International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 12 | Dec - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Multi-Functional Military Robot

Author 1 Name: **Dr. Veeresh Patil**

Author 1 Designation: HOD, ECE department,

Author 1 Institution: Amruta Institute of Engineering and Management Sciences Bidadi Bangalore

Author 2 Name: **Pooja S**

Author 2 Designation: Student ECE department

Author 2 Institution: Amruta Institute of Engineering and Management Sciences Bidadi Bangalore

Author 3Name: **Srusti N**

Author 3 Designation: Student ECE department

Author 3 Institution: Amruta Institute of Engineering and Management Sciences Bidadi Bangalore

Author 4 Name: **Sumaiya Banu**

Author 4 Designation: Student ECE department

Author 4 Institution: Amruta Institute of Engineering and Management Sciences Bidadi Bangalore

Author 5 Name: **Thejaswini K**

Author 5 Designation: Student ECE department

Author 5 Institution: Amruta Institute of Engineering and Management Sciences Bidadi Bangalore

Abstract

The rapid evolution of embedded systems, wireless communication, and computer vision has enabled the development of intelligent robots capable of supporting military operations. This work presents a semi-autonomous military robot powered by an ESP32 microcontroller and integrated with sensors, actuators, and remote processing capabilities. The system includes a metal detector for locating underground objects, IR sensors for autonomous obstacle avoidance, and a differential drive mechanism with an automatic digging unit triggered upon metal detection. Defense features such as a relay-based laser module and alarm buzzer are also incorporated.

Wireless communication is achieved using Zigbee modules, enabling reliable low-power control and data exchange with a laptop-based command center. A 360° surveillance camera provides real-time monitoring, supported by advanced image-processing techniques using OpenCV for face and color recognition. Based on detected threats or visual cues, appropriate commands are sent back to the robot for responses such as LED signalling, laser activation, or motion adjustments. The onboard LCD provides continuous status feedback to field users. By integrating autonomous sensing

and decision-making with remote intelligence and supervision, this system demonstrates a hybrid architecture suitable for smart battlefield applications, enhancing safety, surveillance, and operational efficiency.

Keywords

Military Robotics, ESP32, Zigbee Communication, Computer Vision, OpenCV, Surveillance System, Metal Detection, Autonomous Navigation, Face Recognition, Embedded Systems.

I. Introduction

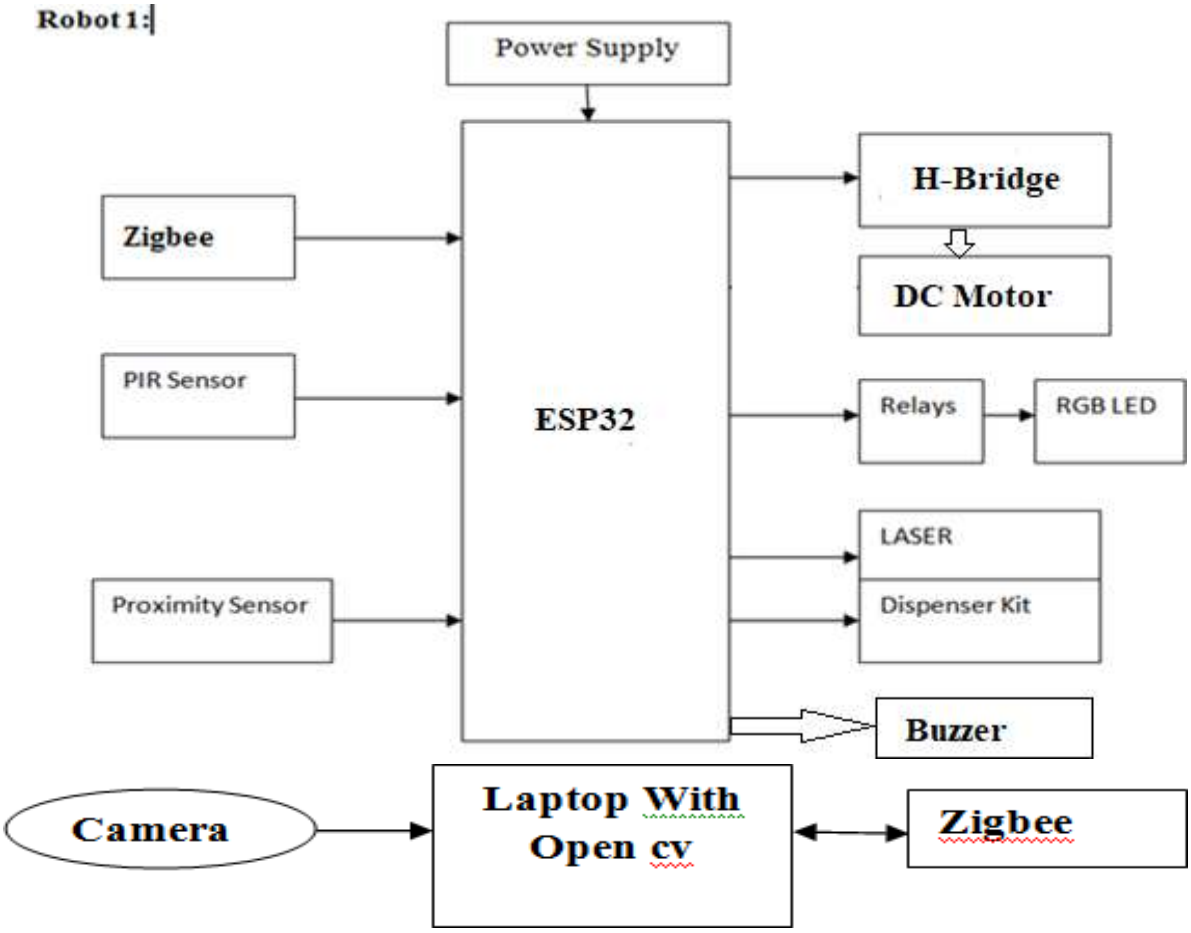
In the modern era, military and security forces face increasing challenges in monitoring, detecting, and responding to potential threats in high-risk or inaccessible areas. Conventional manual surveillance exposes soldiers to unnecessary danger, while traditional wireless communication technologies such as Wi-Fi or Bluetooth often suffer from limited range, high power consumption, and unreliable connectivity in outdoor environments. To address these issues, robotics combined with long-range wireless communication and artificial intelligence as emerged as a promising evolution.

II. Literature Review

Several studies have advancements in automated border surveillance systems using intelligent sensing and drone-based monitoring. Arjun et al. (2022) proposed a subsystem of the Panchendriya framework designed for human intrusion detection in dry leaf–covered border regions using a microphone sensor for footstep detection and a surveillance camera for visual confirmation. The system reduces manpower dependency by integrating wireless communication and a high-performance microcontroller to trigger early alerts when an intrusion is detected. Similarly, Syed Mojib et al. (2023) developed a drone-based border security model employing commercially available quadcopters combined with machine learning for real-time intrusion recognition from aerial footage. Their system demonstrates high area coverage efficiency, where a single drone potentially replaces the workload of multiple border personnel, making large-scale surveillance faster, cost-effective, and more automated.

III. System Design and Methodology

The proposed system introduces a next-generation military robot designed with long-range communication, intelligent vision processing, and adaptive camouflage capabilities. The system integrates ESP32 as the core controller, interfaced with multiple sensors and actuators to achieve advanced functionalities such as surveillance, threat detection, and autonomous decision-making.



IV. Hardware and Software Implementation

The implementation of the multifunctional military robot involves both hardware integration and software programming to ensure seamless operation and intelligent behavior. The hardware component consists of the ESP32 microcontroller as the central processing unit, along with sensors such as ultrasonic modules for obstacle detection, metal detectors for threat identification, RGB LEDs for adaptive camouflage, and actuators including DC motors, relays, and a simulated laser defense system. Communication between the robot and the control station is established using a Zigbee module to enable remote monitoring and control. On the software side, Arduino IDE and Embedded C are used for sensor interfacing and motor control, while Python and OpenCV support advanced functions such as face recognition and color detection. The combination of hardware modules and software algorithms allows the robot to operate autonomously, interact with its environment, and execute defense or alert actions based on real-time data processing.

V. AI and IoT Integration

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) significantly enhances the functionality and autonomy of modern military robotic systems. AI enables intelligent decision-making through advanced features such as face recognition, object detection, adaptive navigation, and threat classification using techniques from machine learning

and computer vision. Meanwhile, IoT enables seamless communication between the robot and remote command centers through wireless technologies like Zigbee or Wi-Fi, allowing real-time monitoring, data transmission, and control. Together, AI processes sensor and camera data to make autonomous responses, while IoT ensures that critical information such as location, detected threats, and system status is shared instantly with military operators. This synergy transforms the robot from a manually controlled machine into a smart, connected, and responsive defense platform capable of operating efficiently in unpredictable combat environments.

VI. Applications

- **Border Surveillance:**

Used for continuous 24/7 monitoring of borders and restricted areas to identify intruders or unauthorized movement.

- **Reconnaissance Missions:**

Deployed in hostile or unknown territories for collecting visual and environmental data without risking soldiers' lives.

- **Landmine and Explosive Detection:**

Equipped with metal sensors to detect buried explosives, making it useful in minefields and post-war clearance activities.

- **Disaster and Search-and-Rescue Operations:**

Assists in locating survivors in disaster zones where human access is difficult or dangerous.

- **Base and Perimeter Security:**

Supports routine patrolling inside military facilities to detect suspicious activities and alert security teams.

VII. Advantages and Limitations

Advantages:

The System is safe even for the user because of the use of robotics.

- The system uses Wi-Fi and this makes the system both accurate and reliable
- Long-Range Wireless Communication
- Uses Zigbee for reliable and low-power communication compared to Wi-Fi/Bluetooth.
- Low Power Consumption ESP32 and Zigbee are energy-efficient, making the system suitable for longer field operations.

Limitations

- Robots have limited capabilities, despite their capabilities in term of object recognition and navigation

VIII. Conclusion

The proposed Military Robot using ESP32, LCD, Metal Sensor, IR Sensor, Relay, Laser Gun, Buzzer, Zigbee Communication, and Vision-based Intelligence provide an effective solution for modern defense and surveillance applications. Unlike existing systems that rely on shortrange communication and limited sensing capabilities, this system integrates long-range Zigbee communication, real-time surveillance, face and color recognition, and adaptive camouflage to enhance both operational efficiency and stealth capability.

IX. Future Scope

The proposed military robot is a step toward developing intelligent, autonomous defense systems, but there are several opportunities for further enhancement.

Acknowledgment

The authors express their heartfelt gratitude to their project guide, department, and institution for their constant guidance and encouragement throughout this research work.

References

[1]. D. Arjun, P. K. Indukala, and K. A. Unni Krishna Menon, “Development of a Framework for Effective Surveillance and Human Intrusion Detection in Border Regions Covered with Dry Leaves,” IEEE, 2022.

[2]. Ekra Bin Syed Mojib, A. K. M. Bahalul Haque, Md. Nafis Raihan, Mahbubur Rahman, and Fahad Bin Alam, “A Novel Approach for Border Security: Surveillance Drone with Live Intrusion Monitoring,” IEEE, 2023.

[3]. Alexander Williams and Oleg Yakimenko, “Persistent Mobile Aerial Surveillance Platform Using Intelligent Battery Health Management and Drone Swapping,” IEEE, 2023.

[4]. Wichai Pawgasame, “A Survey in Adaptive Hybrid Wireless Sensor Network for Military Operations,” IEEE, 2020.

[5]. M. Ashok Kumar and T. Thirumurugan, “Integrated IoT Based Design and Android Operated Multi-Purpose Field Surveillance Robot for Military Use,” Proceedings of ICPEC, 2021

Authors’ Biography

Dr. Veeresh Patil

Dr. Veeresh Patil currently serves as the **Head of the Department (HOD)** of **Electronics and Communication Engineering** at **Amruta Institute of Engineering and Management Sciences (AIEMS), Bengaluru.** His contribution significantly to teaching, mentoring, and department development. Strong teaching professional with a **Doctor of Philosophy (Ph.D)** focused in **Wireless Communication-LTE Networks.** His areas of expertise include **Image Processing, Embedded Systems, Wireless Communication, Artificial Intelligence in Robotics, and IoT-based Systems.**

Pooja S is currently pursuing a **Bachelor’s degree in Electronics and Communication Engineering in Amruta Institute of Engineering and Management Sciences, Bidadi, Bangalore**. Their research interests include **Image Processing, Artifical Intelligence**. They have actively participated in projects and workshops related to smart systems and sustainable technologies.

Srusti N is currently pursuing a **Bachelor's degree in Electronics and Communication Engineering in Amruta Institute of Engineering and Management Sciences, Bidadi, Bangalore**. Their research interests include **IOT, Wireless Communication Machine Learning**. They have actively participated in projects and workshops related to smart systems and sustainable technologies.

Sumaiya Banu is currently pursuing a **Bachelor's degree in Electronics and Communication Engineering in Amruta Institute of Engineering and Management Sciences, Bidadi, Bangalore**. Their research interests include **Frontend Framework (Flask), Frontend Code (HTML, CSS)**. They have actively participated in projects and workshops related to smart systems and sustainable technologies.

Thejaswini K is currently pursuing a **Bachelor's degree in Electronics and Communication Engineering in Amruta Institute of Engineering and Management Sciences, Bidadi, Bangalore. Their** research interests include **Module Inter facing , Sensor Integration.** They have actively participated in projects and workshops related to smart systems and sustainable technologies.