilizing NodeMCU ESP8266 and ESP32 camera modules for military border surveillance applications. The system integrates multiple sensors including PIR sensors for human detection (range up to 7m, 120° coverage), IR sensors for obstacle detection (10cm range), GPS module for geolocation tracking, and a high-intensity laser module for defensive purposes. The robot employs L293D motor driver for movement control and uses the Blynk IoT platform for real-time data monitoring and control through a mobile application. When human presence or obstacles are detected, the system triggers an alerting mechanism consisting of LED indicators (red for danger, green for safe state) and buzzer, while simultaneously sending notifications to authorized personnel via the Blynk app. The ESP32-CAM provides live video streaming accessible through IP address on mobile devices or laptops. The system operates within an 8-10 meter detection range and utilizes relay modules to control the laser shooting mechanism. The authors emphasize the cost-effectiveness and user-friendly interface of their system compared to Raspberry Pi-based alternatives. Real-time monitoring of latitude and longitude coordinates enables precise tracking of the robot's position through the IoT server.

5. Surveillance Robot for Military Application

Authors: Harsh Dugar, Rajat Gahlot, Vedant Rathi, Raushan Kumar, Mrs. Nikhila S

Summary: This paper discusses the development of an autonomous surveillance robot designed for border monitoring and remote war zone applications. The system combines NodeMCU for wireless control with ESP32-CAM for visual surveillance, featuring both autonomous human recognition capabilities and manual control options. The robot incorporates metal detector sensors for landmine detection and ultrasonic sensors for obstacle avoidance and human proximity detection. A key innovation is the integration of smart camera functionality with human identification and alarm features, controllable through both a dedicated website and mobile application. The control interface provides live video feed streaming, directional control (forward, backward, left, right), and pop-up notifications when metals or obstacles are detected. The system architecture emphasizes wireless operation from any location, eliminating line-of-sight limitations associated with traditional RF-based systems. Hardware specifications include the ESP32-S module supporting WiFi and Bluetooth, OV2640 camera with flash, TF card slot supporting up to 4GB storage, and H-bridge circuits for motor control. The paper addresses limitations of existing DTMF and RF-based systems by implementing more reliable communication protocols. Future enhancements proposed include improved battery management, polycarbonate camera protection, drone integration for aerial surveillance, and weatherproofing for operation in adverse conditions. The system represents a cost-effective alternative to existing commercial surveillance solutions while maintaining professional-grade functionality.

III. PROPOSED SYSTEM

The proposed system focuses on the design and development of a smart military robot capable of performing real-time surveillance, explosive detection, environmental monitoring, and remote navigation with minimal human intervention. The system is designed using an IoT-based architecture where sensing, processing, communication, and actuation are tightly integrated to enhance operational efficiency and soldier safety. The robot operates in hazardous and inaccessible environments, transmitting real-time data such as live video, sensor readings, and location information to a remote user interface through cloud platforms. The overall system is modular, scalable, and cost-effective, allowing future enhancements such as autonomous navigation, artificial intelligence-based threat detection, and robotic arms for bomb defusion.

A. System Overview

The proposed Smart Military Robot is a remotely operated unmanned ground vehicle (UGV) designed to perform surveillance and assist in explosive handling operations in hazardous environments. The system is developed using Raspberry Pi as the main controller, which serves as the central processing and decision-making unit. The robot is capable of transmitting real-time video, detecting obstacles, identifying metallic objects, and manipulating suspicious items using a robotic arm. The overall objective of the system is to reduce human exposure to life-threatening situations such as bomb detection zones, border surveillance areas, and terrorist-affected locations while ensuring efficient monitoring and operational control.

B. Hardware Architecture

The hardware architecture of the proposed system consists of multiple integrated subsystems working together under the control of the Raspberry Pi. The locomotion system includes DC gear motors connected through a motor driver module, enabling movement in multiple directions. A Pi camera module is mounted on the chassis to provide real-time surveillance, supported by infrared LEDs for night vision capability. Ultrasonic sensors are used for obstacle detection to prevent collisions during navigation. A metal detector sensor is integrated to identify metallic components that may indicate explosive devices. Additionally, a robotic arm equipped with servo motors and a gripper mechanism is attached

to the robot for safe handling of suspicious objects. The system is powered by a rechargeable battery with proper voltage regulation to ensure stable performance.

C. Software Architecture

The software architecture is designed to efficiently manage control, communication, and data processing tasks. The Raspberry Pi operates on Raspberry Pi OS, and the application is primarily developed using Python programming. The software controls motor operations, processes sensor inputs, manages the robotic arm movements, and handles real-time video streaming. A web-based interface is developed to allow remote access and control through Wi-Fi communication. The software continuously monitors sensor data and generates alerts if suspicious metallic objects or obstacles are detected. The modular software design allows future integration of artificial intelligence and advanced navigation algorithms.

D. Working Mechanism

The working mechanism of the proposed system begins when the operator sends movement or operational commands through a wireless control interface. The Raspberry Pi receives these commands and processes them to control the motor driver and robotic components accordingly. Simultaneously, the camera continuously captures and streams live video to the operator for real-time monitoring. Ultrasonic sensors actively measure distances to detect obstacles and prevent collisions. When the metal detector identifies a metallic object, the system triggers an alert to notify the operator. The robotic arm can then be remotely controlled to approach, lift, or relocate the suspicious object carefully. GPS integration ensures that the robot's real-time location is available for tracking and operational planning.

E. Control and Monitoring System

The control and monitoring system is designed to provide a user-friendly interface for remote operation. The operator can access the robot through a web-based dashboard using a computer or mobile device connected via Wi-Fi. The interface displays live video feed, directional control buttons, robotic arm controls, and sensor status indicators. This setup enables real-time decision-making and precise maneuvering. The system ensures smooth communication between the operator and the robot, allowing immediate response in critical situations. Continuous monitoring enhances operational awareness and improves mission efficiency.

F. Safety and Security Features

Safety and security are critical components of the proposed system. The robot is equipped with obstacle detection sensors to prevent accidental collisions. Secure wireless communication protocols are implemented to prevent unauthorized access. The system includes a low-battery detection mechanism that alerts the operator when power levels are critically low. Additionally, manual override options are provided to ensure full control in emergency situations. These safety measures enhance reliability and ensure secure operation in sensitive military environments.

G. Advantages of the Proposed System

The proposed system offers several advantages, including reduced risk to human life during surveillance and explosive handling operations. It provides real-time monitoring and efficient object manipulation capabilities, making it highly suitable for defense applications. The use of Raspberry Pi makes the system cost-effective and flexible compared to complex military-grade robotic systems. The modular design allows easy expansion and integration of advanced features such as artificial intelligence and thermal imaging. The compact and portable structure ensures easy deployment in various terrains.

H. Expected Outcomes

The expected outcome of the proposed system is the successful deployment of a smart robotic platform capable of performing surveillance and assisting in explosive handling tasks effectively. The robot is expected to provide clear real-time video transmission, accurate detection of metallic suspicious objects, reliable wireless communication, and precise robotic arm operation. Overall, the system aims to enhance safety, improve mission efficiency, and serve as a practical solution for modern defense and security operations.
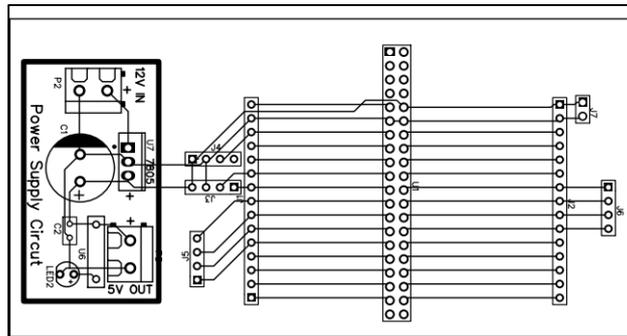
PCB Layout:
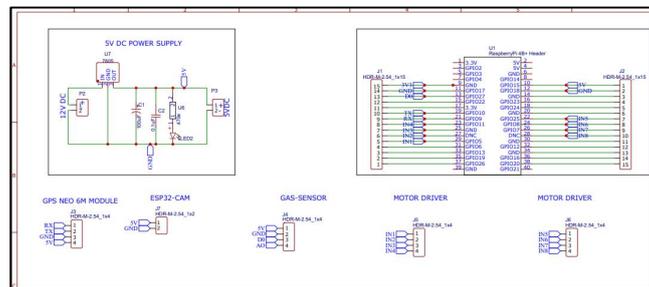

Fig 1: PCB Layout

Circuit diagram:

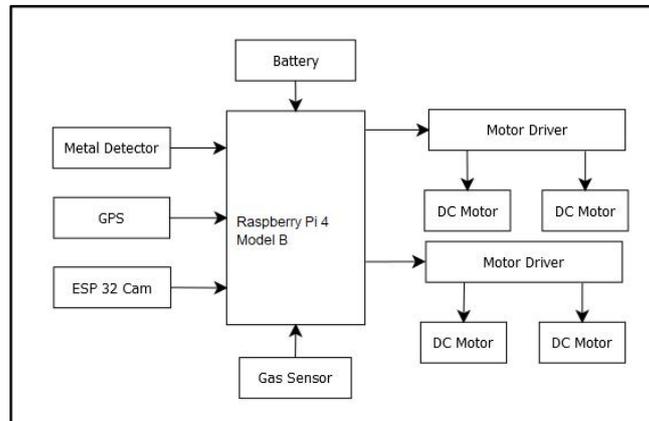Fig 2: Circuit diagram

SYSTEM DESIGN

Fig 3: System Architecture

The hardware design of the **Smart Military Robot** forms the foundation of the entire system, integrating multiple electronic, mechanical, and communication components into a single functional unit. The hardware has been carefully designed to ensure durability, reliability, and seamless interaction among sensors, actuators, and processing units. The design emphasizes real-time object detection, environmental monitoring, and autonomous or semi-autonomous operation suitable for military field conditions. Each component, from the processing controller to the mobility system, plays a critical role in enabling the robot to perform surveillance and hazard detection tasks effectively.

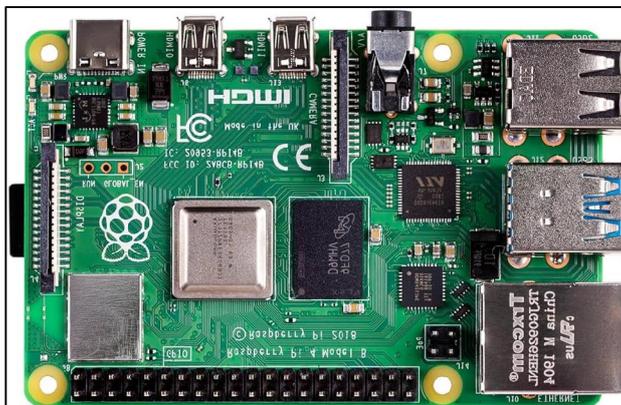**Raspberry Pi 4 Model B (4GB)**

Fig 4: Raspberry Pi 4 Model B

The Raspberry Pi 4 Model B serves as the central processing and control unit of the smart military robot. It is equipped with a Quad-core Cortex-A72 (ARM v8) 64-bit SoC operating at 1.5 GHz, and 4GB LPDDR4 RAM, providing enough computing power to handle multiple sensors, image processing, and communication simultaneously. It features built-in Wi-Fi (2.4/5 GHz) and Bluetooth 5.0, enabling wireless communication and connectivity with external devices such as smartphones or cloud servers. The Raspberry Pi also supports HDMI output, a camera interface (CSI) for the Raspberry Pi Camera Module, and multiple USB ports for peripherals.

In this project, it manages sensor data acquisition, motor control through the L298N driver, GPS data processing, and real-time image transmission through the camera. It also hosts the Python-based software responsible for decision-making and alert messaging via the Telegram API. The compact size, high speed, and energy efficiency of the Raspberry Pi make it ideal for field-based military applications.

Raspberry Pi Camera Module

The Raspberry Pi Camera Module is used for real-time image and video capture, which is essential for surveillance, object detection, and terrain observation. It has an 8-megapixel (MP) sensor and connects to the Raspberry Pi via the CSI (Camera Serial Interface). The camera supports HD and Full HD video recording, ensuring clear and detailed visuals even in dynamic field environments.
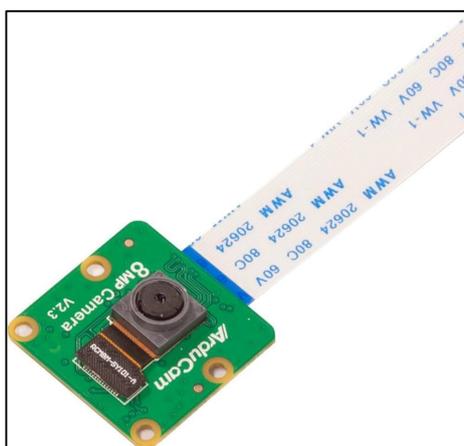

Fig 5: Raspberry Pi Camera Module

In this robot, the camera continuously streams live video to the operator's interface, allowing real-time observation of the surroundings. The captured frames can be processed by image recognition algorithms for object identification or

stored for later analysis. Its compact design, high resolution, and seamless compatibility with Raspberry Pi make it a key component for visual monitoring in military reconnaissance.

GPS Module (Neo-6M or Equivalent)

The GPS Module enables precise geographic tracking of the robot's location in real time. The Neo-6M GPS receiver operates with an accuracy of approximately 2.5 meters CEP and communicates with the Raspberry Pi via the UART (TTL) interface. It operates on a 3.3–5V power supply, making it compatible with the Raspberry Pi's GPIO logic levels.

Fig 6: GPS Module

In this project, the GPS module continuously updates the robot's coordinates, which are transmitted to the operator through the Telegram Bot API. This allows the command center to monitor the robot's movement and operational area effectively. The integration of GPS ensures that the robot's location is always traceable, even in remote or hazardous zones.

Metal Detector Module

The Metal Detector Module is designed to sense metallic objects or explosive casings that may be buried or hidden in the environment. It operates on a 5V DC supply and can detect metals within a range of approximately 3–5 cm, depending on the coil design. The module provides a digital high/low output signal to the Raspberry Pi when metal is detected.

Fig 7: Metal Detector Module

This sensor plays a crucial role in explosive detection and hazard identification. When metallic substances are detected, the Raspberry Pi immediately triggers an alert through the Telegram application, notifying the operator and sending the GPS coordinates. This helps in locating potential explosive threats without requiring direct human intervention.

Gas/Smoke Sensor (MQ-2 / MQ-135)

The Gas/Smoke Sensor is used to detect toxic gases and smoke in the environment. It operates on a 5V DC input and provides both analog and digital outputs. The MQ-2 or MQ-135 sensor can detect a variety of gases, including LPG, methane, carbon monoxide (CO), and smoke.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 3, February 2026

Impact Factor: 8.2

Fig 8: Gas/Smoke Sensor

In this system, it acts as an early warning sensor for hazardous gas leaks, fire, or chemical exposure in military zones or disaster areas. When dangerous gas levels are detected, the Raspberry Pi processes the signal and immediately sends an alert to the control center. This feature enhances the robot's ability to perform safe reconnaissance in contaminated or high-risk areas.
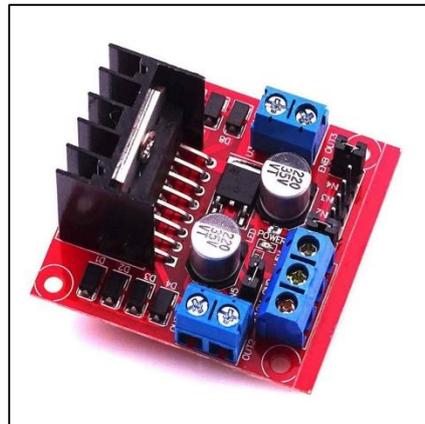
Motor Driver (L298N)

Fig 9: L298N Motor Driver Module

The L298N Motor Driver Module is a dual H-bridge driver capable of controlling two DC motors simultaneously in both forward and reverse directions. It operates within a voltage range of 5–35V and provides an output current of up to 2A per channel.

In this project, it is used to drive four DC motors (two on each channel) that enable the robot's movement. The Raspberry Pi sends PWM (Pulse Width Modulation) signals to the motor driver to control the speed and direction of motion. The L298N also includes onboard diodes and voltage regulators for protection against current spikes, making it highly suitable for rugged robotic applications.

DC Motors (4 Units)

Fig 10: DC motors

The robot utilizes four DC motors to provide mobility and balance. Each motor operates on 6–12V DC, with a speed range of 100–300 RPM, depending on the wheel diameter and load. The motors deliver sufficient torque (1–2 kg·cm) to move the robot across uneven surfaces.

The motors are connected to the L298N driver and controlled through PWM signals from the Raspberry Pi, allowing smooth acceleration, turning, and braking. The four-wheel configuration enhances stability and enables the robot to handle light to moderate terrain, which is essential in outdoor defense operations.

Robotic Arm (Servo-Based)

The robotic arm is a servo motor-based manipulator with 4–6 Degrees of Freedom (DOF), allowing basic object handling and inspection. Each servo motor provides 10–20 kg·cm torque, ensuring precise movement and control. The arm is controlled using PWM signals from the Raspberry Pi GPIO pins or an additional microcontroller.
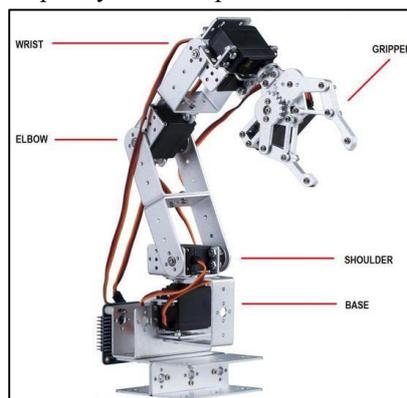

Fig 11: robotic arm

Although not designed for defusing explosives, the arm assists in inspecting and collecting small samples or materials from a safe distance. It improves the robot's versatility and supports missions that require physical interaction with the environment.

Battery Pack

Fig 12: power supply system

The power supply system consists of a 12V, 7Ah rechargeable Li-ion or lead-acid battery, which provides energy to both the motors and the Raspberry Pi through a voltage regulator circuit. The LM2596 step-down regulator converts 12V DC to 5V DC for powering the sensors and Raspberry Pi safely.

This battery pack ensures a stable and long-lasting power source for field operations, with built-in fuses and switches for overload protection. The system is designed to balance efficiency and portability, allowing the robot to operate continuously for several hours.

Wi-Fi / Telegram Communication

The Wi-Fi communication system is handled using the Raspberry Pi's built-in Wi-Fi module, eliminating the need for external transceivers. The system uses the Telegram Bot API to send and receive real-time data, including alert messages, GPS coordinates, and images.

This feature allows operators to control and monitor the robot remotely from anywhere with an internet connection. The use of Telegram provides a secure and user-friendly interface, enhancing situational awareness and enabling instant decision-making during field missions.

Relay Module (Optional)

The relay module acts as a switch that allows the Raspberry Pi to control high-power circuits or external loads, such as activating alarms, lights, or mechanical grippers. It operates on low control signals from the Pi but can switch devices up to 10A at 250V AC. This ensures isolation between the low-voltage control side and high-power load side, improving safety and system reliability.

Mechanical Arm / Gripper

The mechanical arm or gripper enables the robot to handle and lift suspicious objects or explosives. Controlled via servomotors, it can perform precise movements for gripping and releasing objects. The design ensures stability and fine control, allowing safe manipulation from a remote location. The gripper's claws are made of lightweight yet strong material to withstand external forces during handling operations.

Buzzer and LED Indicators

Fig 13: buzzer and LED

The buzzer and LED indicators provide audio-visual alerts during different operational states such as obstacle detection, metal identification, or gas presence. The buzzer gives a sound alert while LEDs indicate the system status visually. These indicators enhance user awareness and are especially useful during testing and emergency responses.
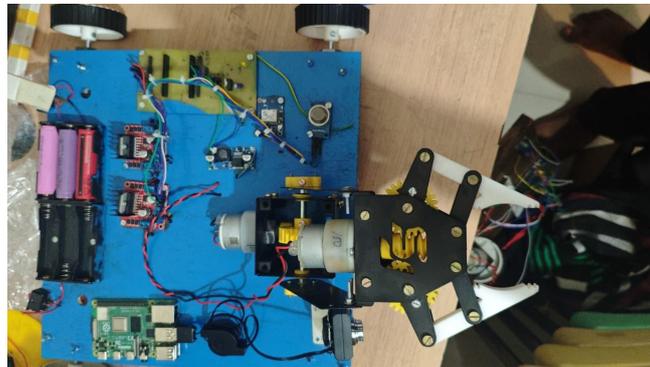
IV. RESULT
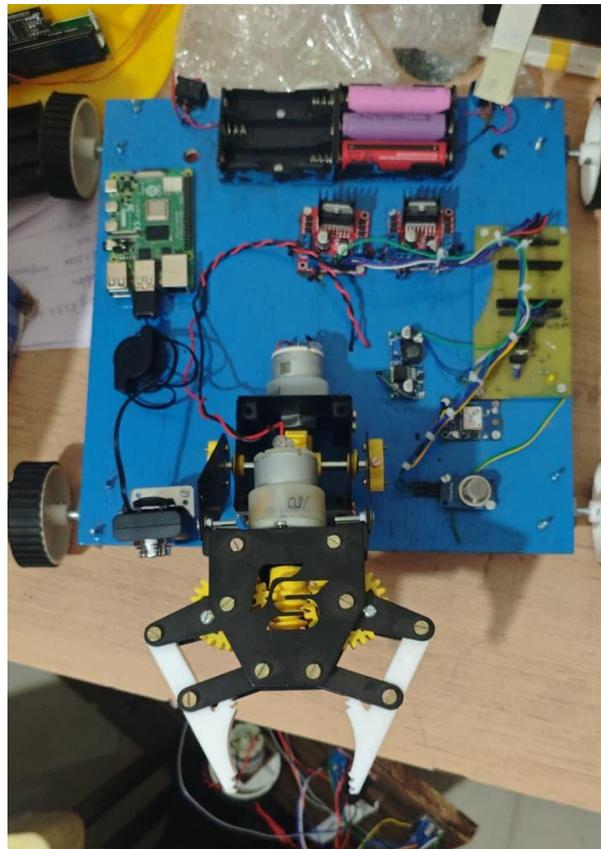
Fir 14: Top view

Fig 15: Side view

The developed smart military robot was successfully designed, assembled, and tested, demonstrating effective performance in surveillance, mobility, threat detection, and explosive handling support. The entire system was integrated onto a single mobile platform, with the **Raspberry Pi** serving as the main controller. It efficiently coordinated all subsystems including motor drivers, sensors, camera module, robotic arm, and wireless communication. The experimental setup confirmed stable structural design and smooth interaction between mechanical and electronic components.

The mobility and surveillance systems performed reliably during testing. The four-wheel drive mechanism enabled smooth movement in multiple directions, while the Raspberry Pi ensured quick response to control commands through

its GPIO interface. The camera module connected to the Raspberry Pi provided stable real-time video streaming, allowing remote monitoring without noticeable delay. This enhanced situational awareness and supported safe reconnaissance operations.

The threat detection and explosive handling features also operated effectively. The metal detector and gas sensor successfully identified simulated threats, and the Raspberry Pi processed these inputs in real time to generate alerts. The robotic arm, controlled using PWM signals from the Raspberry Pi, performed gripping and lifting operations smoothly without disturbing the robot's balance. The power system supplied consistent voltage, ensuring uninterrupted performance. Overall, the results confirm that the proposed system meets its objectives and provides a practical, cost-effective solution for safe surveillance and remote handling tasks in high-risk environments.

V. CONCLUSION

The design and development of the smart military robot for surveillance and explosive handling have been successfully completed, demonstrating effective integration of embedded systems, IoT technology, and robotic mechanisms to improve safety and operational efficiency in high-risk environments. The system minimizes human involvement in dangerous zones by enabling real-time video surveillance, environmental sensing, and remote-controlled operation. The Raspberry Pi, used as the main controller, efficiently coordinates all subsystems including motor control, sensor data processing, camera streaming, and wireless communication, ensuring smooth and reliable performance during reconnaissance and threat monitoring tasks.

Experimental results confirm the proper functioning of mobility, threat detection, and robotic arm modules. The four-wheel drive system provides stable navigation on uneven surfaces, while the metal detector and gas sensor successfully identify potential hazards. The robotic arm performs precise gripping and object handling operations without affecting balance. With Raspberry Pi's multitasking capability and built-in Wi-Fi support, the system enables seamless real-time monitoring and alert generation. Overall, the proposed robot is a cost-effective, scalable, and reliable solution that enhances operational safety and supports intelligent automation in hazardous surveillance and handling scenarios.

VI. FUTURE SCOPE

The smart military robot developed in this project provides a strong foundation for future advancements in intelligent surveillance and automated security systems. One major enhancement would be the integration of artificial intelligence and machine learning algorithms using the Raspberry Pi platform to enable automatic threat recognition, object classification, and motion detection. With AI-based image processing and pattern recognition, the robot could autonomously identify suspicious objects, detect unusual movement, and support faster decision-making with minimal human supervision. Additionally, incorporating advanced sensors such as LiDAR, depth cameras, and infrared modules would enable fully autonomous navigation, allowing the robot to detect obstacles and select optimal paths in complex or unknown terrains, thereby reducing reliance on manual control.

Future improvements can also focus on upgrading the robotic arm for advanced explosive handling tasks by incorporating multi-degree-of-freedom movement, precision control, and force feedback mechanisms. Communication systems may be enhanced through long-range and secure technologies such as LoRa, satellite communication, or encrypted wireless protocols to ensure reliable operation in remote or sensitive areas. Enhancements in energy efficiency, including high-capacity batteries and intelligent power management, can extend operational time. Furthermore, integration with aerial drones or swarm robotic systems could enable coordinated surveillance over large areas. These advancements would transform the current system into a more autonomous, intelligent, and resilient robotic platform capable of addressing evolving security challenges effectively.

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