AARMS Vol. 24, No. 1 (2025) 93–104.

10.32565/aarms.2025.1.6

Robots on the Battlefield

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Robotic systems are revolutionising modern warfare, with applications ranging from reconnaissance and bomb disposal to autonomous combat and logistics. While these technologies reduce human casualties and enhance operational efficiency, they raise critical ethical and legal questions about accountability, autonomy, and the future of human-soldier roles. Robots are ideal for use in military operations because they can perform such tasks that are too dangerous for humans. Robots can be used to traverse dangerous terrain, locate and eliminate threats, and support and supply troops on the ground. They can also be used to protect troops from enemy fire and can serve as decoys to draw fire away from troops. In addition, robots can be used to provide intelligence and real-time information on the battlefield that can be used to make strategic decisions. This paper examines the evolution of military robotics, analyses current battlefield applications, and evaluates the moral challenges posed by autonomous systems, advocating for urgent regulatory frameworks.

Keywords: *battlefield, robots, drones, embedded systems, industry*

Can we credit Heron of Alexandria with the invention of combat robots?

The first written source of self-moving applications can be tied to the ancient Greek mathematician and engineer Heron of Alexandria. To be precise, it is the Aeolipile, which was an early steam-powered rotating machine, and the first programmable humanoid robot, the Mechane.[2] Even if not directly, this was the first historical example of a device that operated independently of human power. From today's perspective, technological developments were not particularly noteworthy in Heron's time; rather, they excelled in philosophy and religion, political and legal institutions, poetry and drama, and in the realm of scientific speculation.[3] That is why we had to wait for a while for revolutionary changes, but in the meantime, thanks to the technological and subsequent industrial revolution processes, many surprising and strange inventions saw the light of day. Barely 2,000 years after Heron's time, not only in the minds of science fiction writers such as Isaac Asimov,

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[2] Norman 2014.

[3] Buchanan s. a.

but also in industrial equipment, steam-powered mechanical instruments and autonomous electrical devices, which we can call robots, appeared. The first combat robots were generally and basically used for remote-controlled reconnaissance operations, although some were designed for offensive operations. As technology advanced, the capabilities of combat robots have become more sophisticated and versatile. Today, combat robots are used for a variety of purposes, including reconnaissance, search and rescue, surveillance, and increasingly for combat purposes.

The aim of the research

This study employs a multidisciplinary approach to analyse three key dimensions of military robotics: basic terminology of robotics, technological advancements, ethical dilemmas in deploying lethal autonomous weapons. Case studies from NATO, Israel and Russia are the basis of the analysis in real-world applications.

As one of the key dimensions of the paper, it covers the legal and ethical aspects of military robotisation. This includes ethical issues in the use of autonomous weapon systems, an examination of international legal regulations. The research aims to contribute to a comprehensive understanding of the military applications of robotics, while highlighting the future directions and challenges of the field in modern warfare.

About robots in general

The term ‘robot’, derived from the slavic robota (forced labour), entered popular lexicon through Karel Čapek’s 1920 play R.U.R., foreshadowing their role as substitutes for human labour.[4] Today, military robots extend this concept, performing tasks deemed too dangerous, precise, or logistically complex for soldiers.

Although some early literature explains the concept of robots as if they were perpetual slaves, is this the present picture in this sector? Firstly, if we look at today’s market, we can see many commercial robots. Next to Japan, Switzerland[5] is the biggest manufacturer of these products that mainly serve industrial purposes, but Japan is also a leader producer of the entertainment electronic devices for people. The most widespread are the very useful vacuum cleaner robots and the flying robots or drones of which the most spectacular are quadcopters. These products are the cheapest and are the most popular and, in many cases, the most frequent users of these techniques are the former airplane model makers who often set up wireless cameras in these machines.

Secondly, in factories many human workers have been replaced by industrial robots mainly in operations where semi-skilled workers made a portion of the assembly line and where highly precise work was required. These factories are where most of the electrical gadgets, automobile parts and food are produced. In these plants, of course, not

[4] Čapek 2013.
[5] Owen-Hill 2021.

just individual work operations are automated but the whole workflow is robotised and coordinated by a central system. The applications are using enormous IT architectures in the background such as servers, BigData structures and many-many Internet of Things (IoT) components.

The third biggest area is the military industry where many questions about robotics arise. How can we integrate robot technology into the battlefield? How does it change the art of warfare? Are robots as smart as humans? Could this technology be more effective than human warriors? What are the benefits of substituting the soldier in the battlefield? Based on my scientific research, I have concluded that industrial devices operate using the same processes and IT architectures, but work with different data, and their appearance in cyberspace and physical space differs.

What are robots?

The different applications of robots could fill several books, therefore in this section I would like to give a general overview of the different names of robots and their characteristics.

As technology advances, understanding the distinctions between these robotic systems is crucial. While there can be overlap and hybrid solutions, recognising the specific characteristics and purposes of each type helps in accurately discussing and applying robotic technologies.

Renowned robotics expert George Bekey defines a robot as a device that combines sensing, cognitive processing and action. In essence, a robot must possess:

- sensors to perceive its environment
- processing capabilities that mimic certain cognitive functions
- actuators to interact with its surroundings

From a cultural perspective, robots are often envisioned as mechanical entities that display human-like abilities and behaviours. This popular conception aligns with Bekey's technical definition, emphasising the blend of perception, decision-making and physical interaction that characterises robotic systems.[6] Think about C-3PO from Star Wars or the Terminator. While this pop-culture image emphasises humanoid forms and sentient behaviour, real-world robotics prioritises function over form. For example, autonomous drones or warehouse sorting bots may lack a "face" or "limbs", but they excel at specialised tasks through advanced perception and decision-making.

Summarising, devices that can only perform preprogrammed operations under human control may not necessarily qualify as robots. Additionally, the term "droids" is a fictional concept popularised by science fiction, while "co-bots" is a commonly used term for collaborative robots that work alongside humans. Sometimes we find sources that refer to droids as androids, which is a term for humanoid robots, or they are also referred to as droids.[7] Just to mention movies, we see cyborgs, human-based robot hybrids, but in reality,

[6] Bekey 2017.
[7] Khillar 2018.

we already have medical devices such as touch-sensitive limbs, which unfortunately are not as high-tech as the devices we know from famous pop culture movies, so in real life, cyborgs are not the same as what we see on screen.

My own theory: From industry to the battlefield

In the past, when we spoke about robots, people generally imagined large, motor-driven machines or analogue devices with basic functions, but nowadays the highly developed microchip and embedded systems give new meaning to these instruments. Thanks to advancements made by developers, electrical parts have undergone miniaturisation, resulting in various improvements such as increased efficiency, lower power consumption, and faster processors and sensors. This has allowed these gadgets to become more than simple robots.

As a result, we can cram formerly unimaginable applications in small embedded systems and thanks to it we can create previously unseen structures. With the help of these advancements, we can create systems what can collect, transmit, process and evaluate information immediately from multiple aspects of the industrial production line and according to my theory we can simply just transform the procedures of these sustainable and human-centric Industry 5.0[8] solutions to be applicable in operational areas.

Industrial examples allow us to learn about many of the rules of the mature model, such as the cooperation between robots and the human "interface", which fully meets the expectations of modern warfare. Generally, it can be said that the implementation of autonomous systems used in factories and military equipment is different, but their direction of use is the same. In light of this, we can see some examples of how the industrial environments can be adapted for use in the field.

Thus, in addition to commercial and industrial applications, one of the largest areas is the military sphere, where many questions arise regarding the use of robotics. How can we integrate robot technology into the battlefield? How does it change the art of warfare? Is it as smart as a human? Could this technology be more effective than that of the warrior? What are the benefits of substituting the soldier in the battlefield?

Comparing the industrial and battlefield robots, both are used to perform tasks that may be dangerous or too difficult for humans to do. Industrial robots are used in a variety of settings including manufacturing, assembly and construction, to automate and streamline processes. Battlefield robots, on the other hand, are used on the battlefield to reduce the need for human personnel in dangerous situations. Robots can operate autonomously and make decisions without human intervention, allowing them to respond to threats and protect soldiers without risking lives. Both types of robots are typically equipped with sensors and cameras, allowing them to gather data and detect obstacles. Additionally, both industrial and battlefield robots are able to operate autonomously, meaning that they can be programmed to make decisions without constant human supervision.

[8] European Commission 2022.

Applying robots to the battlefield is a huge breakthrough because it changes the strategy of the assault and the preparation of the war to a great extent. Firstly, we could make movements much safer because the main face of our motions are the robots. They can help warriors to gain more information about the battlefield such as place positioning and clarification, reconnaissance, with guarding the user's personal safety. In fact, in the real world, we could achieve greater efficiency by thinking in terms of systems such as connecting all our reconnaissance robot systems to our satellite communication system and collecting all the information in a common database so that we can identify our forces and all the gained information about the enemy and neutral powers. If we follow this path, then in certain cases our soldiers could control movements from their chairs far away from the battlefield, and maybe someday we could even create a fully automated, unmanned cyber warfare system.

Construction of the robots

Nowadays, robot construction is based on several twenty-first century technologies. First of all, the creators have to design the Kinect of the robots in a CAD/CAM design software, then prepare every component of the robots, and finally manufacture them using additive manufacturing technologies such as 3D printing for testing.[9] Meanwhile the electrical engineers have to design the digital circuits together with the microchip programmers.

There are several components that go into creating a robot, depending on its intended use. The most important components of a robot include the body, the control system, the motor, and the sensors and actuators. The body is typically made from a sturdy material, such as aluminum or steel, that can withstand the rigors of the environment in which the robot will be used. The control system manages the robot's functions and enables it to interact with its environment. The motor is responsible for the robot's movement, and the sensors and actuators allow the robot to perceive and interact with its environment. Finally, the robot must be tested and calibrated to ensure that it is performing optimally.[10]

Generally, the robot software is the most time-consuming part of the entire process, as software engineers must write numerous software exception handlers in low-level languages, primarily Assembly or C. Many companies offer embedded boards or multifunction microchips and the result depends on the designer's work.[11] Especially for military demands, a few manufacturers offer special military grade microchips but at the end of the production process the designers have to plan the whole device with such materials that meet the military requirements.

9 Kuhn 2016.
10 Rundle 2014; Sandin 2003.
11 Barr–Massa 2006.

Battlefield application of the robots

Let us examine the potential advantages of utilising robots, or collaborative robots (co-bots), within military operations. I have mentioned above the main purpose of networked cooperation with robots and remote-controlled or fully automated systems. These are very important if we want to protect our soldiers. In many countries economists debate whether it is cheaper to train soldiers or to build more expensive, high-tech machines. In this discussion I would like to strengthen those parties who vote for the machine building because in no way could we measure a human life with the value of a machine. Application of the robots on the battlefield can reduce casualties on both sides of the conflict and they are also cheaper and more efficient than humans for many tasks. They require fewer resources to operate and can be programmed to perform tasks quickly and efficiently, reducing the need for staff. I guess it is not an economic but rather ethical question. Based on classical studies, we know that an injured soldier requires more logistical support than a robot that has been fired or destroyed. So, using co-bots we can guarantee the safety of our soldiers, they can be deployed quickly and easily, allowing operations to be carried out quickly and without complex logistics. This can significantly reduce the time required for missions and increase the efficiency of operations.

Robots are very useful and helpful on the ground but of course they will never replace humans, meaning a robot will never be able to conduct a hostage negotiation, assess a battlefield injury, lead an assault, or decide between friends and enemies because there are situations where the human presence is necessary; however, these gadgets can facilitate victory on the battlefield. On the other hand, there are many cases when these machines could be used more effectively than humans because they can be deployed much more quickly, consume less energy and pose less danger to human life.

Let us examine which countries are developing different types of robots, without attempting to be exhaustive. Robots come in many forms and are used in many areas. Some countries use these unique technologies for very specific reasons. In European countries, the most common are Explosive Ordnance Disposal (EOD) robots, which have been used by soldiers since the Second World War to locate explosives hidden underground. For example, even today nobody lives in the area of the Verdun Forest in France because there are so many active explosive devices underground, and French EOD teams still use their robots to clear the area and remove the hidden explosives. These robots are also common in mission areas where terrorists use improvised explosive devices (IEDs).

NATO uses a very complex Missile Defence System, whose launch and detection systems are partially automated and operate with digital circuits, making it a kind of robotic system. Maybe in this dangerous political situation, a fully automated system that malfunctions close to the Russian border could cause unfortunate diplomatic problems. The reason why I started with the NATO system is that Israel has also made its own self-defence air missile system, which is integrated into the Iron Dome system that is fully automated and does not require a human operator, only system supervision and maintenance. This system is very useful against missile attacks, which are very frequent in the area. According to new information, the system is now even more effective as Israeli

engineers have begun replacing all missile launchers with high-energy laser beams so that they can destroy artillery missiles from a distance of up to 7 kilometres.[12]

During the Cold War, nuclear weapons posed the main threat, but today, the production of war robots has also come to the fore in Russia. I could not get enough information about Russian robots because the sources were in Russian, but I was able to watch some videos about the Russian Army Expo (RAE) in the English-language media, where some very serious robots with guided and remote-controlled firing systems were presented. One of these is a self-propelled Kalashnikov, but the video did not reveal whether these systems had been approved for use by the Russian Army.[13]

Examples of battlefield application

Advanced robotics are being used by modern militaries more and more to improve tactical capabilities, lower human risk, and obtain strategic advantages. Below are a few of the most noteworthy instances of battlefield robotics in operation, ranging from unorthodox designs to extensively used systems.

Reconnaissance snake robot (Israel)[14]

Israel's camouflaged snake robot, a covert reconnaissance instrument that imitates biological snakes, is among the most inventive designs. At two meters in length, it mimics the slithering motions of an actual snake, allowing it to slither through tight spaces, scale barriers, and sneak into dangerous environments without being noticed. It can relay voice and video data over 5–6 km thanks to its high-resolution cameras, audio sensors, and real-time transmission capabilities. In addition to surveillance, this robot also functions as a "suicide snake" by carrying explosives to destroy valuable targets, like enemy weapons or fortified positions, without endangering the lives of soldiers. Because of its versatility, it is perfect for counterterrorism and urban warfare.

Neutralising explosive threats: EOD robots

One of the most prevalent and useful weapons in contemporary warfare are EOD robots. Modern systems like the TALON or PackBot integrate sophisticated manipulator arms with human-like dexterity, whereas early models concentrated on simple tasks like moving explosives or cutting wires. Using instruments like X-ray scanners, disruptors and precision cutters, operators remotely operate these robots to disarm complex IEDs or

[12] Rutman 2021.
[13] Mizokami 2017.
[14] NBC News 2009.

UXO in real time. Modular payloads are another feature of some high-end models that let technicians switch out tools for different situations. These robots, which have more than 50 documented disarming techniques, are essential for reducing casualties during bomb disposal operations.

Quadruped logistics support: Boston Dynamics' BigDog and WildCat[15]

BigDog: This quadruped robot, standing one meter tall, can carry up to 100 kg of cargo (such as supplies or equipment) over rocky, muddy and snowy terrain. Even after slipping or being shoved, it can still walk, run and climb thanks to its dynamic stabilisation system.

WildCat: With a top speed of 32 km/h, WildCat is the fastest quadruped robot. It combines speed and agility to avoid obstacles and change directions quickly. Both robots follow soldiers on their own, which eases their physical strain while on missions. Subsequent versions might incorporate combat payloads or surveillance.

Drones and UAVs: From reconnaissance to combat

Platoon-level reconnaissance, GPS mapping and the delivery of vital supplies (like medical kits) are all made possible by smaller drones, such as quadcopters like the PD-100 Black Hornet. They are perfect for stealth missions because of their small size and silent operation.[16]

Long-endurance platforms with missiles, laser-guided bombs and high-resolution sensors are provided by larger UAVs such as the MQ-1 Predator and MQ-9 Reaper. The Predator, for instance, can loiter for 24 hours at speeds of 220 km/h, delivering real-time intelligence and precision strikes.[17] These systems allow for "over-the-horizon" engagements with little risk to personnel because operators operate them remotely, frequently from continents away.

Future trends: Swarm robotics and AI integration

Inspired by the collective behaviour of insects, birds, or fish, swarm robotics has the potential to completely transform military operations. Swarms, as opposed to single-robot systems, use emergent intelligence, redundancy and decentralised coordination to accomplish challenging tasks. These systems work especially well in electronic warfare, distributed surveillance and saturation attacks. Two innovative swarm robotics applications are shown below, along with technical details and documented use cases.

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15 Legacy Robots s. a.
16 Fahlstrom–Gleason 2012.
17 U.S. Air Force s. a.

Perdix Drone Swarm (U.S. Department of Defense): Using Perdix, an autonomous, AI-driven micro-UAV, the DoD demonstrated one of the biggest micro-drone swarms to date in 2017. Three F/A-18 Super Hornets launched 103 Perdix drones in mid-air during a test in California, and the drones self-organised into a unified swarm to carry out a mock reconnaissance mission over a disputed area.

Turkey's Kargu-2 Kamikaze Drone Swarm:[18] During the 2020 Libyan conflict, one of the earliest known instances of AI-driven swarms being employed in combat was a loitering munition created by STM. A UN report claims that without direct human supervision, a swarm of Kargu-2 drones tracked and attacked fleeing enemy forces.

Legal questions

We should mention the legal implications of robot application in the battlefield. What is happening if a robot kills an innocent person or just simply does harm to an estate or a property? Who is guilty in these cases? What happens when a terrorist or insurgent group equip themselves with autonomous weapons?[19] Do we know the concept of robot ethics? Robotics ethics refers to the study of ethical considerations related to the design, construction, use and treatment of robots. It is concerned with how humans interact with robots and how robots can be designed to behave ethically. In other words, robotics ethics explores the moral implications of our interactions with robots. A possible answer to the above questions may be provided by a study that states that there are no such current laws in any of the previously mentioned countries. The current position is based on human moral values, as it states: "The final part counters objections that responsibility for Lethal Autonomous Robot System (LARS) killing in war automatically lies with the software programmers, politicians and military commanders."[20] According to the legal approach, when a robot kills an innocent person or causes damage to property, the jurisdiction where the incident occurred determines who is liable. In some cases, criminal or civil liability may be assessed against the robots' owner, depending on the type of harm or damages caused. Additionally, the extent of damages that the robot's owner may be liable for may be limited by the terms of any contract that governed the owner's use of the robot. Civil liability may also apply in situations where a robot causes harm to a property.[21] Generally speaking, if the robot's owner was found to be negligent in their use of the robot, then the owner may be liable for any damages caused by the robot.

Through my argumentation above, I have tried to point out that international law struggles to address autonomy in warfare. Article 36 of the Additional Protocol I to the Geneva Convention mandates review of new weapons,[22] but autonomous systems like the STM Kargu-2 (used in Libya with alleged AI-targeting) operate in legal gray zones.

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18 Nasu 2021.
19 Dawes 2021.
20 Roff 2013.
21 Anderson-Waxman 2012.
22 Boulanin 2015.

Directive 3000.09 of the U.S. Department of Defense[23] requires "appropriate levels of human judgment" over lethal decisions, yet fails to define "appropriate". The best example for this exploited loophole is in contested zones like Ukraine.

Summary

To summarise all the robotic technologies, we find them very useful on the battlefield, but many of them are immature at the current stage of development. In the future, warfare and battlefields will change significantly due to the expected proliferation of robots. New techniques have emerged on the battlefield thanks to developments over the past decades, as my basic research shows. Companion robots are becoming an even more integral part of the battlefield, and it is only a matter of time before these machines are advanced enough to be deployed in combat situations. As technology advances, the capabilities and potential of robots and robots on the battlefield will only continue to grow as the theory of my basic research also shows; Industry 5.0 solutions were placed to the operational area from the factories.

The military landscape is undergoing significant transformation with the increasing integration of robotic technology. These machines offer numerous advantages, including the reduction of human casualties and enhanced operational efficiency. As technological advancements continue, robots are expected to assume more sophisticated roles and execute increasingly complex operations in combat scenarios. Consequently, the nature of warfare is rapidly evolving, driven by the deployment of various robotic entities, including collaborative robots and humanoid machines, on the battlefield. The Cold War led to the war on terrorism expanding into the digital realm, resulting in hybrid warfare. In this new form of conflict, the primary display of strength is no longer the traditional method of amassing troops for mutual deterrence. Instead, it involves the utilisation of cutting-edge weaponry to acquire power. Although these advanced weapons may initially prove effective, countermeasures will inevitably be developed. The most significant threat to these sophisticated robotic systems comes from hackers, necessitating our adaptation to this aspect of modern warfare. Future generations will witness the dramatic transformation of our approach to armed conflict.

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[23] Department of Defense 2023.

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