Advanced Military Spying and Bomb Disposal Robot Using Esp32 and Image Processing

Mr. Dr. Vijayakumar T[1], Abhay Surya J[2], Adarsh G[3] , Kushal BT[4], Kushal S[5]

[1]Vijayakumar T, Prof, Dept. of ECE, SJB Institute of Technology, Bengaluru
[2]Abhay Surya J, Dept. of ECE, SJB Institute of Technology, Bengaluru
[3]Adarsh G, Dept. of ECE, SJB Institute of Technology, Bengaluru
[4]Kushal BT, Dept. of ECE, SJB Institute of Technology, Bengaluru
[5]Kushal S, Dept. of ECE, SJB Institute of Technology, Bengaluru

---***---

Abstract-The growing deployment of intelligent robotics in war operations is vital for reducing human risk and increasing efficiency in dangerous and dynamic combat environments. The paper proposes a multi-purpose military ground robot called WARBOT-X that is intended to tackle the key challenges confronting soldiers in surveillance, explosive ordnance disposal, and medical emergencies. The main characteristics of the robot are the facial recognition-based surveillance system that detects unfamiliar persons and evokes a mock laser reaction. It also has a metal detection system to detect buried landmines or IEDs and alert the remote base station for further suitable action. For stealth, the robot uses an adaptive camouflage system through RGB lighting that dynamically matches its environment. Moreover, WARBOT-X offers life- critical medical assistance by deploying a first-aid kit and activating a GPS-based location-tracking system to notify the location of wounded soldier to the medical staff.

Key words: Multi-Functional Robot, Military Robotics, Unmanned Ground Vehicle (UGV), Facial Recognition, Metal Detection, Adaptive Camouflage, GPS Tracking, Soldier Support.

1.INTRODUCTION

The application of robotics in contemporary military and defence applications is a major technological revolution spurred on by the essential requirement to protect human life in hazardous areas. Unmanned Ground Vehicles (UGVs) and various other robots are being ever more utilised to conduct tasks long performed by foot soldiers, including border patrols, reconnaissance, and detonator weapons disposal.

2.RELATED WORK

Several researchers have contributed to the development of unmanned ground vehicles for military surveillance and explosive handling applications. Early bomb disposal robots mainly relied on wired control systems, which restricted mobility and operational range. These systems were effective in controlled environments but lacked flexibility in real-world military scenarios. Localization. With advancements in wireless communication, microcontroller-based robotic systems using technologies such as Bluetooth, RF modules, and Wi-Fi were introduced. These systems enabled remote operation, improving safety by allowing operators to control robots from a distance.

3.METHODOLOGY

Step 1: System Initialization

When the system is powered ON, the ESP32 initializes all connected peripherals such as motors, camera module, and robotic arm. The Wi-Fi module establishes a secure connection with the operator's control interface.

Step 2: Real-Time Surveillance

The camera module continuously captures live video and streams it wirelessly to the remote operator. This visual feedback enables the operator to inspect the environment and identify suspicious objects from a safe distance.

Step 3: Image Processing

The captured video frames undergo basic image processing techniques such as noise reduction and frame enhancement. These techniques improve visibility and assist in identifying potential threats without increasing computational complexity.

Step 4: Remote Navigation

Based on the live video feed, the operator sends movement commands to the ESP32. The motor driver receives control signals and drives the DC motors to navigate the robot toward the target location.

Step 5: Bomb Detection and Handling

Once a suspicious object is located, the robot approaches it carefully. The robotic arm is remotely controlled to grip, lift, or relocate the object to a safe disposal area.

Step 6: Status Feedback

The ESP32 continuously sends system status updates, including movement confirmation and operational alerts, back to the operator to ensure safe execution of tasks.

Key Features of the Methodology

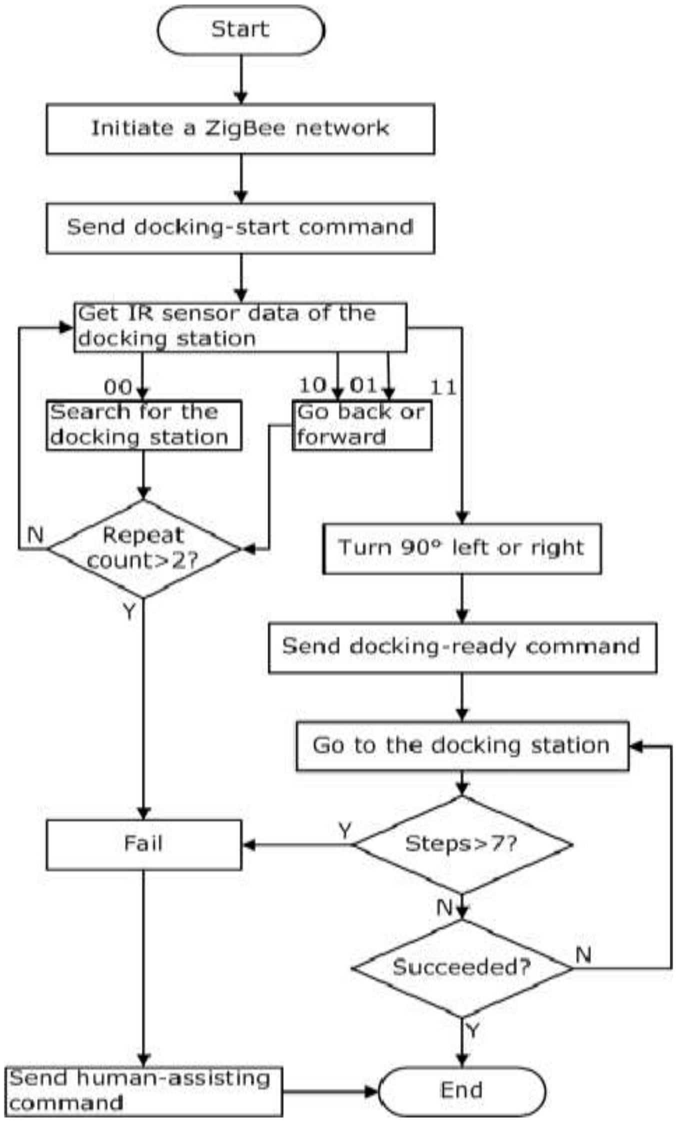
Human risk is minimized through remote operation

Real-time visual monitoring improves decision-making

Low computational load ensures fast response

Modular design allows easy upgrades

3.2 Image Processing Techniques



A. Preprocessing

Preprocessing is a critical stage in the image processing pipeline that enhances image quality and prepares the captured frames for accurate analysis. In the proposed system, preprocessing ensures reliable surveillance and object identification under varying environmental and lighting conditions.

1. Image Resizing
2. Noise Removal
3. Color Space Conversion
4. Illumination Normalization
5. Image Smoothing

B. Feature Enhancement and Segmentation

Feature enhancement is performed to improve the visibility of important visual details in the captured images. In military surveillance environments, images may suffer from poor lighting, shadows, or low contrast.

Enhancement techniques help highlight critical features such as object boundaries, surface textures, and structural details, which are essential for accurate identification.

- Feature Enhancement
- Segmentation

3.3 LITERATURE SURVEY

One paper introduces a multi-functional military robot designed for security and surveillance missions, using an ESP32-CAM module for wireless video streaming. The robot is controlled via a mobile phone application, allowing it to gather real-time intelligence and operate in difficult-to-access areas [1]. Another research effort focuses on a robot for surveillance that uses an Arduino Uno and an ESP32 camera module to traverse terrains and wirelessly transmit live data. This system is designed to minimize human risk and enhance situational awareness for military operations [2]. The development of multi-purpose military robots is further explored in a paper outlining a cost-effective Internet-based system for surveillance. This movable robot can be controlled from any location via a mobile app, providing a user-friendly solution for remote reconnaissance [3]. A separate study details a real-time, remote user-controlled military robot system with multiple functionalities to reduce casualties. This Raspberry Pi-based robot performs video surveillance with face recognition and uses ultrasonic sensors for obstacle avoidance [4]. A key struggle in military operations is the identification and disposal of hazardous devices, which a paper addresses with a robotic bomb detection and disposal application using an Arduino. The system uses a metal detector and a wireless camera to verify threats, and a robotic arm to safely dispose of explosives from a distance [5]. The detection and clearance of landmine a major challenge that one paper tackles with a sophisticated robot featuring a 6 - DOF articulated system. This intelligent system uses sensor fusion to enhance detection accuracy and ensure the safe retrieval of threats, keeping human operators at a safe distance [6]. Another paper presents a war field spy robot with metal detection and live streaming capabilities. The prototype is equipped with a metal detector, a 360 -degree night vision camera, and GPRS for real-time location tracking. This makes it a valuable tool for surveillance, security, and search and rescue operations [7]. This unified framework not only integrates existing innovation but also introduces a new framework for improved person and situational protection.

3.4 System Workflow

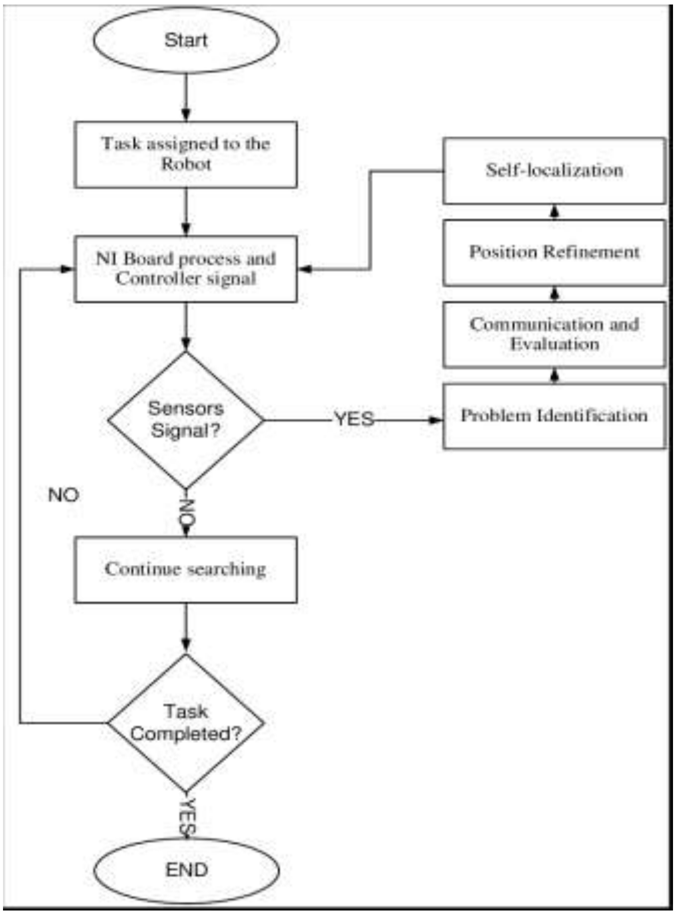


Fig 3.4: System Workflow

When the system is powered ON, the ESP32 initializes the camera, motors, and Wi-Fi communication. The camera captures live video, which is processed to enhance image quality and identify suspicious objects. Based on the visual feedback, the operator remotely navigates the robot. If a threat is detected, the robotic arm is activated to safely handle and dispose of the object.

4. IMPLEMENTATION

The implementation of the proposed military spying and bomb disposal robot is carried out by integrating hardware components with embedded software on the ESP32 platform. Initially, the ESP32 is programmed to establish a Wi-Fi connection for remote communication and control. The camera module is interfaced with the ESP32 to capture live video, which is streamed to the operator for real-time surveillance.

Motor driver circuits are connected to the ESP32 GPIO pins to control the movement of DC motors, enabling forward, reverse, and directional navigation. Servo motors used in the robotic arm and gripper are controlled through PWM signals generated by the ESP32, allowing precise bomb handling operations. Image preprocessing techniques such as noise reduction and contrast enhancement are applied to the captured frames to improve visibility.

Based on the processed visual data and operator commands, the ESP32 coordinates robot movement and activates the robotic arm for safe object handling. The entire system is powered by a regulated battery supply, ensuring stable and continuous operation during field deployment.

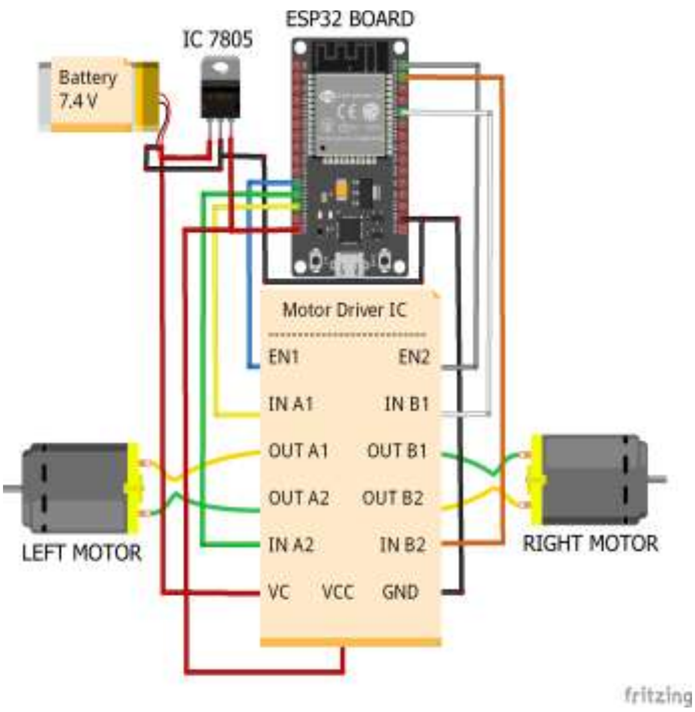
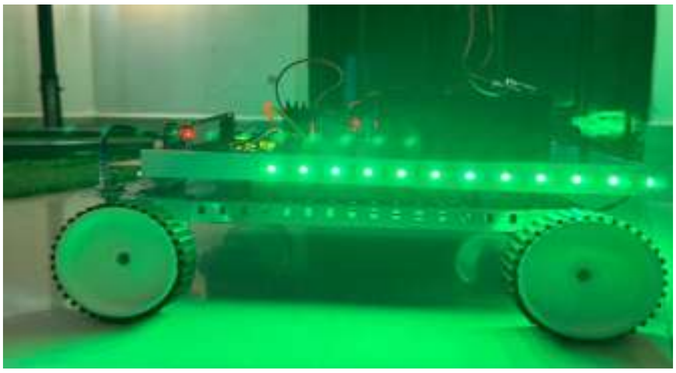


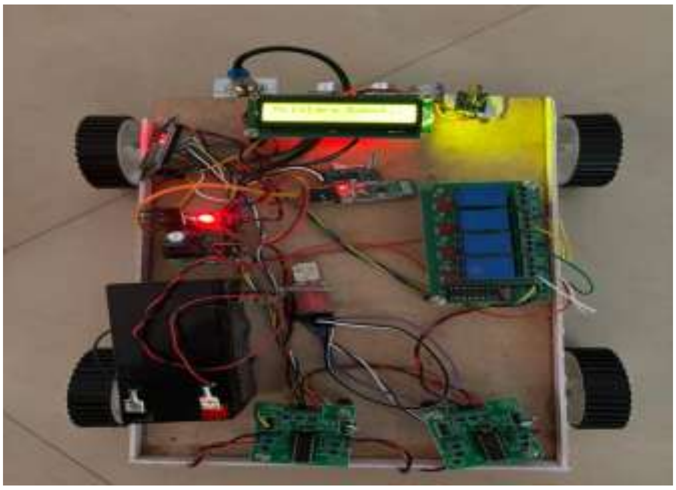
Fig 4.1: Implementation Diagram military robot

The system is implemented using an ESP32 microcontroller as the central control unit with built-in Wi-Fi for remote communication. A camera module is interfaced with the ESP32 to capture and stream live video for real-time surveillance. DC motors are controlled through a motor driver to enable robot movement, while servo motors operate the robotic arm and gripper for bomb handling. Image preprocessing techniques are applied to enhance video clarity and assist object identification. Control commands are received wirelessly from a mobile or web interface. A regulated battery supply powers all modules to ensure stable operation in field conditions. The system is implemented using an ESP32 microcontroller that controls robot movement, camera-based surveillance, and wireless communication. Live video is processed and monitored remotely, and a robotic arm is activated to safely handle and dispose of suspicious objects.

5. Result and Discussion

The ESP32-based military spying and bomb disposal robot was successfully tested in controlled environments to evaluate its performance. The camera module provided clear live video streaming, enabling effective surveillance and identification of suspicious objects.The robot movement was smooth and responsive due to reliable motor control through the ESP32. The robotic arm and gripper accurately picked and relocated test objects, demonstrating safe bomb handling capability. Wireless communication remained stable with minimal delay during operation. Remote control commands were executed in real time, ensuring precise navigation. Overall, the system proved to be efficient, low-cost, and suitable for hazardous military and security applications.





6. CONCLUSIONS

The project successfully developed a robust, multi-functional military ground robot, directly addressing the high risks of frontline operations. Key achievements include reliable intruder deterrence via OpenCV-based facial recognition, effective hazard mitigation using a metal detection sensor for landmine threats, and the innovative use of adaptive camouflage matching RGB colours for visual stealth. Ultimately, the integrated design provides a new framework for enhanced situational awareness and significantly contributes to personnel safety through both combat support and emergency medical coordination.

7. REFERENCES

[1] D. S. Navare, Y. R. Kapde, S. Maurya, D. B. Pardeshi and P. Willia m , "Robotic Bomb Detection and Disposal: Application using Arduino," 2022 7th International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2022

[2K. Janani, S. Gobhinath, K. V. Santhosh Kumar, S. Roshni and A. Rajesh, "Vision Based Surveillance Robot for Military Applications," 2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2022

[3] B. Balakrishnan, P. Pandaram, P. Shinde, S. Parne and V. Mukku, "Real time Remote User Controlled Military Robot," 2022 5th International Conference on Advances in Science and Technology (ICAST), Mumbai, India, 2022

[4] N. P. Kulkarni, S. N. Khan, R. R. Rathod, A. R. Choure and M. G. Chinchole, "Advanced Camouflage Robot for Military Spying Applications using Sensor Fusion and Machine Learning," 2024 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS), Pune, India, 2024

[5] J. P. Krishna and K. V. Thilagar, "Landmine Detection and Safe Booming Using 6 DOF Articulated System With Artificia l Intelligence," 2024 15th International Conference on Computing Communication and Networking Technologies (ICCCNT), Kamand, India, 2024

[6] R. M. Ismail, S. Muthu Kumara swamy and A. Sasikala, "Military Support and Rescue Robot," 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2020

[7] R. Pavai Yarkarasi , K. K. Veni, M. Shyam, S. B. P. Richard, R. P. Kumar and N. S. A, "Empirical Development of Army Spying Robot using Bomb Sensing and Removal Mechanism," 2023 International Conference on Advances in Computing, India, 2023

[8] C. Gnana prakasam, M. Swarna, R. Geetha, G. Saranya, and S. M. K. H., "A Novel Design of Smart and Intelligent Soldier Supportive Wireless Robot for Military Operations," 2023 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI), Chennai, India, 2023

[9] S. S. Chiwande, N. Nimje, S. Barbaile, A. Singh, A. Dhote and A. Pathade, "War Field Spy Robot with Metal Detection and Live Streaming," 2023 7th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2023

[10] K. Rajeshwaran, M. Rishma, V. Ovia Pavai and D. Nandhini, "Sensor Assisted War Field Spying Robot using Internet of Things (IoT)," 2023 4th International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2023.