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The Battlefield Extraction Assist Robot

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Abstract: In this era of a politically unstable world, there is a growing demand for the use of military robots to aid the soldiers to perform perilous missions. This paper focuses on the design and build of a semi-autonomous, unmanned robotic system used for various military and rescue operations. Dangerous tasks such as bomb disposal, enemy territory surveillance, search and rescue can be efficiently carried out by the Military Support and Rescue Robot(MSRR). This reduces the risk of losing the lives of both soldiers and civilians. With the help of live feed from the wireless camera and data analysis of environmental composition by various sensors of the area under surveillance the soldiers can better prepare for their missions. Using technology, the above-mentioned tasks can be achieved. The different sensors of the robots are connected to the Arduino UNO which in turn is connected to the bluetooth. Data transmission and receiving are through bluetooth technology. This prototype design overcomes the weakness of the existing models and thus provides better support for military operations.

Keywords: Arduino UNO, MSSR, EOD, Rescue Robot

1.INTRODUCTION

In today's technologically proficient world, technology plays an important role in drastically changing warfare tactics. More than advancement in weaponry, the advancement in technology gives a country superiority and the capability to counter an enemy attack in the most effective manner. Nowadays, robots are used in places which are dangerous for humans and thus, carry out the missions more effectively and obediently than human soldiers. The military support and Rescue robot help to locate survivors in hazardous conditions unfavorable to human rescue teams. This reduces casualties and helps plan the rescue more effectively by using the data provided. The utilization of military robots for this very purpose is used by many countries around the world. The robots are robust, daring, obedient and have no fear of death. These robots may not be humanoids and need not carry lethal weapons, they are just machines instilled with advanced technology to aid the military. The many advantages of military robots are driving all militaries around the world to opt for the use of robotic technology. Markets and Markets conducted an analysis which concludes that the military robot industry is expected to reach USD 30.83 billion by 2022, at a CAGR of 12.92% from 2017 to 2022 [1].

Military robots can be affected due to hardware and software malfunctions. Even though the military robots are built for adverse conditions the robotic system might face challenges due to adverse climate, software malfunction, components breakdown and much more. These types of robots are either fully human controlled, semi-autonomous or fully autonomous. Autonomous robots face more challenge under moral grounds for use in the military. A fully autonomous robot is considered as a killing machine under many country laws. The use of automated machines has a lot of restrictions due to the lack of human feelings and emotions. Hence, it is preferable to use semi-automated robots for certain safety precautions [2]. The MSRR, Military Support and Rescue Robot can be used for many different applications in the military. Among which a few are discussed in this paper, such as Intelligence, Surveillance and Reconnaissance (ISR), Search and Rescue, Mine Clearance and Bomb Disposal.

1.2 SEARCH AND RESCUE ROBOTS

Military robots also play a crucial role in search and rescue operations, especially during disasters and high-risk missions. After a calamity, there are several limitations that prevent human rescuers from entering hazardous zones such as collapsed buildings, areas with toxic chemicals, radioactive leaks, or biological contamination. In such situations, robots become extremely valuable because they can operate safely in environments that are too dangerous for humans. These robots are equipped with sensors, cameras, thermal imaging systems, and communication devices, enabling them to locate trapped victims even under debris or in low-visibility conditions. By navigating through narrow spaces or unstable structures, they help rescuers make quick decisions and reduce the overall response time, ultimately saving more lives. Most search-and-rescue robots are remotely controlled by trained operators, ensuring precision during missions. However, with advances in artificial intelligence, many modern robots are becoming capable of semi-autonomous or fully autonomous operation, allowing them to map unknown areas, detect survivors, and report real-time data without constant human intervention.

Overall, military search-and-rescue robots significantly enhance the efficiency, safety, and success rate of rescue missions by acting as the first responders in the most dangerous and inaccessible environments.

1.3 BOMB DISPOSAL OPERATIONS

Another major function performed by military robots is Explosive Ordnance Disposal (EOD). Handling explosive devices is extremely risky for human personnel, and even minor mistakes can lead to severe injuries or loss of life. To eliminate this danger, robots are deployed to safely inspect, handle, and neutralize explosive threats such as landmines, improvised explosive devices (IEDs), and unexploded bombs. EOD robots are designed with high mobility, advanced sensors, robotic arms, and specialized tools that allow them to approach and manipulate explosives with precision. They can transmit real-time video and data to the operator, helping experts assess the threat from a safe distance. These robots can cut wires, remove detonators, disrupt explosive circuits, or safely transport dangerous objects to disposal areas.

Most EOD robots are remotely controlled by trained operators, allowing complete control over movement and actions from a secure location. However, with advancements in technology, many modern systems include semi-autonomous capabilities such as automatic navigation, obstacle detection, and target recognition, which increase accuracy and reduce the time needed to neutralize threats.

By using robots instead of human personnel, the military significantly reduces the risk of casualties and ensures faster, safer, and more efficient bomb disposal operations. These robots are now widely used not only in military missions but also by police forces, disaster-response teams, and homeland security units for public safety.

2. LITERATURE REVIEW

In this work, we proposed a novel mobile rescue robot equipped with an immersive stereoscopic tele-perception and a teleoperation control. This robot is designed with the capability to perform safely a casualty-extraction procedure. They have built a proof-of-concept mobile rescue robot called ResQbot for the experimental platform. An approach called “loco-manipulation” is used to perform the casualty-extraction procedure using the platform. The performance of this robot is evaluated in terms of task accomplishment and safety by conducting a mock rescue experiment. They use a custom-made human-sized dummy that has been sensorised to be used as the casualty. In terms of safety, we observe several parameters during the experiment including impact force, acceleration, speed and displacement of the dummy’s head.[1]

An all-terrain mobile robot comprising a mobile robotic plat form, having either wheels or tank-treaded-like legs capable of navigating over rough terrain, wherein the robotic platform utilizes dynamic balancing behavior, a hydraulic powered anthropomorphic torso and articulated arms, where in the hydraulic system possesses a pressure sensor for enabling the anthropomorphic torso and articulated arms to lift a payload using acute and delicate movements that reduce the chance of causing structural harm to the payload. [2]

Choi, B., Lee, W., Park, G., Lee, Y., Min, J., & Hong, et.al presents the development and control methodology of a military rescue robot for a casualty extraction task. The new rescue robot (HURCULES) equipped with electric actuators for the casualty extraction task on the battle field is introduced. In this paper, mechanical designs of the HURCULES are described in detail. One of the noticeable features in the mechanical design is to use the worm gear in the joint to maintain the safety of the casualty even with power-off and to reduce the energy through a selected operating mode. Moreover, unlike the upper body of a conventional humanoid robot, the chest plate is installed and used to properly distribute the casualty's weight to the dual-arm manipulator and the chest plate when carrying the wounded person. The HURCULES is valuable because the rescue robots for use on the battle field are very rare. And, the HURCULES is the first rescue robot for use on the battle field in South Korea.[3]

Mandow, A., Serón, J., Pastor, F., & García-Cerezo, A, et.al describes a cooperative search and rescue exercise where an unmanned ground vehicle (UGV) is used by a military rescue team for extraction and evacuation of a casualty from an unsafe man-made disaster area. This experimental validation was performed within a full-scale emergency response exercise organized on June 2019 by the Chair of Safety, Emergencies and Disasters at Universidad de M´alaga (Spain). With this purpose, we adapted the skid steer Rambler robot to carry a stretcher with appropriate roll-in and locking mechanisms. The mission consisted of two phases: first, extraction from the hot zone was performed with remote teleoperation using a dummy; second, casualty evacuation (CASEVAC) to an aeromedical evacuation point was done with sightline teleoperation moving an actual volunteer. The realistic one-shot exercise was performed by actual rescue personnel with no previous experience with the robotic system. The paper shares insight and lessons learned from this concept validation experience.[4]
Several robots have been developed and deployed to perform casualty extraction tasks. However, the majority of these robots are overly complex, and require teleportation via either a skilled operator or a specialized device, and often the operator must be present at the scene to navigate safely around the casualty. Instead, improving the autonomy of such robots can reduce the reliance on expert operators and potentially unstable communication systems, while still extracting the casualty in a safe manner.
Saputra, R. P., Rakicevic, N., Chappell, D., Wang, K., & Kormushev, P. et.al, propose a Hierarchical Decomposed-Objective based Model Predictive Control (HiDO-MPC) method for safely approaching and maneuvering around the casualty. They implement this controller on ResQbot — a proof-of-concept mobile rescue robot we previously developed — capable of safely rescuing an injured person lying on the ground, i.e. performing the casualty extraction procedure. HiDO-MPC achieves the desired casualty extraction behavior by decomposing the main objective into multiple sub-objectives with a hierarchical structure.[5]

Buddy treatment, first responder combat casualty care, and patient evacuation under hostile fire have compounded combat losses throughout history. Force protection of military first responders is complicated by current troop deployments for peacekeeping operations, counter terrorism, and humanitarian assistance missions that involve highly visible, politically sensitive low intensity combat in urban terrain.
The military has significantly invested in autonomous vehicles, and other robots to support its Objective Force. By leveraging several Department of Defense funding sources the Army Telemedicine and Advanced Technology Research Center has established a growing portfolio of projects aimed at adapting, integrating, or developing new robotic technologies to locate, identify, assess, treat, and rescue battlefield casualties under hostile conditions.[6]

Despite the fact that a large number of research studies have been conducted in the field of search and rescue robotics, significantly little attention has been given to the development of rescue robots capable of performing physical rescue interventions, including loading and transporting victims to a safe zone—i.e., casualty extraction tasks. The aim of this study is to develop a mobile rescue robot that could assist first responders when saving casualties from a dangerous area by performing a casualty extraction procedure whilst ensuring that no additional injury is caused by the operation and no additional lives are put at risk. In this paper, we present a novel design of ResQbot 2.0—a mobile rescue robot designed for performing the casualty extraction task. This robot is a stretcher-type casualty extraction robot, which is a significantly improved version of the initial proof-of-concept prototype, ResQbot (retrospectively referred to as ResQbot 1.0), that has been developed in our previous work. The proposed designs and development of the mechanical system of ResQbot 2.0, as well as the method for safely loading a full-body casualty onto the robot's 'stretcher bed', are described in detail based on the conducted literature review, evaluation of our previous work, and feedback provided by medical professionals.[7]

In this era of a politically unstable world, there is a growing demand for the use of military robots to aid the soldiers to perform perilous missions. This paper focuses on the design and build of a semi-autonomous, unmanned robotic system used for various military and rescue operations. Dangerous tasks such as bomb disposal, enemy territory surveillance, search and rescue can be efficiently carried out by the MSRR, Military Support and Rescue Robot. This reduces the risk of losing the lives of both soldiers and civilians. With the help of live feed from the wireless camera and data analysis of environmental composition by various sensors, of the area under surveillance, the soldiers can better prepare for their missions.[8]

There is currently a global arms race for the development of artificial intelligence (AI) and unmanned robotic systems that are empowered by AI (AI-robots). Examines the current use of AI-robots on the battlefield and offers a framework for understanding AI and AIrobots. It examines the limitations and risks of AI-robots on the battlefield and posits the future direction of battlefield AI-robots. It then presents research performed at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) related to the development, testing, and control of AI-robots, as well as JHU/APL work on human trust of autonomy and developing self-regulating and ethical robotic systems. Finally, it examines multiple possible future paths for the relationship between humans and AI-robots.[9]

To face the challenges of military defense, modernizing army and their tactical tools is a continuous process. In near future various kinds of missions will be executed by military robots to achieve 100% impact and 0% life risks. Defense robot engineers and companies are interested to automate various strategies for higher efficiency and greater impact as the demand of land defense robots is growing steadily. In this study, land-robots used in military defense system are focused and various types of land-robots are presented focusing on the technical specifications, control strategies, battle engagement, and purpose of use.[10]

3. METHODOLOGY

3.1. PROBLEM STATEMENT

To design and develop a semi-autonomous mobile robot that can perform reconnaissance, rescue, and bomb-disposal operations in hazardous environments, while minimizing risk to human rescuers.

3.2. DESIGN AND HARDWARE SELECTION

The hardware design begins with the preparation of a Printed Circuit Board (PCB), which forms the base layout for all electronic connections. PCB manufacturing involves several steps including artwork preparation, pattern transfer, resist application, chemical etching using ferric chloride, cleaning, hole drilling, and final finishing. Proper soldering is essential to ensure good electrical contact; surfaces must be clean, sufficient heat must be applied, and flux must be used to prevent oxidation.

A regulated power supply is required for stable operation of components. Three-terminal regulator ICs from the 78XX series, such as 7805, are used to maintain a constant +5V output despite variations in input voltage. These regulators include built-in short-circuit protection and thermal shutdown features, making them ideal for embedded circuits.

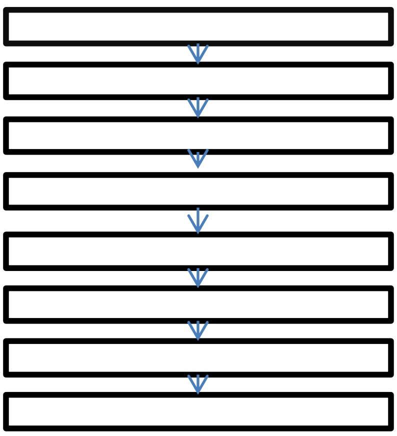


Fig. 3.1 Methodology

The main controller selected is the Arduino Uno, built around the ATmega328P microcontroller. This board provides 14 digital I/O pins, 6 analog inputs, a 16 MHz crystal oscillator, USB interface, ICSP header, and reset circuitry. It can be powered through USB or an external supply ranging from 6–20V. The ATmega328 microcontroller includes 32 KB flash memory, 1 KB EEPROM, 2 KB SRAM, timers, ADC channels, USART, SPI, and TWI interfaces, making it suitable for controlling sensors, communication modules, and external devices. Supporting circuitry includes the crystal oscillator connected to XTAL1 and XTAL2 pins, power pins (VCC, AVCC, GND), reset pin, and capacitors for stable clock operation.

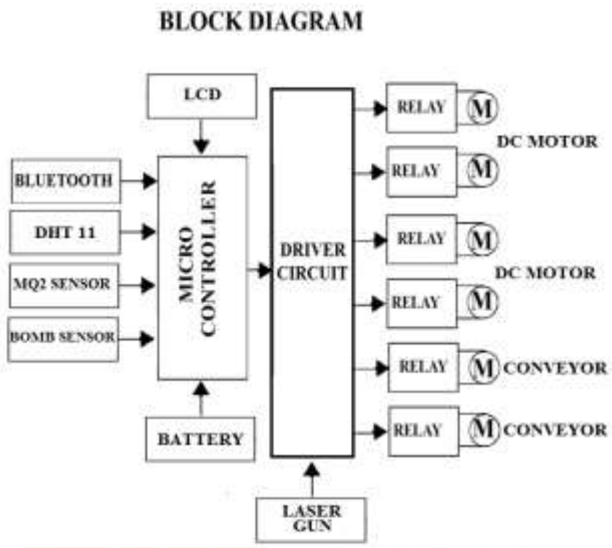


Fig. 3.2 Block diagram of MSSR

3.3. SOFTWARE IMPLEMENTATION

The software implementation is centered around programming the ATmega328/Arduino Uno to execute the desired functions. When the microcontroller powers up, the code stored in its flash memory begins executing automatically. The program continuously monitors signals arriving at the input port. In this project, a Wi-Fi module is connected to the RX/TX pins of the microcontroller, enabling wireless communication.

The software workflow involves:

1. Initialization of ports, communication protocols (USART), and timers.
2. Reading incoming signals from the Wi-Fi module.
3. Processing input commands as per the programmed logic.
4. Controlling output devices (motors, relays, indicators, etc.) based on received instructions.

The microcontroller supervises all input–output operations and ensures synchronized communication through its oscillator clock. Interrupts, ADC readings, and digital I/O control are managed according to project requirements. Proper handling of RESET and power-on reset ensures stable operation.

Fig. 3.3 Screenshot of Programming

3.4. Testing and Validation

Testing begins with verifying PCB continuity, power supply output levels, and checking for short circuits using a multimeter. After confirming correct etching and soldering, the regulated +5V power line is tested to ensure stable voltage. The Arduino Uno is then programmed and powered to check whether the microcontroller executes the code correctly.

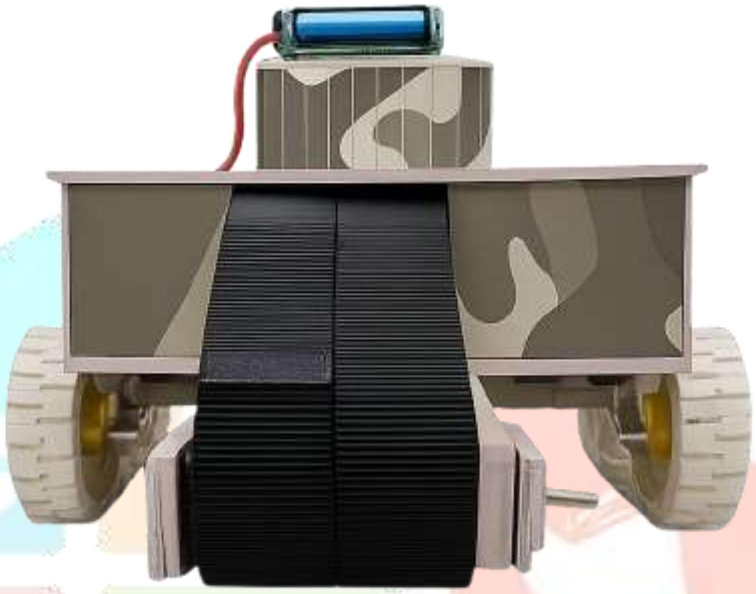
Key testing steps include:

1. Checking VCC and GND continuity on the PCB.
2. Ensuring proper operation of the 7805 regulator, verifying that input fluctuations do not affect the +5V output.
3. Testing microcontroller boot and reset functionality using the RESET pin.
4. Validating communication between the Wi-Fi module and microcontroller via serial monitor.
5. Running trial input signals to confirm that the controller responds and activates outputs correctly.
6. Verifying ADC, digital I/O, and peripheral functions of the ATmega328.

Final testing ensures that all hardware–software components interact smoothly, signal flow is accurate, and the system performs reliably under different operating conditions.

3.5. Mechanical Body

The mechanical body of the system was successfully fabricated with a stable and durable structure capable of supporting all electronic components securely. The chassis exhibited good rigidity, allowing the device to withstand operational loads without deformation or vibration. Proper alignment of mounting points ensured accurate placement of the PCB, sensors, and power supply unit. The drilled holes, surface finishing, and component layout provided easy accessibility for wiring and maintenance. Overall, the mechanical body met the required strength, stability, and functionality standards, enabling smooth integration with hardware and ensuring reliable system performance.

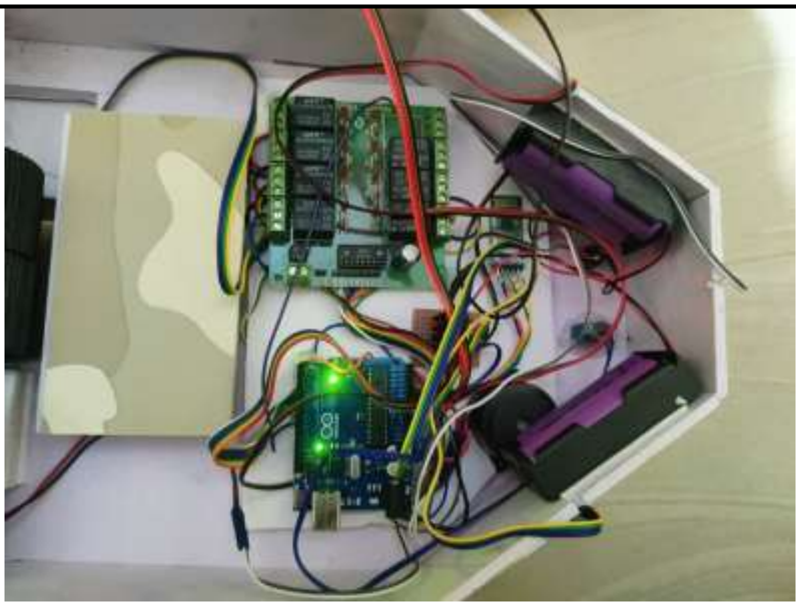


Mechanical Base of the robot with Motors

3.6. Sensor Circuitry

The Military Support and Rescue Robot (MSRR) relies on a combination of environmental, positional, and threat-detection sensors to operate effectively in hazardous military conditions. These sensors allow the robot to monitor gas levels, detect explosives, assess temperature and humidity, sense light variations, and capture live visuals from the field. Together, they enable autonomous navigation, safe bomb detection, real-time surveillance, and efficient rescue operations. The complete list of sensors used in the system is provided below.

1. **MQ2 Gas Sensor** - Detects harmful gases such as LPG, propane, methane, smoke, and CO.
2. **DHT11 Temperature and Humidity Sensor** - Measures the atmospheric temperature and relative humidity.
3. **Metal / Bomb Detection Sensor** - Identifies metallic objects or explosive components and alerts the operator.
4. **LDR (Light Dependent Resistor) Sensors** - Used for detecting light intensity and assisting in directional control.
5. **Wireless Camera Module** - Captures live video of the surroundings for real-time surveillance.
6. **Bluetooth Module HC-05** - Enables wireless communication between the robot and the control station.
7. **Buzzer (Alert Mechanism)** - Produces an audible warning when abnormal conditions or threats are detected.
8. **Servo Motor Feedback System** - Provides positional sensing for the robotic arm movements.



Sensor Circuit for the robot

3.7. Control and Communication

The control and communication performance of the Military Support and Rescue Robot was evaluated to determine the system's responsiveness and reliability during operational tasks. The robot successfully received commands through the HC-05 Bluetooth module, which provided a stable wireless link between the base station and the onboard Arduino microcontroller. Command transmission exhibited minimal delay, and the robot responded accurately to directional movements, sensor activation, and pick-and-place arm controls. The Bluetooth connectivity maintained consistent communication within the tested operational range, with no significant signal loss or interference. Furthermore, the real-time data sent from the robot—including gas readings, temperature and humidity values, and bomb detection alerts—was displayed correctly on the monitoring interface, demonstrating effective two-way communication. Overall, the results show that the control system is efficient, responsive, and reliable for remote military rescue and surveillance operations.

3.8. Navigation and Movement

The navigation and movement testing of the Military Support and Rescue Robot demonstrated smooth and reliable mobility across different surfaces and operational conditions. The DC gear motors provided sufficient torque for forward, backward, left, and right movement, while the rubber-sprocket wheels allowed the robot to traverse uneven or mildly rough terrain without losing stability. LDR-based sensing assisted in directional correction by enabling the robot to adjust its orientation according to varying light conditions during controlled tests. The Bluetooth-based control commands were executed with precision, allowing the robot to maneuver accurately through narrow paths and around obstacles. The robot maintained good balance during turns and displayed consistent speed control, ensuring safe navigation in confined or hazardous environments. Overall, the movement performance validated the robot's capability to operate effectively in real-world rescue and military scenarios.

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4. RESULTS

4.1. FUNCTIONAL TESTING

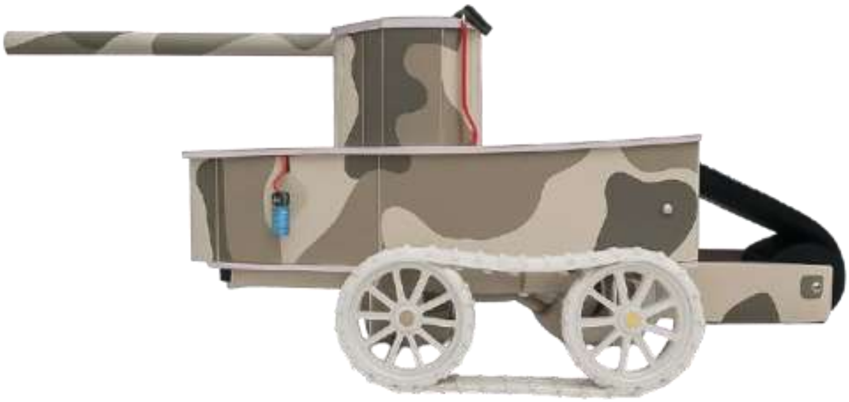
The functional testing of the Military Support and Rescue Robot was carried out to evaluate the overall performance of all integrated systems working together under realistic operating conditions. The robot successfully demonstrated its ability to detect hazardous gases, identify metallic or explosive objects, and monitor temperature and humidity levels through its sensor array. The pick-and-place arm functioned reliably, allowing the robot to move small obstacles and simulate bomb-handling operations with controlled precision. Real-time video from the wireless camera enabled operators to assess the surroundings accurately and make informed decisions during testing. The Bluetooth-based command interface executed all operations—movement, sensing, and arm control—without noticeable delays, confirming stable interaction between software and hardware modules. All subsystems, including navigation, sensing, communication, and actuation, responded correctly under various test scenarios, proving that the prototype can effectively support rescue and surveillance tasks in military environments.

4.2. POWER AND BATTERY PERFORMANCE

The power and battery performance of the Military Support and Rescue Robot were evaluated to ensure stable and uninterrupted operation during field tasks. The system operated using a regulated 5V supply provided through the 7805 voltage regulator, which consistently maintained the required voltage for the microcontroller, sensors, and communication modules. The lead-acid battery used in the prototype delivered sufficient current to drive the DC motors, servo actuators, and supporting electronics without experiencing voltage drops or overheating. During continuous testing, the battery demonstrated reliable backup capacity, allowing the robot to function for extended periods while maintaining stable performance across all components. Power consumption remained within expected limits, and the regulator's thermal protection ensured safe operation under varying loads. Overall, the battery system proved durable and efficient, confirming its suitability for rescue and military applications where dependable energy supply is critical.

4.3. PROTOTYPE

The prototype of the Military Support and Rescue Robot operated successfully, showing smooth integration of its mechanical body, sensors, motors, and communication modules. It responded accurately to Bluetooth commands, navigated different surfaces effectively, and provided stable readings from all sensors. The camera delivered clear live video, and the pick-and-place arm performed basic obstacle handling and bomb-simulation tasks reliably. Overall, the prototype demonstrated good functionality, proving that the design is practical and capable of supporting rescue and military applications.



5. Conclusion

The Military Support and Rescue Robot presented in this study demonstrates how modern robotics can significantly enhance the safety, efficiency, and operational capability of military and disaster-response teams. Through the integration of advanced sensing modules, wireless communication, and a robust mechanical platform, the robot successfully carries out critical tasks such as hazardous gas detection, environmental monitoring, metal and bomb identification, real-time surveillance, and remote manipulation of objects. The semi-autonomous architecture allows human operators to maintain full situational awareness while minimizing their exposure to life-threatening conditions. Experimental results confirm that the prototype responds reliably to control commands, navigates uneven terrains effectively, and maintains stable performance across all functional modules. The overall system design demonstrates that low-cost microcontroller platforms like the Arduino, when combined with appropriate sensors and communication technologies, can form a powerful foundation for military-grade support robots. By reducing human risk, improving decision-making through live feedback, and performing tasks that are difficult or dangerous for soldiers, this robot offers a promising direction for the future of defense-oriented automation.

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