International Conference KNOWLEDGE-BASED ORGANIZATION
Vol. XXXI No 1 2025

MODULARIZATION OF A ROBOTIC QUADRUPED PLATFORM FOR DEPLOYMENT IN TACTICAL MILITARY APPLICATIONS

Ionuț-Cristian ȚOPA*,, Silviu-Mihai PETRIȘOR*,****

***University of Oradea, Romania**
****"Nicolae Bălcescu" Land Forces Academy, Sibiu, Romania**
topaionutcristian@gmail.com

Abstract: *This study explores the feasibility of adapting a robotic quadruped platform for tactical military demonstration applications through its structural modularization. The main objective of the scientific approach consists in the design and realization of a modular system for the support and integration of an airsoft machine pistol on a mobile quadruped robot, with the aim of implementing it in tactical military demonstration applications specific to infantry and artillery weapons. The robotic platform employed is a commercially available model designed for civilian use, and the proposed modifications do not involve irreversible interventions on its architecture, leaving the possibility of rapid reconfiguration for various purposes. The designed mount ensures the integration of a remotely controllable non-lethal weapon system, and the modular design allows for easy installation and dismantling according to mission needs.*

Keywords: **mobile robot, modularity, military applications, technological humanism, human-artificial partnership**

1. Introduction

The rapid advancement of technology has heightened the demand for developing robots capable of performing complex tasks akin to human abilities [1].

Four-legged robots are now no longer just prototypes. The field of robotics is focused on finding new application areas for robots, more than just locomotion [2].

Thus, quadruped robots have started to be used not only for research purposes but also in various industrial sectors such as security, rescue, environmental monitoring and even military applications. Their adaptability and ability to operate in difficult and varied environments gives them a significant advantage over other types of robots. In addition, the integration of complex systems such as surveillance cameras, sensors, or even weapon systems, allows their functionality to be extended for tactical and security applications. The integration of a remotely controlled weapon system turns these four-legged robots into effective solutions for reconnaissance, attack or defense missions, with the human factor remotely controlling the operation and thus significantly reducing the risks to human health.

2. State of the Art

Several types of tracked, limbed and wheeled robots are known in the literature to serve the military and play a crucial role in modernizing military operations, thereby contributing to improving the efficiency, safety and protection of human personnel. Several classes of robots are routinely

DOI: 10.2478/kbo-2025-0026

deployed by the military, and two of the most important are unmanned aerial vehicles or “drones” (UAVs) and small unmanned ground vehicles (UGVs). Drones in their many forms have been outstandingly successful in reconnaissance and surveillance missions and in delivering lethal payloads [3].
At the tactical level, AI can improve partly autonomous control in unmanned systems so that human operators can operate unmanned systems more efficiently to, eventually, increase battlefield influence [4].
Figure 1 shows a robot designed and built to perform both Chemical, Biological, Radiological and Nuclear (C.B.R.N.) threat detection operations and Improvised Explosive Device (C-I.E.D.) recognition and neutralization missions. This multi-functional robot is equipped with specialized sensors, real-time analysis equipment and remote intervention systems, allowing interventions to be carried out in hazardous environments without direct exposure of human personnel.

Figure 1: Crawler robot for C.B.R.N. applications [5]

Many of the robots that are used in military applications are designed and built with a modular design so that they can be easily reconfigured due to the volatility of military-specific operations.

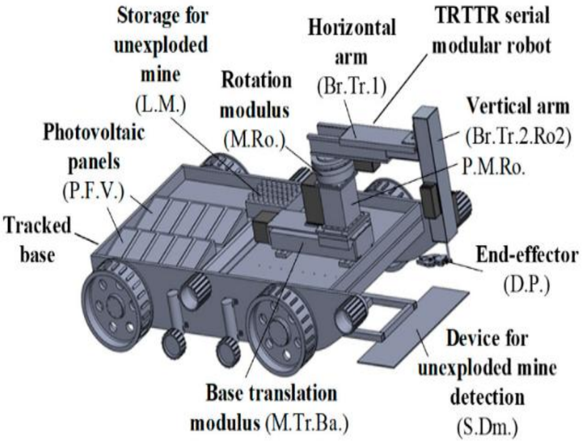


Figure 2: Modular humanitarian demining robot [6]

An example is shown in figure 2, representing a patent for a modular serial robot for humanitarian demining.
The "Unitree Go1" robot is a quadruped robot capable of reaching a speed of 4.7 m/s. It is equipped with an Intelligent Side Tracking System (ISS) and a Super Sensory System (SSS), integrating artificial intelligence to improve performance and interaction with the environment [7]. The Super Sensory System (SSS) includes five wide-angle stereo cameras and uses patented wireless vector control and positioning technology, allowing the robot to move with the user in a natural way.

Figure 3: Four-legged robot Unitree Go1 [7]

According to figure 3, the Unitree Go1 robot is a robot that possesses four limbs that serve its locomotion and flexibility.

3. Aim of the Work

Can a commercial quadruped robot be modularly modified to integrate a non-lethal system while maintaining structural stability and remote functionality in tactical conditions?

The main goal of this scientific approach is the realization of a system for the support and integration of an airsoft machine pistol on the "Unitree Go1" four-legged platform, in order to use it in tactical military demonstrative applications. The objective is to transform the robotic platform into a support device capable of actively participating in reconnaissance, patrol and demonstrative missions to aiming to engage targets in complex terrain or in environments hazardous to human operators. To achieve this goal, an optimized mechanical support will be designed to ensure a secure grip of the airsoft weapon without adversely affecting the stability or mobility of the robot. The design of the mount will take into account the mass distribution, the center of gravity of the integrated system, the vibrations generated by the weapon during firing, as well as the need to allow the robot to perform agile and precise maneuvers in rough terrain. The system will also be fully compatible with the structural design and materials from which the Go1 robot is constructed, in order to avoid compromising the platform's physical robustness, mechanical integrity, or its overall functional performance during operation. The system integrates a pneumatic actuator, wirelessly controlled to activate the weapon trigger, enabling the operator to maintain a secure distance from the robot.

4. Materials and Methods

The support structure was designed and 3D-modeled using CATIA V5 software taking into account the dimensioning and the corresponding structural constraints.

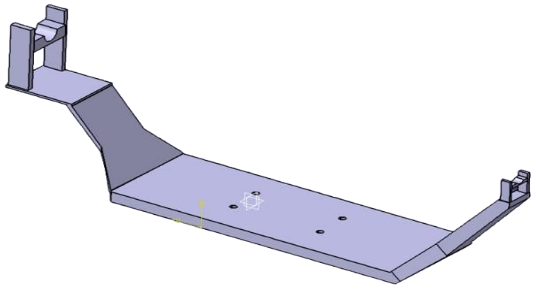


Figure 4: Isometric view of the mobile airsoft machine pistol support system (personal contribution)

Figure 4 shows the isometric view of the pistol-rifle attachment system realized with Catia software. The model was then 3D printed from a PETG-CF (Polyethylene terephthalate glycol) material, which is a lighter material due to the carbon fibers and has a very high material strength. Following assembly and stability testing, the mount was camouflaged, as illustrated in figure 5, to reduce visibility in natural environments .

Figure 5: Airsoft machine pistol support system (personal contribution)

5. Results and Discussions

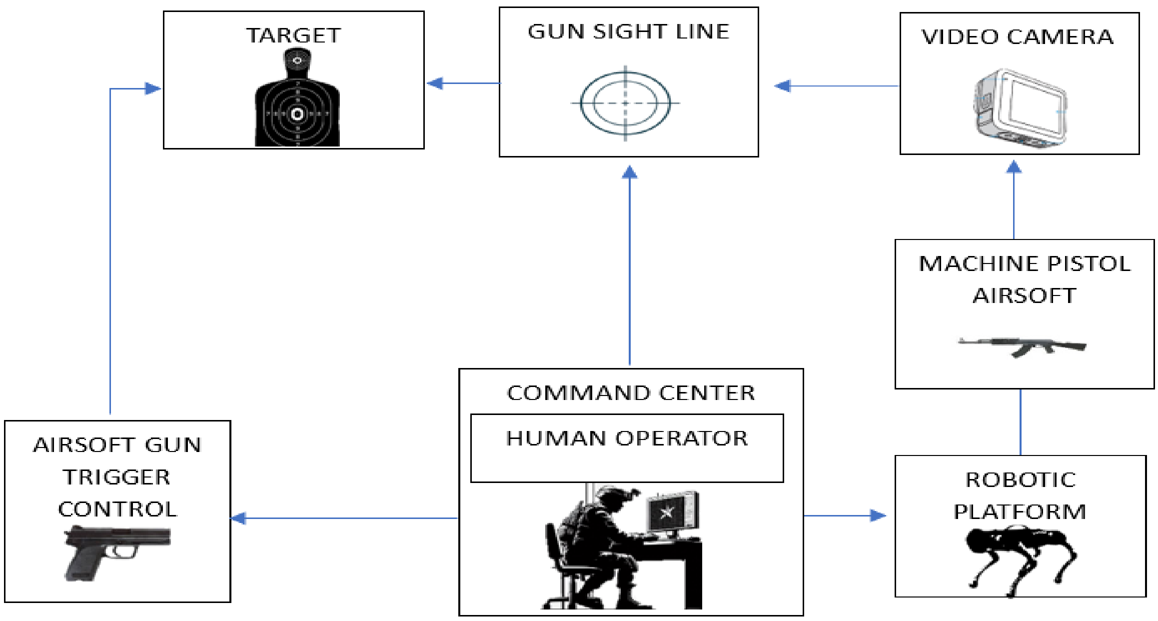
As shown in figure 6, the machine gun support system was successfully mounted on the quadruped robot chassis using structural elements optimized for low weight and high rigidity. The gripper assembly was fixed at strategic points on the chassis to ensure a balanced mass distribution and not to negatively affect the center of gravity of the platform. This configuration made it possible to maintain a favorable center of gravity and good mobility.

Figure 6: Machine gun support system on the robotic platform (personal contribution)

Given the high visibility of the robot in the operational environment, camouflage elements were applied directly on its structure (fig. 7) to reduce its visual signature and make it difficult to detect in the field. The camouflage solution was tailored to the specific mission environment, ensuring an effective integration with the landscape and decreasing the probability of visual interception by observers or optical systems.

Figure 7: Robot platform camouflage (personal contribution)

The trigger actuation system was designed using a miniature pneumatic piston, selected for its reliability and quick response in precision applications. This piston is integrated into a mechanical mount adapted to the profile of the weapon and is controlled remotely. The choice of pneumatic actuation was due to both the small size and the controllable force generated, sufficient for repeatable and reliable trigger release without compromising the structure of the weapon or the mount. A high-resolution video camera, capable of transmitting clear and detailed images in real time, has been mounted on the firearm for sighting the weapon and accurately establishing the line of sight. This camera was essential for remote viewing and allows the operator, from a safe point of command, to identify targets with a high degree of accuracy. Transmission is via a stable, high-power wireless connection designed to operate efficiently over a range of approximately 500 m, even in environments with moderate interference. This communication infrastructure ensures continuous system control and low latency, which is essential for fast and accurate tactical actions. The robotic platform is additionally equipped with a wireless remote control dedicated to the emergency stop function, an essential element to ensure operational security during mission deployment. This device allows rapid intervention by the operator in the event of malfunctions, loss of control, unexpected obstacles or other dangerous situations, thus providing a preventive mechanism.



Scheme 1 - Block diagram and functional principle of the system (personal contribution)

Scheme 1 shows the operating principle of the system, illustrated as a block diagram reflecting the information and functional flow between the components. The system is operated by a human user - trained military personnel - who is located in a secure command point, remote from the area of operation. He remotely controls the quadruped robotic platform, on which an airsoft machine pistol has been mounted via a customized mount. To enable precision aiming, a high-resolution video camera is mounted on top of the airsoft machine pistol. This camera is intended to provide the operator with a real-time image of the line of sight, virtually replicating the perspective of a traditional sight through the scope. Using this wirelessly transmitted video stream, the operator can accurately identify a target, track its movements and decide when to trigger. Trigger actuation of the airsoft gun is achieved by a pneumatic mechanism also remotely controlled and integrated into the system. The whole assembly is designed to allow fast, accurate and safe intervention, significantly reducing the risks to the human operator and providing effective control in tactical reconnaissance or target striking operations.

6. Ethical Considerations

The ethical aspect is an essential element in the context of the use of advanced robotized technologies in the military field and requires a judicious approach in terms of technological humanism. The scientific approach involves mounting a demonstrative weapon system on a robotic, quadruped platform and thus naturally raises moral and ethical questions about its implementation and use. Thus, since the design phase, particular attention has been paid to the respect of the fundamental principles of human responsibility and decision control.

A first ethical aspect of the system is the possibility of maintaining human control over the weapon firing decision. A firing subsystem has been realized with respect to the other components in order to prevent possible functional interferences or command conflicts between modules. The system is not autonomous, so the human factor is responsible for both controlling the robot's locomotion and actuating the weapon to fire at targets. The project was developed exclusively for experimental and demonstrative objectives without use of lethal weaponry. Throughout all phases of testing and integration of the system, replicas of airsoft guns, which pose no real risk of injury and are frequently used in simulation or training scenarios, were used. The choice of this type of equipment was made deliberately, both to eliminate any hazards associated with testing the technology and to keep the project within the bounds of legal regulations regarding the safety and ethics of practical-applied scientific research. The main goal of the scientific approach was not to develop an active combat system, but to explore the technical feasibility of mounting and operating tactical systems on a mobile robotic platform. The project provides a controlled framework for the evaluation of mechanical integration, structural stability, sighting capability and remote control, focusing on the engineering aspects of modularization and functional compatibility between the weapon, the actuation system and the robot.

A risk matrix (table 1) was used to prioritize risks according to the likelihood and severity of impact based on international guidelines for safety [8], military standards [9] and accepted frameworks for robotics risk evaluation [10].

Table 1- Risk Assessment Matrix – Modular Quadruped Weaponized Robot System (personal contribution)

Potential Risk	**Possible Cause**	**Consequence**	**Likelihood**	**Severity**	**Risk Level**	**Mitigation Strategy**
Loss of wireless control	Signal interference / range exceeded	Uncontrolled robot movement or unintended weapon activation	Medium	High	High	Implement auto-shutdown fail-safe; use encrypted and robust RF communication
Accidental weapon discharge	Pneumatic actuator failure /	Unintended firing of non-lethal system	Low	High	Medium	Add redundant mechanical safety

	design flaw					mechanisms; conduct reliability testing of actuators
Platform instability due to added weapon	Improper mounting / center of gravity shift	Robot falls or struggles to move over terrain	Medium	Medium	Medium	Redesign mounting structure weight; validate through dynamic simulations
Ethical misuse in non-demonstrative environments	Unauthorized access / system repurposing	Legal, ethical, and reputational consequences	Low	Very High	High	Enforce human-in-the-loop control; restrict system and software access
Camouflage system failure	Poor pattern selection / physical detachment	Robot becomes visible in tactical exercises	Medium	Low	Low	Test and optimize multiple camouflage patterns;

7. Conclusions

The scientific approach proposed by the authors has highlighted the possibility of integrating an airsoft weapon on a commercial quadruped robotic platform, in order to demonstrate the technical possibility of adapting mobile robots for controlled tactical scenarios. The scientific work focused on the development of a remotely controllable system, where tactical functionality was added to the robotic platform without changing its internal structural composition. Experimental results have demonstrated the feasibility of real-time operation of an airsoft firing system mounted on a quadruped robotic platform. By carefully integrating mechanical, electronic and communication components, a system capable of responding quickly to human operator commands while maintaining the stability and accuracy required for simulated tactical actions was realized. The project also integrated visual cloaking solutions to reduce the optical signature in operational environments. All these aspects were designed to ensure functionality, safety and full system control in an application-experimental setting.

Beyond the technological component, the project emphasizes the importance of an ethical and responsible approach to the use of robots in fields such as the military. The system is not intended for application in conflict zones, but to test the technical capabilities of mobile robotics in simulated tactical scenarios. Future research directions aim to field test the modular system in realistic tactical environments to validate operational performance and structural robustness. It is envisaged to extend the platform by integrating additional sensors, both for environmental monitoring and to increase targeting

accuracy through technologies such as thermal cameras or LIDAR sensors.
At the same time, the dual applicability of the system will be explored in civilian scenarios such as search objects or perimeter surveillance, capitalizing on the mobility and modularity of the robot.
An important direction is the introduction of controlled autonomy through artificial intelligence algorithms to improve mission adaptability and tactical decision accuracy while maintaining human surveillance.

8. Acknowledgement

Project PNRR: "DigitalArmyAcademy: Integration of digitalized educational processes in the Land Forces Academy", Component C15- Education, Investment 16: Digitalization of universities and their preparation for the digital professions of the future

References

[1] B, Sujendra & B, Shruthi. Humanoid Robot on Military Applications. International Journal of Innovative Science and Research Technology (IJISRT), 2024.

[2] Gyrichidi, N.; Romanov, M.P.; Tsepkin, Y.Y.; Romanov, A.M. Enabling Navigation and MissionBased Control on a Low-Cost Unitree Go1 Air Quadrupedal Robot. Designs, 9, 50, 2023.

[3] Bogue, R. The role of robots in the battlefields of the future. Industrial Robot: An International Journal, 43(4), 354–359, 2016.

[4] Anuradha, Janith. Used of Artificial Intelligence & Robotics in Military Field, 2023.

[5] Nowy robot mobilny PIAP PATROL®, https://piap. pl/2020/05/19/nowy-robot-mobilny-piap-patrol/, last accessed on 13.01.2025.

[6] Petrişor, S.M., Bârsan, Gh., Simion, M., Virca, I., Moşteanu, D.E., “Tracked robot destined for humanitarian demining operations”, Invention Patent No. RO 132301B1/30.12.2021, ISSN 2065-2100, 2021.

[7] Unitree Go1, site, https://shop.unitree.com/products/unitreeyushutechnologydog-artificial-intelligence-companion-bionic-companion-intelligent-robot-go1-quadruped-robot-dog, last accessed on 05.01.2025.

[8] International Organization for Standardization, ISO 31000:2018 Risk Management – Guidelines, ISO, 2018.

[9] U.S. Department of Defense, Standard Practice: System Safety, MIL-STD-882E, 2012.

[10] Siciliano, B., & Khatib, O. (Eds.). Springer Handbook of Robotics (2nd ed.). Springer, 2016.