MULTI-PURPOSE ROBOT FOR MILITARY APPLICATIONS

Prof. Seema Mahalungkar[1], Swapnil Salve[2], Vikas Tarange[3], Aniket Khamkar[4], Pravinkumar Shinde[5]

[1]Assistant Professor Nutan College of Engineering and Research – 6419 Talegaon Dabhade, Pune

[2,3,4,5] B.Tech Student Computer Science Engineering Nutan College of Engineering and Research – 6419 Talegaon Dabhade, Pune

Email-mahalungkar.seema@gmail.com[1],salveswapnil211@gmail.com[2],vikastarange7@gmail.com[3], akhamkar028@gmail.com[4], pravinkumarshinde2003@gmail.com[5]

ABSTRACT

This project focuses on the development of a multi-purpose military robot designed to enhance operational efficiency and reduce risks to human personnel in hazardous environments. The robot is built around the NodeMCU ESP32 microcontroller, which enables high-speed data processing and wireless communication via built-in Wi-Fi and Bluetooth. Equipped with GPS and GSM modules, the robot supports real-time location tracking and communication, critical for missions in remote or unfamiliar terrain. Key sensors, including ultrasonic and NPN sensors, enable obstacle detection and environmental monitoring, allowing the robot to navigate autonomously while assessing air quality and identifying potential threats. A durable acrylic chassis supports four DC motors controlled by an L293D motor driver, providing robust mobility across rough terrains. A live video feed from the mounted camera enhances remote surveillance via a mobile application. The system is powered by a 12V battery, ensuring prolonged autonomous operation. This robot exemplifies the integration of modern robotics, IoT, and embedded systems for defense applications. Future enhancements may include AI-based path planning, sensor fusion, 5G communication, and swarm coordination for collaborative missions. The robot stands as a strategic asset for modern military operations, capable of executing reconnaissance, surveillance, and logistical support while ensuring personnel safety in combat zones.

Keywords: Military Robot, NodeMCU ESP32, GPS, GSM, Ultrasonic Sensor, Autonomous Navigation, Surveillance, IoT, Defense Technology

1. INTRODUCTION

In the contemporary landscape of defense technology, there is an increasing reliance on robotics to enhance operational efficiency, improve safety, and minimize the risks to human personnel, especially in high-risk environments [1]. The integration of advanced robotics into military applications has proven to be a game-changer, offering capabilities that traditional human forces cannot match in terms of endurance, safety, and precision. This project revolves around the design and development of a cutting-edge, multipurpose military robot that aims to revolutionize defense operations. The robot is engineered to perform a variety of tasks, from surveillance and reconnaissance to environmental monitoring and hazardous material detection, all while ensuring that human personnel are kept out of harm's way. With its advanced features and sophisticated design, the robot promises to significantly enhance the safety and effectiveness of military operations.

Central to the robot's design is the robust and highly capable NodeMCU ESP32 microcontroller [2]. The ESP32 microcontroller is at the heart of the robot's control system, serving as the brain that processes data from various sensors, manages communication, and coordinates the robot's movements. Known for its high processing power, reliability, and versatility, the ESP32 microcontroller ensures that the robot operates efficiently and smoothly even in the most challenging environments. Its ability to handle multiple tasks simultaneously, thanks to its dual-core processor, makes it an ideal choice for this application, where real-time data processing and decision-making are essential. The microcontroller also provides seamless connectivity through its Wi-Fi and Bluetooth capabilities, enabling the robot to communicate effectively with remote control units or command centers.

Equipped with GPS and GSM modules, the robot is capable of real-time location tracking and communication, two features that are crucial for modern defense operations [3]. The GPS module allows the robot to pinpoint its exact geographical location at any given time, providing crucial data that can be used for navigation, surveillance, and mission planning. Knowing the precise location of the robot ensures that operators can track its movements in real-time, which is particularly useful when the robot is deployed in hostile or unfamiliar terrain. The integration of a GSM module further enhances the robot's functionality, as it allows for reliable communication even in remote areas where traditional communication infrastructure may be unavailable. With the GSM module, the robot can send and receive critical information, including status updates, location data, or emergency alerts, ensuring that it remains connected to the command center throughout its mission.

The robot is also equipped with a variety of sensors that contribute to its autonomous navigation and environmental monitoring capabilities [4]. One of the key sensors is the ultrasonic sensor, which plays a vital role in obstacle detection. The ultrasonic sensor uses sound waves to measure the distance between the robot and objects in its path, allowing it to detect obstacles and avoid collisions in real-time. This is particularly important for navigating complex and dynamic environments, such as urban settings or rough terrains, where unexpected obstacles may be present. The ability to autonomously detect and navigate around obstacles without human intervention significantly enhances the robot's efficiency and safety, ensuring that it can carry out its tasks without putting itself or its surroundings at risk.

In addition to the ultrasonic sensor, the robot is equipped with an NPN sensor for environmental monitoring. The NPN sensor can detect various environmental parameters, such as changes in air quality, temperature, and humidity, and is capable of identifying hazardous conditions such as chemical or biological threats [5]. Environmental monitoring is particularly important in military operations, where the presence of harmful substances, radiation, or other dangerous factors can pose serious risks to both personnel and equipment. By providing real-time data on the environmental conditions of the robot's surroundings, the NPN sensor enables operators to make informed decisions, mitigate risks, and ensure the safety of both the robot and the personnel involved in the operation.

The robot's chassis is constructed from durable acrylic, providing a lightweight yet robust frame that houses all the essential components [6]. Acrylic is chosen for its ability to withstand environmental stress, including exposure to extreme temperatures, moisture, and impacts, ensuring that the robot remains operational even in challenging conditions [7]. The acrylic chassis is designed to be both functional and resilient, providing a stable platform for the robot's motors, sensors, and control systems. The chassis also incorporates space for the 12V battery system that powers the robot. This power system is designed to provide sufficient energy to the robot's components, ensuring that it can operate autonomously for extended periods without the need for frequent recharging. The 12V battery system is crucial for long-duration missions where access to charging infrastructure may be limited or unavailable, such as in remote or hostile environments.

The motorized mechanism of the robot is powered by four DC motors, which are controlled by an L293D motor driver. The L293D motor driver is a dual H-bridge, allowing for precise control of the motor's speed and direction [8]. This motorized system enables the robot to navigate various types of terrain, from smooth surfaces to rough, uneven ground. The use of four DC motors provides the robot with the necessary maneuverability to perform a wide range of tasks, including turning, moving forward and backward, and navigating through obstacles. Whether the robot is performing surveillance, reconnaissance, or assisting in logistical operations, the motorized mechanism ensures that it can move with agility and precision, adapting to the needs of the mission.

Overall, the design of the robot is focused on ensuring that it can operate autonomously, safely, and efficiently in a variety of defense applications. Its advanced sensors, robust power system, and powerful control mechanism enable it to perform complex tasks in challenging environments, all while minimizing the risks to human personnel. The robot's ability to track its location, detect obstacles, monitor environmental conditions, and communicate with remote operators makes it a highly effective tool for a wide range of military applications, including surveillance, reconnaissance, and hazardous material detection. Moreover, the integration of cutting-edge technologies such as the NodeMCU ESP32 microcontroller, GPS and GSM modules, ultrasonic sensors, and the NPN sensor ensures that the robot is capable of meeting the high demands of modern defense operations [9].

This project exemplifies the potential of robotics in transforming military operations, offering a glimpse into the future of autonomous systems that can enhance operational efficiency, increase safety, and reduce the need for human involvement in dangerous and high-risk tasks. By leveraging the power of advanced technology, this military robot offers a significant step forward in the development of intelligent, multipurpose machines that can support and augment the capabilities of military forces worldwide [10]. As technology continues to evolve, such robots will likely become indispensable assets in military operations, providing vital support in critical situations while protecting human lives.

2. RELATED WORK

The growing interest in military robots has led to significant advancements in the development of multi-purpose robots tailored for military applications. These robots are designed to enhance operational efficiency, ensure safety, and provide strategic advantages in complex combat zones. A number of scholarly papers have contributed to the understanding of various military robot systems, their applications, and the challenges associated with their development.

In the comprehensive survey "A Survey on Military Robots: Applications and Challenges" (2018) by S. P. Singh and Arora and Chauhan, a detailed overview of different types of military robots is provided [11]. These include unmanned ground vehicles (UGVs), aerial robots, and reconnaissance robots, all of which play crucial roles in military operations. The paper discusses the wide array of applications such as surveillance, bomb disposal, and reconnaissance, with a particular focus on the growing demand for these robots in combat zones [12]. However, while the paper offers a theoretical exploration of military robot applications, it lacks specific implementation details or case studies. It emphasizes the challenges in military robot development, such as mobility, autonomy, and communication, and highlights the future research areas of improving autonomy, real-time decision-making, and energy efficiency for military robots. Singh and Gupta’s work underscores the potential of military robots but points to the need for more practical research to bridge the gap between theory and real-world applications.

Another significant contribution is the "Design and Development of Autonomous Robots for Military Surveillance" (2023) by Mohsan et .al. This paper focuses on the design of a mobile robot integrated with ultrasonic and infrared sensors for military surveillance [13]. The system incorporates GSM and GPS technologies to enable real-time communication and location tracking, providing a reliable solution for surveillance tasks in military operations. The successful design of an autonomous robot capable of obstacle avoidance and real-time tracking is presented as a major achievement. However, the paper's scope is limited to basic surveillance tasks and does not extend to full-scale military operations. The authors suggest that future work should integrate advanced AI for autonomous navigation and real-time analysis, which would further enhance the robot’s capabilities in dynamic military environments. Mohsan et al., work offers valuable insights into the practical application of autonomous surveillance robots, but it highlights the need for further advancements to meet the complex demands of military operations [14].

The paper "Obstacle Avoidance in Mobile Robots: A Survey" (2016) by M. Y. Tan and Wang provides a thorough review of various algorithms for obstacle detection and avoidance, particularly in mobile robots [15]. It compares technologies such as ultrasonic sensors, infrared sensors, and LiDAR for obstacle sensing, detailing the advantages and disadvantages of each approach for different operational scenarios. While the survey provides a deep understanding of the obstacle avoidance techniques, it lacks detailed practical implementation data and does not discuss specific hardware required for real-time applications. Tan and Zhang suggest incorporating AI-based path planning and sensor fusion for more reliable obstacle detection in dynamic environments [16]. This paper is crucial for those developing multi-purpose military robots that require robust navigation capabilities in complex and uncertain environments. The research stresses the importance of integrating AI and sensor fusion to improve the adaptability and reliability of obstacle detection systems, which is essential for military robots operating in hostile or unpredictable terrains.

In "Wireless Communication for Military Robots Using GSM and GPS" (2019), S. K. Sharma and Karim et .al. explore the use of GSM and GPS technologies for wireless communication and location tracking in military robots [17]. Their proposed system demonstrates the potential of using GSM for real-time control and monitoring of robots in military operations, along with GPS for precise tracking of robot movements, especially in large, unknown environments. While this system is successful in demonstrating the real-time control and location tracking capabilities of GSM and GPS, it is dependent on the quality and reliability of GSM networks, which may not be dependable in certain remote or war-torn regions. Sharma and Patel suggest investigating newer communication technologies, such as 5G or satellite communications, to improve the reliability of military robots, particularly in areas where GSM networks are inadequate [18]. This work contributes significantly to the development of communication systems for military robots, emphasizing the need for better connectivity in remote military zones.

The study "Design and Control of Wheeled Mobile Robots for Military Applications" (2015) by L. L. Wang and Y. W. Zhang focuses on the design and control strategies for wheeled mobile robots, which are widely used in military operations due to their cost-effectiveness and simpler design compared to tracked robots [19]. The paper presents the implementation of a control system using motor drivers and sensors for mobility and precision, which is crucial for military robots navigating in various terrains [20]. Despite its success in demonstrating reliable mobility in suitable terrains, the wheeled robot design struggles with rough or soft terrains, which limits its overall effectiveness in some military operations. Wang and Zhang suggest focusing on improving navigation capabilities in challenging terrains and enhancing the autonomous decision-making capabilities of these robots [21]. Their work is valuable for military robots requiring precision mobility and cost-effective solutions, though future developments should aim to address the limitations of wheeled robots in more demanding environments.

R. A. Smith and P. J. Williams, in their paper "Integration of IoT in Military Robots: A New Frontier" (2020), explore the integration of Internet of Things (IoT) technology into military robots for real-time data collection, analysis, and remote operation. They propose a cloud-based infrastructure to support data analysis and communication, enhancing real-time monitoring and control of military robots [22]. This paper highlights the advantages of integrating IoT for scalable military robot deployments, as it allows for sophisticated data analysis and improved coordination between robots in the field [23]. However, the major limitation of this system is its dependence on stable internet connections, which may not always be available in military zones, especially in remote or conflict-ridden areas. Smith and Williams recommend further development of IoT capabilities to improve communication and autonomy in military robots, ensuring that they can operate effectively even in disconnected environments. Their research paves the way for more sophisticated military robots with enhanced real-time control and data analysis capabilities.

In conclusion, the literature on military robots highlights the diverse range of applications and the growing importance of multi-purpose robots in military operations. While numerous studies, including those by Singh and Gupta, Khan and Mohamed, Tan and Zhang, Sharma and Patel, Wang and Zhang, and Hagos and Rawat, explore various aspects of military robots such as surveillance, communication, obstacle avoidance, and real-time data integration, there is a clear need for further research and development. The challenges identified in these studies—such as mobility, autonomy, communication, and real-time decision-making—must be addressed to improve the effectiveness of military robots in combat zones [24]. Future work should focus on integrating advanced AI, sensor fusion, and reliable communication technologies to enhance the performance and adaptability of military robots, ensuring they can meet the evolving demands of modern warfare.

3. ISSUES IN EXISTING SYSTEMS

Existing technologies like Radio Frequency (RF), Bluetooth, and GSM (Global System for Mobile Communication) come with certain limitations [25]. These include a restricted operational range, making them less effective for long-distance surveillance or spying tasks. Additionally, these systems face constraints such as limited data transfer capabilities and bandwidth delays, which can hinder their efficiency in real-time applications.

3.1 Design Structure

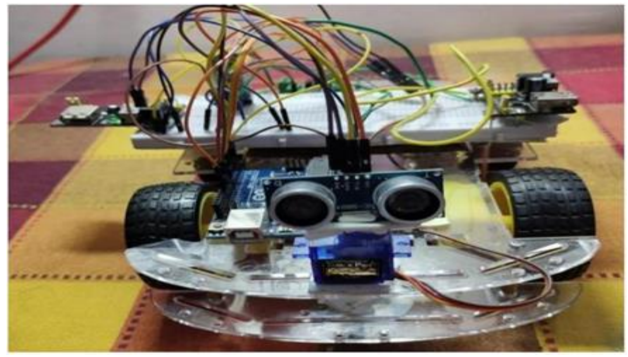

Fig.3.1.1. Design of the robot

This section introduces a prototype of a multi-purpose robot designed for military applications and equipped with various advanced components. The system integrates proximity sensors, a GPS module, a camera module, a motor driver, a relay module, servo motors, rugged wheels or tracks, a lithium-ion battery, a buck converter, a microcontroller or processor, and a secure communication module. These components enable seamless interaction between the robot and its software environment for efficient data exchange and Multi-Purpose Robot for Military Application 5 task execution. Further details about the robot's design, including mechanical schematics and electronic circuitry, are discussed in subsequent sections. The robot operates through four fundamental processes.

3.2 Implementation Hardware

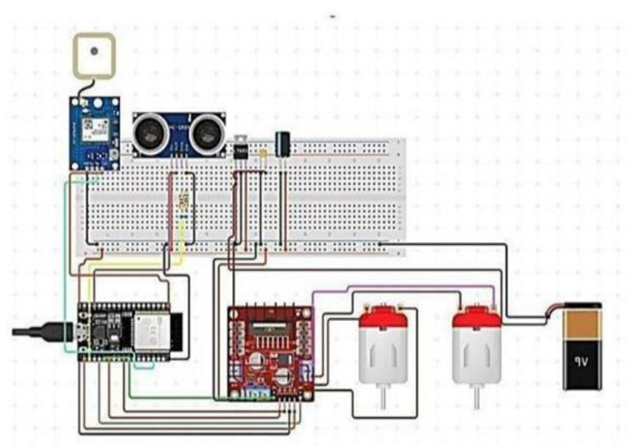

Fig.3.1.2. Circuit Diagram

To develop a multi-purpose robot for military applications, the hardware components play a pivotal role in ensuring functionality and adaptability to diverse missions. These components include a microcontroller (e.g., Arduino UNO or STM32), proximity sensors, servo motors, rugged wheels or tracks, a motor driver, a buck converter, a GPS module, a camera module, a communication module (e.g., NRF24L01 or SIM800L), a lithium-ion battery, and a robust chassis.

Figure 3 illustrates the internal structure of the robot, which incorporates multiple sensors as input devices to detect environmental changes, obstacles, and potential threats.

3.3 Hardware

The NodeMCU ESP32, built on the ESP32 microcontroller, is a versatile development board designed for diverse IoT (Internet of Things) applications. It features a dual-core processor, along with built-in Wi-Fi and Bluetooth capabilities, enabling efficient remote control and real-time data processing. This makes it highly suitable for projects like smart home automation, sensor networks, and robotics, where reliable wireless communication is essential. The board includes multiple digital and analog pins and supports various expansion modules, allowing easy integration with sensors, motors, and other devices. With its comprehensive features, the NodeMCU ESP32 serves as a dependable and adaptable solution for modern connected applications.

Fig .3.1.3.Node MCE ESP 32

The GPS NEO-6M module is a compact and dependable GPS receiver that operates using the u-blox NEO-6M chipset. It excels in providing precise location data, including latitude, longitude, altitude, and time, by capturing signals from GPS satellites. This module is frequently employed in projects requiring real-time location tracking, such as vehicle monitoring, navigation systems, and outdoor robotics. Its support for update rates of 1Hz and 10Hz ensures suitability for applications that demand continuous and accurate positioning updates. Featuring a straightforward serial communication interface (UART), it can easily connect to microcontrollers like Arduino or ESP32, facilitating integration into IoT and tracking solutions. Thanks to its small size and energy efficiency, the NEO-6M is an ideal choice for embedded systems and portable devices.

Fig.3.1.4. GPS NEO-6M

The L293D Motor Driver is an Integrated Circuit (IC) commonly used to control the operation of DC motors and stepper motors in robotics and automation applications. This 16-pin IC allows for the simultaneous control of two DC motors or a single stepper motor, offering bidirectional movement (forward and reverse) and speed adjustment using Pulse Width Modulation (PWM). It operates by managing the flow of current to the motors through a network of transistors and diodes, ensuring smooth and efficient performance. Additionally, the L293D is equipped with built-in safety features, such as thermal shutdown and overload protection, to prevent damage from overheating or excessive current, making it a reliable choice for motor control tasks.

Fig.3.1.5. L293D Motor Driver

A DC motor, or Direct Current motor, operates using direct current (DC) electricity to convert electrical energy into mechanical motion. This makes it an essential component in areas like robotics, automation, and home appliances. DC motors are valued for their ability to precisely control speed and adjust torque, making them perfect for applications where detailed performance control is necessary. The motor consists of two main parts: the stator, which remains stationary, and the rotor, which rotates.

Fig.3.1.6. DC Motor

Battery 12 V: A 12V battery is a versatile power source widely used in various applications, including robotics, automotive systems, and backup power supplies. Available in both lead-acid and lithium-based types, it provides a stable 12-volt output, making it ideal for powering motors, sensors, and other peripherals. Leadacid batteries are commonly used for their affordability and high energy storage, though they are heavier and less efficient. In contrast, lithium-ion and Lithium Polymer (LiPo) batteries are lighter, more efficient, and offer higher energy density, making them popular in portable electronics and robotics. These batteries are compatible with motor drivers and microcontrollers, providing reliable power for systems requiring moderate to high energy

Fig.3.1.7. Battery 12 V

An ultrasonic sensor is a device that measures distance by sending out high frequency sound waves and calculating the time it takes for these waves to reflect back after hitting an object. It consists of two main components: a transmitter that emits the sound waves and a receiver that detects the reflected waves. The sensor measures the time it takes for the sound to travel to the object and back, using the speed of sound to calculate the distance. Ultrasonic sensors are commonly used in fields like robotics, automation, and obstacle detection due to their precision, reliability, and ability to function in various conditions. They are particularly useful for applications such as distance measurement, object detection, and proximity sensing in areas like self-driving cars, collision avoidance, and liquid level monitoring.

Fig.3.1.8. Ultrasonic Sensor

The SIM800L is a small GSM/GPRS module designed to facilitate communication between microcontrollers and cellular networks. It enables devices to perform tasks such as sending and receiving text messages, making and receiving phone calls, and accessing the internet using GPRS (General Packet Radio Service).

Fig.3.1.9. Sim800L

An NPN sensor is a type of sensor that utilizes an NPN (Negative-Positive Negative) transistor as its switching component. When activated, typically by detecting an object or specific environmental condition, the sensor produces a low output signal (logic 0) that is connected to the ground. This behavior contrasts with a PNP sensor, which generates a high output signal (logic 1) upon activation.

Fig.3.1.10. NPN sensor

The image above shows an NPN sensor, typically used in various applications, including robotics, automation, and industrial systems. This type of sensor works on the principle of detecting the presence or absence of an object through the reflection of signals, such as electromagnetic waves or light. In the context of a Multi-Purpose Robot for Military Applications, the NPN sensor can be used for detecting obstacles, providing feedback on the robot's environment, and enabling precise navigation. NPN sensors are known for their ability to produce a signal output when an object is detected, making them ideal for collision avoidance and surveillance tasks in military environments. The sensor's wiring is shown in the image, where the red wire typically serves as the power input, while the black wire is used for the ground connection.

4. BLOCK DIAGRAM

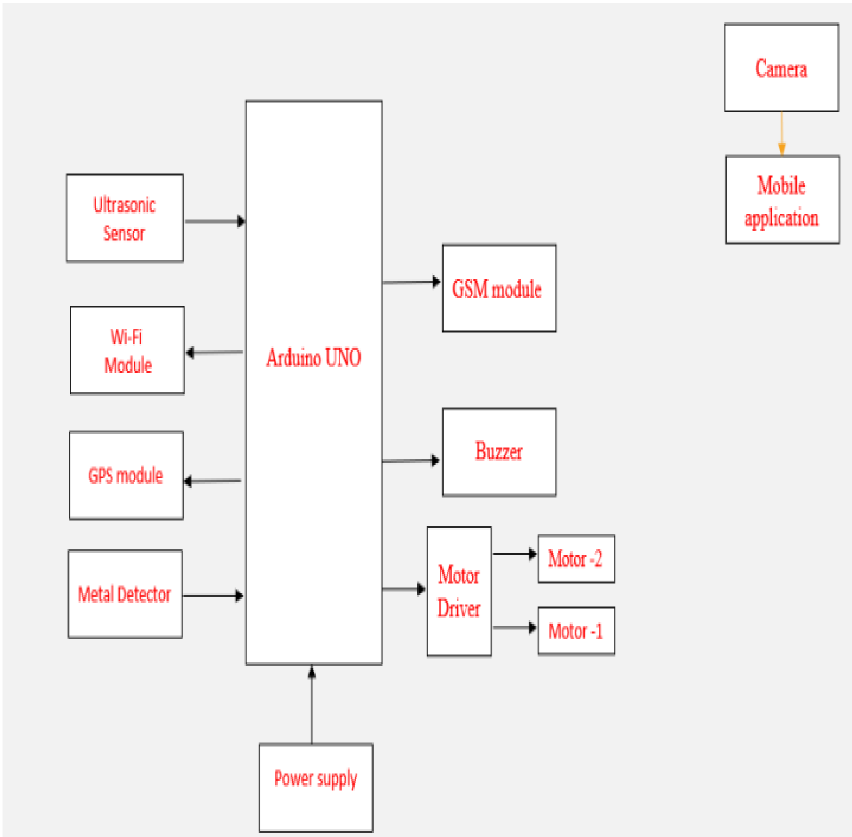

Fig.4.1.Block Diagram

The Multi-Purpose Robot for Military Applications is an advanced system designed to serve various functions in challenging environments. Central to its operation is the Arduino UNO, a microcontroller that processes data from the robot's sensors and coordinates its movements. The robot is equipped with an ultrasonic sensor, allowing it to detect obstacles in its path and avoid collisions. This is crucial for maintaining safety during missions in unpredictable environments. The Wi-Fi module ensures seamless wireless communication, enabling remote control and monitoring through a mobile application. This feature enhances the robot's adaptability, enabling the operator to control it from a distance.

Another vital component is the GPS module, which provides real-time location tracking. This allows the robot to navigate efficiently in military operations where precise location information is critical. The inclusion of a metal detector significantly boosts the robot's utility by enabling it to detect metallic objects, such as landmines or unexploded ordnance, a task essential for bomb detection and disposal. With a motor driver controlling the two motors, the robot can move in any direction, while the GSM module and buzzer alert operators in case of emergencies. Together, these components work in unison to create a versatile and efficient military robot capable of handling a variety of complex tasks.

5. METHODOLOGY

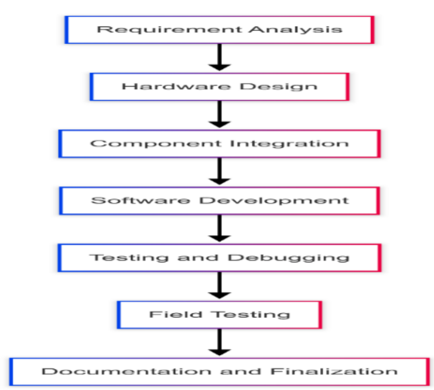

Fig.5.1.Development Process Flowchart

This flowchart illustrates the sequential steps involved in a typical development process. It starts with Requirement Analysis, where the project's needs are identified. The process proceeds through Hardware Design and Component

Integration**,** followed by Software Development and Testing and Debugging**.** Afterward, Field Testing is conducted, and the project is finalized with Documentation and Finalization. The flow is represented with alternating blue and pink boxes to signify distinct phases of the development cycle.

5. RESULTS

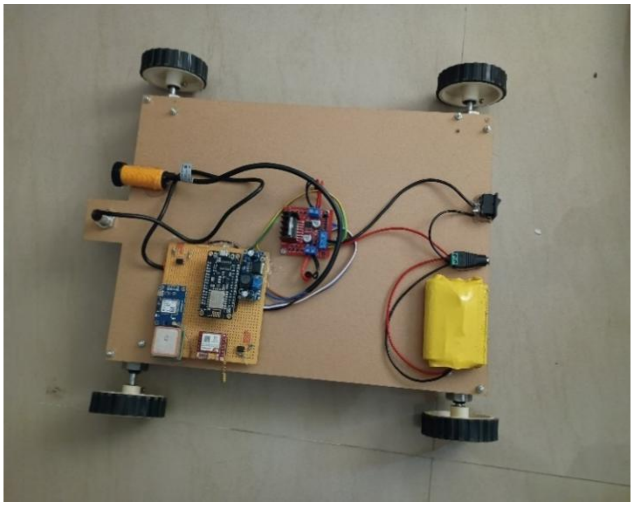

Fig.6.1. Top View of the Advanced Multipurpose Military Robot

The image shows the top view of a multipurpose military robot, highlighting its central components. The NodeMCU ESP32 microcontroller manages control functions, while the GPS module ensures location tracking. Additionally, the motor driver and 12V battery power the robot's movement and functionality.

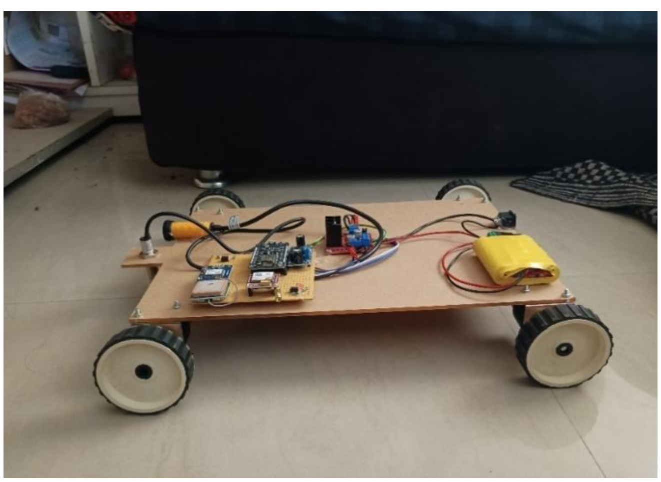

Fig.6.2. Side View of the Advanced Multipurpose Military Robot

The image shows a side view of the military robot, showcasing its essential components mounted on a sturdy acrylic chassis. The NodeMCU ESP32 microcontroller is clearly visible, connected to the GPS module and motor driver, which enable communication, navigation, and control of the robot. The 12V battery powers the system, ensuring the robot can operate efficiently across extended periods. The robot's wheels provide mobility, allowing it to navigate various terrains autonomously.

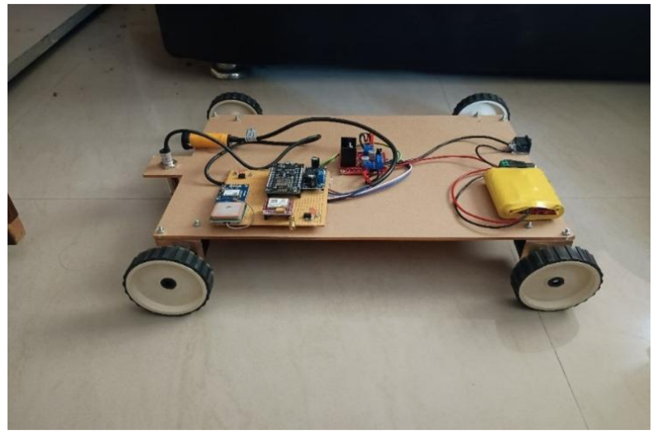

Fig.6.3. Side View of the Multipurpose Military Robot with Electronics and Power System

This side view of the multipurpose military robot reveals its structure and key components. The NodeMCU ESP32 microcontroller is positioned at the center, connected to a GPS module for location tracking, while the motor driver and wires allow control over the robot's movement. The 12V battery provides the necessary power for operation, and the wheeled chassis ensures mobility across different surfaces. This design ensures the robot can perform autonomous navigation, surveillance, and communication tasks in various military environments.

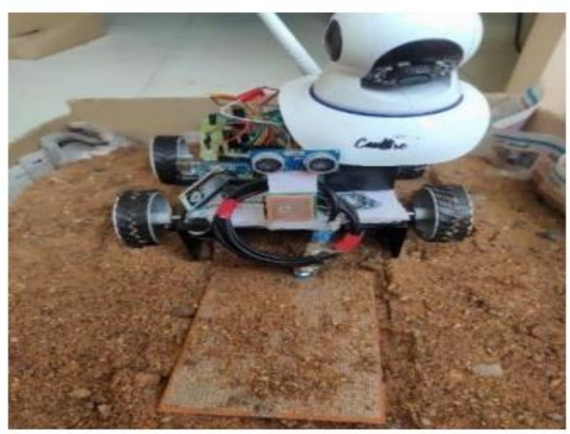

Fig.6.4.Multipurpose Military Robot in Operation on Rough Terrain

The image shows the multipurpose military robot in action, positioned on a rough surface that simulates a real-world terrain scenario. The robot is equipped with a camera module at the top, which likely aids in surveillance and monitoring tasks. Visible components include the ultrasonic sensor for obstacle detection and the GPS module for location tracking. The motorized wheels allow the robot to navigate the uneven terrain, and the microcontroller on the chassis controls all the robot's functions, ensuring smooth operation in real-time. The rugged setup showcases its potential in complex military operations.

Fig .6.5. Top view of robotic Vehicle

The figure shows a prototype robotic vehicle equipped with a wireless camera and sensors, mounted on a chassis with four wheels. It appears to be operating in a sandbox-like test environment, likely for soil or terrain navigation experiments. The system includes an Arduino microcontroller and additional electronic components for control and communication**.**

6. CONCLUSION

The design and development of multi-purpose robots for military applications have become essential in enhancing operational efficiency, improving safety, and minimizing risks to human personnel in high-risk environments. The integration of advanced robotics, such as the multi-purpose military robot described in this project, has revolutionized defense operations by providing capabilities that traditional human forces cannot match. This robot, powered by the NodeMCU ESP32 microcontroller, is equipped with various sensors, including ultrasonic and NPN sensors, GPS and GSM modules, and DC motors, allowing it to perform tasks such as surveillance, reconnaissance, environmental monitoring, and hazardous material detection.

The robot's design emphasizes autonomy, safety, and efficiency, enabling it to navigate complex environments, detect obstacles, and provide real-time communication with command centers. Its robust chassis, reliable power system, and advanced sensor capabilities ensure that it can operate in challenging terrains, enhancing the effectiveness of military missions while reducing the risks faced by human personnel. However, as seen in the related works section, there are still challenges to overcome, such as improving communication systems in remote areas, enhancing mobility in challenging terrains, and incorporating AI for better decision-making and navigation.

Future research and development should focus on integrating these technologies to create more advanced systems that can adapt to dynamic military environments. The growing use of robotics in military operations demonstrates the significant potential of autonomous systems in transforming defense strategies. In conclusion, this project highlights the vast possibilities that multi-purpose military robots offer in modern defense operations. By continuing to develop and refine these technologies, military robots will play an increasingly critical role in supporting military forces worldwide, performing tasks that are too dangerous, complex, or resource-intensive for human soldiers. The integration of cutting-edge technologies will ultimately result in safer, more efficient, and effective military operations.

7. FUTURE SCOPE

1. AI Integration: Incorporating advanced AI and machine learning for autonomous decision-making will enhance navigation, obstacle avoidance, and mission planning in complex environments.
2. 5G and Satellite Connectivity: Real-time communication through 5G and satellite links will ensure reliable command control and data transfer in remote or hostile zones.
3. Energy Efficiency: Optimizing energy usage, including solar energy and advanced battery systems, will extend the robot's operational duration during extended missions.
4. Specialized Applications: Robots could be designed for medical support, such as evacuating injured personnel or delivering supplies, and for combat roles like deploying reconnaissance drones.
5. Swarm Robotics: Advancements in swarm robotics will enable multiple robots to collaborate in coordinated operations, improving mission efficiency and scalability across larger areas.

REFERENCES

[1] A. Haskard and D. Herath, "Secure Robotics: Navigating Challenges at the Nexus of Safety, Trust, and Cybersecurity in Cyber-Physical Systems," *ACM Comput. Surv.*, vol. 57, no. 9, pp. 1–48, Sep. 2025, doi: 10.1145/3723050.

[2] A. T. Abu-Jassar, H. Attar, A. Amer, V. Lyashenko, V. Yevsieiev, and A. Solyman, “Development and Investigation of Vision System for a Small-Sized Mobile Humanoid Robot in a Smart Environment,” *Int. J. Crowd Sci.*, vol. 9, no. 1, pp. 29–43, Jan. 2025, doi: 10.26599/IJCS.2023.9100018.

[3] T. Kaur and D. Kumar, “Wireless multifunctional robot for military applications,” in *2015 2nd International Conference on Recent Advances in Engineering & Computational Sciences (RAECS)*, Chandigarh, India: IEEE, Dec. 2015, pp. 1–5. doi: 10.1109/RAECS.2015.7453343.

[4] M. Dunbabin and L. Marques, “Robots for Environmental Monitoring: Significant Advancements and Applications,” *IEEE Robot. Automat. Mag.*, vol. 19, no. 1, pp. 24–39, Mar. 2012, doi: 10.1109/MRA.2011.2181683.

[5] C. K. Ho, A. Robinson, D. R. Miller, and M. J. Davis, “Overview of Sensors and Needs for Environmental Monitoring,” *Sensors*, vol. 5, no. 1, pp. 4–37, Feb. 2005, doi: 10.3390/s5010004.

[6] S. F. Hassan and M. Gupta, “Development of high performance magnesium nano-composites using nano-Al2O3 as reinforcement,” *Materials Science and Engineering: A*, vol. 392, no. 1–2, pp. 163–168, Feb. 2005, doi: 10.1016/j.msea.2004.09.047.

[7] J. Ekeocha, C. Ellingford, M. Pan, A. M. Wemyss, C. Bowen, and C. Wan, “Challenges and Opportunities of Self-Healing Polymers and Devices for Extreme and Hostile Environments,” *Advanced Materials*, vol. 33, no. 33, p. 2008052, Aug. 2021, doi: 10.1002/adma.202008052.

[8] T. H. Kaffale and J. Liu, “Speed and Direction Control of DC Motor Using Arduino Uno Microcontroller,” *OALib*, vol. 12, no. 03, pp. 1–11, 2025, doi: 10.4236/oalib.1113007.

[9] V. Kumar, “Digital Enablers,” in *The Economic Value of Digital Disruption*, in Management for Professionals. , Singapore: Springer Nature Singapore, 2023, pp. 1–110. doi: 10.1007/978-981-19-8148-7_1.

[10] J. Khurshid and Hong Bing-rong, “Military robots - a glimpse from today and tomorrow,” in *ICARCV 2004 8th Control, Automation, Robotics and Vision Conference, 2004.*, Kunming, China: IEEE, 2004, pp. 771–777. doi: 10.1109/ICARCV.2004.1468925.

[11] R. G. Arora and A. Chauhan, “Faculty perspectives on work from home: Teaching efficacy, constraints and challenges during COVID’ 19 lockdown,” *Journal of Statistics and Management Systems*, vol. 24, no. 1, pp. 37–52, Jan. 2021, doi: 10.1080/09720510.2021.1875567.

[12] J. Trevelyan, W. R. Hamel, and S.-C. Kang, “Robotics in Hazardous Applications,” in *Springer Handbook of Robotics*, B. Siciliano and O. Khatib, Eds., in Springer Handbooks. , Cham: Springer International Publishing, 2016, pp. 1521–1548. doi: 10.1007/978-3-319-32552-1_58.

[13] M. Ashokkumar and S. Muthukumaran, “Effect of Ni doping on electrical, photoluminescence and magnetic behavior of Cu doped ZnO nanoparticles,” *Journal of Luminescence*, vol. 162, pp. 97–103, Jun. 2015, doi: 10.1016/j.jlumin.2015.02.019.

[14] S. A. H. Mohsan, N. Q. H. Othman, Y. Li, M. H. Alsharif, and M. A. Khan, “Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, and future trends,” *Intel Serv Robotics*, vol. 16, no. 1, pp. 109–137, Mar. 2023, doi: 10.1007/s11370-022-00452-4.

[15] R. Wang, “AdaBoost for Feature Selection, Classification and Its Relation with SVM, A Review,” *Physics Procedia*, vol. 25, pp. 800–807, 2012, doi: 10.1016/j.phpro.2012.03.160.

[16] M. Aizat, N. Qistina, and W. Rahiman, “A Comprehensive Review of Recent Advances in Automated Guided Vehicle Technologies: Dynamic Obstacle Avoidance in Complex Environment Toward Autonomous Capability,” *IEEE Trans. Instrum. Meas.*, vol. 73, pp. 1–25, 2024, doi: 10.1109/TIM.2023.3338722.

[17] R. Karim, A. Iftikhar, B. Ijaz, and I. Ben Mabrouk, “The Potentials, Challenges, and Future Directions of On-Chip-Antennas for Emerging Wireless Applications—A Comprehensive Survey,” *IEEE Access*, vol. 7, pp. 173897–173934, 2019, doi: 10.1109/ACCESS.2019.2957073.

[18] P. Sharma, “THEORETICAL ANALYSIS OF SOIL NAILING: DESIGN, PERFORMANCE AND FUTURE ASPECTS,” 2015.

[19] R. Priyadarshini, R. M. Mehra, A. Sehgal, and P. J. Singh, Eds., *Robotics and smart autonomous systems: technology and applications*, First edition. in Wireless communications and networking technologies. Boca Raton London New York: CRC Press, 2025.

[20] F. Kendoul, “Survey of advances in guidance, navigation, and control of unmanned rotorcraft systems,” *Journal of Field Robotics*, vol. 29, no. 2, pp. 315–378, Mar. 2012, doi: 10.1002/rob.20414.

[21] D. Wong and T. K. Lam, “The role of tranexamic acid in breast and body contouring surgery: a review of the

literature," *Australas J Plast Surg*, vol. 5, no. 1, pp. 24–31, Mar. 2022, doi: 10.34239/ajops.v5n1.277.

[22] H. Zhang, "Exploring the Impact of AI on Human Resource Management: A Case Study of Organizational Adaptation and Employee Dynamics," *IEEE Trans. Eng. Manage.*, vol. 71, pp. 14991–15004, 2024, doi: 10.1109/TEM.2024.3457520.

[23] L. A. Grieco *et al.*, "IoT-aided robotics applications: Technological implications, target domains and open issues," *Computer Communications*, vol. 54, pp. 32–47, Dec. 2014, doi: 10.1016/j.comcom.2014.07.013.

[24] D. H. Hagos and D. B. Rawat, "Recent Advances in Artificial Intelligence and Tactical Autonomy: Current Status, Challenges, and Perspectives," *Sensors*, vol. 22, no. 24, p. 9916, Dec. 2022, doi: 10.3390/s22249916.

[25] D. Raychaudhuri and N. B. Mandayam, "Frontiers of Wireless and Mobile Communications," *Proc. IEEE*, vol. 100, no. 4, pp. 824–840, Apr. 2012, doi: 10.1109/JPROC.2011.2182095.