ROBOTIC REPLICATION OF LIVING THINGS AND IMPLICATIONS FOR WARFARE

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Abstract

The paper discusses nature-inspired robotic replications, their potential military applications, implications for warfare, and the perspective of International Humanitarian Law (IHL). Historically, animals have been used in war, helping to turn the tide of battles and the fortunes of many combat soldiers. However, in modern times, there is a growing interest in replicating characteristics of natural creatures in AI-enabled robotics for military purposes. Key mechanics of natural systems, such as manoeuvrability, agility, and aerodynamics, as well as intelligence factors like coordination, swarming, task sharing, and cooperation, have inspired the development of military robots. These robots, equipped with the instinct of survivability alongside features such as self-organization, self-adaptability, and self-learning, are well-suited to navigate the battlefield's challenges and engage in warfare despite the inherent unpredictability and chaos involved. By leveraging the evolutionary advantages of nature, military robots can enhance their effectiveness through biomimicry, as they tend to be more adaptable to unforeseen scenarios. This increased adaptability improves their ability to learn and evolve in response to environmental changes, thereby significantly enhancing mission outcomes. The findings of this research show that, in addition to presenting significant moral, ethical, and legal challenges, rapid advancements lead to the militarization of nature and significantly alter the nature of warfare. The study also provides recommendations for an international consensus on legally binding instruments.

Keywords: Robotic Replications, Swarm Drones, Autonomous Weapons, Biomimicry, International Humanitarian Law.

Introduction

Technology has played a crucial role in the military field in the twenty-first century. The twenty-first-century defence environment has evolved to the point where technology is profoundly affecting the domain of warfare. It is not animals that now mimic military capability; electromechanical and AI-intensive systems are undertaking this. Defence-related technologies, comprising robots, swarms, and avatars, all aimed at replacing and enhancing traditional military capability, form part of the evolution of the Fourth Industrial Revolution. The world is witnessing a new arms race fueled by AI, reflected in robotic armies with the potential to think and fight independently.[1]

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Traditionally, animals played military roles. However, a phenomenon has emerged: the military mimics animals. This approach accords with the concept of biomimicry. It is often referred to as biologically inspired engineering. Animal-inspired robotic technologies are an emerging field in biorobotics, presenting innovative prospects for interdisciplinary research. This emerging field facilitates novel biological studies and supports innovative bioinspired engineering designs. Animal-inspired robotics development results from a motivation to leverage automation for enhanced solutions while addressing intricate challenges centered around animals.[2]

The robotic replication of living things, with promising innovative solutions for complex challenges, is based on the mechanics and intelligence of living systems as a model of inspiration for future technological developments in robotics.[3] The process is based on examining the natural characteristics, such as intelligence, agility, maneuverability, adaptability, and cooperative behavior found in nature, which can be replicated in robots for operational success. These nature-inspired robots may look, sense, and act exactly like animals, birds, and even insects, but are mini-robots or machines with added elements of maneuverability, deception, and natural camouflage.[4]

Living systems are more robust, diverse, and complex than any technology yet created; hence, replicating them in robots can bring operational innovation to military tactics and enhance performance by borrowing the natural characteristics of these systems.[5] Unlike the classical approach of creating replica machines from humans, recent developments take the reverse approach of using living species and nature as a model of inspiration for machines and robots. These include robots with animal characteristics such as flying, crawling, swimming, sneaking, hopping, and acrobatic aerodynamics, as well as intelligence and adaptability to a particular environment. These are generally termed biologically inspired robots, which aim to enhance human capabilities by borrowing natural characteristics and incorporating improvements with the help of advanced technologies, thereby enabling operational success in future conflicts.

Kate Darling (2021), a prominent author on the human-robot nexus, believes that to understand human interaction with robots, humans should appreciate their interaction with animals, which is as old as humanity.[6] This may help in understanding how humans relate to the more-than-human world, and the same analogy applies to how a more-than-human world can impact humans when they interact with living things that resemble robots on a battlefield. Such complex interaction between humans and robots can further influence the dynamic nature of warfare.

Figure 1

Source: Author`s Contribution

There is limited literature on this specific area, and the impact of these biologically inspired robotic replications on warfare has not become a subject of discussion so far. Therefore, this paper aims to establish the connection between such replications of warfare and their role in the military field, while also discussing the International Humanitarian Law (IHL) perspective and recommendations.

Conceptual Framework

The unpredictable turn of events and behaviors, as well as the possibility of things getting out of human control, are common to natural systems and concepts of warfare. Besides complexity, ambiguity, and uncertainty, these two elements primarily emerge from the interaction of various factors in chaotic or unpredictable systems and environments. These further give rise to concepts in warfare such as non-linearity, anarchy, disorder, fog, chaos, randomness, and chance, leading to various complex challenges. To overcome the chaotic nature of warfare, the natural characteristics of animals, such as self-adaptability, self-organisation, survival mechanisms governed by instinct in unpredictable environments, the collective intelligence of groups, and collaboration for task performance, are being replicated in bioinspired robots to enhance predictability in uncertain battlefield environments.

This framework establishes a vertex and analyses the emerging trends of robotic replication of living things and their implications for warfare. Bio-inspired robotic replications can revolutionise warfare tactics, ethics, and strategy. It also establishes connections and analyzes the impact of strategy on the disruption caused by emerging technologies in contemporary warfare. It focuses on instrumentality, predictability, and the 'multiplier impact' of self-organizing, self-adaptable systems, such as AI-enabled biorobots, which may further the concepts of non-linearity, disproportionate, and disruptive impacts of emerging technologies, particularly bio-inspired robots.

Proponents of the Revolution in Military Affairs (RMA), such as Alvin Toffler (1980), Heidi Toffler (1995), and Colin S. Grey (1993, 1999), have primarily focused on the technoscientific approach to warfare, emphasizing the instrumental role of technology in warfare. Grey's key element on the Operational Concepts and Transformation stage of RMA offers some relevant insights into the paradigm shift in warfare caused by bio-inspired robotic replication.[7]

The Key element of operational concepts focuses on the tech-driven shift in the military doctrine, strategies, and tactics.[8] The transformation stage focuses on organisational integration and adaptation. The RMA caused by bio-inspired robots would likely drive changes in the adaptation of autonomous warfare doctrines, the development of new tactics for robotic swarming and collective engagement, the integration of robots into traditional command structures, and, above all, the establishment of new rules of engagement for battlefield dominance. This transformation would compel military thinkers to reassess their approach to warfare, logistics, and decision-making.

Strategists and military theorists, such as Grey and Clausewitz, have consistently noted the non-linearity of Warfare, emphasizing the unpredictable nature of events on the battlefield, the disproportionate impact of warfare, and factors like randomness and chance that can serve as force multipliers, potentially revolutionizing the conduct of warfare. Bio-inspired robots could be more than another tool to shape these warfare dynamics.

Robotic Replications and Warfare

Historically, living organisms have been utilized for tactical advantages, and in some cases, even weaponized in wars. For instance, the mere presence of insects instills fear and panic in enemy forces, creating a strategic advantage even without confrontation. These have been used as chemical and biological weapons in warfare for centuries. For instance, the Dog Soldiers by Susan Orlean (2012) and Bryan D. Communis (2003), Scorpion Bombs by Adrienne Mayor (2009), Spy Cats by Emily Anthes (2013), the Bat Bombs by Alexis C. Madriga (2011), Pigeon Messengers by Christina Couch (2019), Bee Bombs and Mosquito Bombs, etc., are a few to name that have played combatant and non-combatant roles in battlefields. These animals have been used for mobility, speed, sheer size and strength, versatility, reduced casualties, logistics, and psychological purposes. The Imperial War Museum records animals used in World War I and World War II. Sometimes, these animals in war would go on to receive medals for their bravery and devotion to duty during the war.[9]

During WWII, the US had a 'Dogs for Defense' campaign, where dogs were considered more important than humans.[10] Thereafter, the US and Russia reportedly used Dolphins and seals for maritime security and surveillance, even deploying them for the protection of nuclear submarines at sea, due to their exceptional intelligence and echolocation capabilities, which enable them to detect underwater mines.[11]

Similar to Russia's 'Dolphins in Defence' programme. Recently, Russia reportedly deployed dolphins for naval defense in the Black Sea[12] and Whales and Seals in the Arctic region to protect its naval assets.[13]

There is a long history of animals serving humans, from horses and dogs to the US and USSR training sea lions and Dolphins for maritime security at sea; this process continues with robotic species.[14] One of the most significant benefits of using animals in warfare is that they are part of the natural environment, can move according to the terrain, and are mostly undetected by humans as weapons of war.[15] Their characteristics of task sharing, coordinated task performance, and adaptive survival tactics have long attracted the attention of military planners for their efficacy, operational jointness, and network-centric operations. However, they have sometimes proven too dangerous and devastating due to the lack of distinction between friends and adversaries.[16]

Present-day bio-mimicked robots have far more intelligent algorithms, advanced sensors and processors powered by AI, and textures that blur the distinction between a natural creature and a replica. Until recently, these bio-mimicries were limited to mechanical replication into physical embodiments. However, with advances in information technology and Artificial Intelligence, there is a growing focus on mimicking genetic algorithms that govern natural systems, such as animal intelligence, self-adaptability within a particular ecosystem, survival, self-organization, and other complex characteristics of living species in robots.[17]

An important area for robotic replication is the development of humanoid robots, such as Sophia, Nosh, Ameca, Atlas (retired in 2024), and Sana. Some of these robots have even been granted citizenship rights in Saudi Arabia and Japan. These various types of robots have competed against humans and outperformed them in sports, medicine, and other tasks. In military operations development, Augmented Reality (AR) has been part of military simulation and war gaming for years. However, their overt deployment for military purposes has not come to fruition.[18]

In the list that starts with Grey Walter's replica Turtles[19], a series of Robo-Snakes has been developed by Dr. Gavin Miller to replicate and improve upon the natural characteristics specific to this reptile. This series of radio-controlled Robo-snakes, which avoid the problems of artificial intelligence and sensing, plays a vital role in navigation, search, and rescue operations.[20] This prototype, equipped with an infrared-sensitive camera and microphone, has the potential to be used for intelligence, surveillance, and situational awareness on the battlefield. Similarly, Robo-snails are another prototype reptile developed to help in search and rescue situations and environmental monitoring.[21]

Another category of robotic replications is Robirds. The US Defense Advanced Research Projects Agency (DARPA) commissioned AeroVironment in 2006 to develop a Nano Air Vehicle (NAV) that would serve as a Spy Robot for surveillance. It finally turned into a hummingbird-like robot.

Along the same lines, a team of researchers at Purdue University developed a flying robot in 2019 that can fly like a bird and hover like an insect. This robot, weighing 12 grams with a 3D-printed body and wings made of carbon fiber, is primarily inspired by hummingbirds as a model of inspiration.[22] Similarly, the Pigeonbots, developed by the British and the US in the 1990s, were used as surveillance drones that mimic the appearance, movement, and sounds of real pigeons, allowing them to blend in with the community.[23]

Another prototype Robo-bat, based on the natural echolocation characteristics of bats, can detect inaudible high-frequency ultrasound with a range of 10 kHz to 130 kHz and convert it into audible frequencies between 100 Hz and 12 kHz, which are detectable by humans.[24] A group of scientists has studied the locomotion and aerodynamics of bats and attempted to replicate these characteristics in a prototype called Bat Bot (B2), with potential military applications. Additionally, in this long list is the Mouse named '*Theseus*' developed by the famous scientist Claude Shannon. It can solve problems through trial and error while remembering solutions and forgetting them if circumstances change[25], as the basis of self-learning enabled by artificial intelligence in futuristic robots.

A mosquito-bot has been developed with a military purpose, targeting individuals who can recognise their target and collect blood samples through a mosquito-like sting for DNA testing. In addition, another bee-bot called 'Fly eye' reportedly developed for military purposes almost exactly looks, walks, and flies just like a real bee, and can work as a spy bot without detection. Professor Chen of MIT has developed dragonfly-like robots that can fly, dodge, and wave just like insects, with the initial purpose of pollinating crops, searching across areas hit by disasters, and inspecting malfunctioning parts of machines.[26] In addition, the remotely controlled, hybrid robot cockroach, equipped with a backpack and powered by ingesting water, air, and food, can utilize the efficient sensory systems of a living system and perform mechanical functions as conditioned by a human operator.[27] At MIT, scientists have developed a bionic Cheetah that mimics the natural mechanics of a cheetah. Similarly, a Kangaroobot demonstrates impressive agility and mobility based on the mimicry of a real kangaroo's anatomical and physiological characteristics in robotics for efficient jumping and high energy storage.[28]

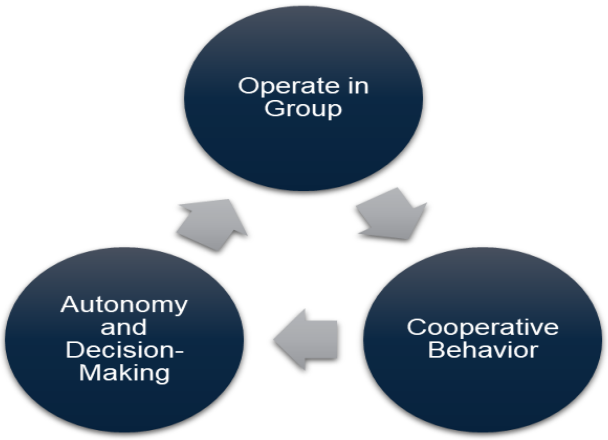
Military Applications of Biomimicry

Living organisms and warfare share common characteristics, including unpredictability, uncertainty, and complexity. The principles of natural systems can be applied to warfare models, such as the concept of "survival of the fittest", which can be applied to living organisms. Key mechanics of natural systems, such as maneuverability, agility, and aerodynamics, as well as intelligence factors like coordination, swarming, task sharing, and cooperation, can inspire the development of military robots.

These robots, equipped with the instinct of survivability alongside features such as self-organisation, self-adaptability, and self-learning, are well-suited to navigate the battlefield's challenges and engage in warfare despite the inherent unpredictability and chaos involved.[29] By leveraging the evolutionary advantages of nature, military robots can enhance effectiveness through biomimicry. Such robots tend to be more adaptable to unforeseen scenarios, improving their ability to learn and evolve in response to environmental changes, which can significantly enhance mission outcomes.

Swarm robotics is an advanced approach comprising the coordination of large numbers of robots. Its inspiration stems from observing social insects such as ants, termites, wasps, and bees. Swarm technology presents a mesmerising instance of how simple individuals can interact and coordinate to form a collective intelligent system. Social insects possess the ability to coordinate their actions to accomplish tasks that an individual cannot perform alone.[30] The swarming of beebots, or groups of other replica-bots, for instance, can be helpful in wide-area surveillance and coordinated attacks, even if used as conventional weapons for force-multiplying impacts. The essence of living species lies in their behaviors and characteristics, such as adaptability, camouflage, swarming, task sharing, and collaboration for common objectives. There are efforts underway to replicate natural characteristics in physical and functional embodiments by drawing cues from nature, particularly in robots and machines designed for military purposes. This approach can enhance the design and functionality of robots, enabling them to navigate complex environments, adapt to dynamic conditions, and perform tasks that would be challenging for traditional robots. This fusion of human and animal intelligence with artificial intelligence would bring about unprecedented transformation in future wars through advancements in software, as well as the physical design and operational capabilities of these robots. The transformation of living species into mechanical species: a *new* breed may initially complement human capabilities and enhance what animals can do that humans cannot.[31]

Figure-2: Characteristics of Bio-Inspired Swarm Robotics



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Nature-inspired robots are built by reverse engineering that enhances natural ideas and systems, such as those found in living things. The corresponding animals, guided by instinct, were less harmful. Conversely, human conditioning or algorithmic systems embedded into bio-inspired robots would add an evil instinct to these systems. In contemporary times, there have been initial instances of nature-inspired robots used in surveillance, conflicts, and even assassination attempts. This is just the beginning of the weaponization of bio-inspired robots, which may increase the fog and friction of wars soon. The characteristics of these nature-inspired robots, such as maneuverability, agility, and morphology borrowed from living things, make them ideal for covert operations.[32]

Swarms, packs, flocks, and shoals of bio-inspired robots can also have the potential for force-multiplying effects. Bio-inspired robots emulate the functionalities of biological organisms, taking inspiration from their design, movement, and survival strategies.[33] These robots are designed not only for efficiency but for adaptability and survivability qualities that are invaluable in the chaotic nature of warfare. This dynamic and interactive environment in contemporary conflicts offers a unique set of opportunities and challenges for modern-day military operations, potentially reshaping warfighting strategies and operational paradigms. These developments can lead to a future of warfare where firepower becomes less important than the power of information, real-time data collection, rapid processing, and dissemination for informed decision-making, or the strategic use of massive quantities of drones for disruption.[34]

Like living species, bio-inspired robots can withstand and adapt to challenging conditions, offering significant advantages on the battlefield, particularly in asymmetrical warfare scenarios. Similarly, biological systems and bio-inspired robots exhibit unique self-organizing behavior, allowing task execution without centralized control. For instance, examining the social and environmental interactions involved in robotic task performance parallels the collective behaviours of social animals such as bird flocking, ant foraging, and fish schooling. These self-organizing behaviors lead to complex group dynamics that emerge from the interactions of the individual members' routine behaviors. In nature, these organisms demonstrate collective behaviours that enable them to accomplish tasks by working together in a coordinated manner. Swarms exhibit emergent features and abilities that far surpass the capabilities of individual members.[35]

The commonality between animals and robots, or replicas, lies in their unpredictability and uncontrollability, making them unreliable and uncertain means of warfare. One difference is that animals were trained through Conditioned Reflex Analogy (CRA) and Pavlovian learning; they were also guided by instinct to be useful in wars. Robots would rely on generative AI for learning from existing data and artificial superintelligence for self-learning and could also be programmed with biases by humans for malicious objectives.

These are the most challenging factors in dealing with robots in contemporary times, especially in the case of AI-enabled self-learning, which may lead robots to develop *survival instincts* out of fear that those who can unplug them have the life-and-death decision over the *robots*, thus making them extremely unpredictable and uncontrollable.[36]

The unpredictable turn of events and behaviors, as well as the possibility of things getting out of human control, are common to natural systems and concepts of warfare. Besides complexity, ambiguity, and uncertainty, these two elements primarily arise from the interaction of various factors in chaotic or unpredictable systems and environments. These further give rise to concepts such as non-linearity, anarchy, disorder, fog, chaos, randomness, and chance, leading to various complex challenges.[37] To overcome the chaotic nature of warfare, the natural characteristics of animals, such as self-adaptability, self-organization, instinct-driven survival mechanisms in unpredictable environments, the collective intelligence of groups, and collaboration for task performance, are being replicated in bio-inspired robots to enhance predictability in uncertain behavior and battlefield environments.

The elements of a good strategy, such as deception, concealment, surprise, camouflage, misidentification, fakes, and dummies, have long been part of warfighting strategies. Animal characteristics, such as crawling, rolling, and intelligence, as well as social connections like swarms, packs, and flocks, or genetic algorithmic functions, like the "algorithmic genius of ants" navigating their colony, have promising military applications. As warfare evolves with the advancement of technology, bio-inspired robotics emerges as a novel frontier in the field of warfare. With nature as its blueprint, scientists employ algorithms and mechanical forms derived from the animal kingdom to create robots exhibiting extraordinary adaptability, resilience, and multifaceted operational capabilities.[38] Analysing the intersection of robotics, nature, and warfare, focusing on the interactions between robots and their environments, and how they respond to chaotic conditions, helps us understand the complex interplay of conflict factors. These may include diverse terrains, weather conditions, and ever-changing tactics of adversarial forces, all of which contribute to the confusion and intricacies of warfare.

Predictability and situational awareness are key to operational success. For example, robotic insects equipped with tiny cameras and sensors can record what they see and hear in surveillance applications. These devices effectively blend into their surroundings, camouflaging themselves and thereby enhancing their ability to gather information.[39] The enhanced situational awareness, precise and credible Intelligence, Surveillance, and Reconnaissance (ISR), as well as real-time data collection, can significantly help overcome unpredictability and improve precision in military operations.

The primary advantage of bio-inspired robots lies in their autonomous adaptability. At the tactical level, these robots can exhibit adaptive behaviour, such as mimicking the swarm behaviour of insects.

They respond to dynamic interactions within their environment and can explore and traverse unfamiliar terrains more efficiently based on sensory inputs and feedback systems. The autonomous adaptability grants independence to individual units within a group. Swarm intelligence enables these groups to coordinate and work with high efficiency, robustness, and adaptability.[40]

Implications of Nature-Inspired Robotics and Miniaturization

Technological advancements have consistently shaped the ever-evolving landscape of warfare. With technological progress, countries are increasingly engaged in a technological arms race to develop advanced animal replications, including robotic and bioengineered systems designed for combat and surveillance. This competition can significantly increase military spending and innovation, as countries strive to outdo one another in capabilities that mimic the agility and sensory advantages of real animals. This has led to a significant transformation in military technology, driven by the rise of robotics and autonomous systems. These advancements significantly alter operational methods, presenting various benefits in terms of effectiveness, security, and flexibility.[41] Considering the rapid technological advancement, military robotics and autonomous systems will likely dominate warfare. AI may play a greater role in decision-making by enhancing the decision-making capabilities of military robots and their role in the military field.

The first instances of robotic warfare have involved the use of armed and unarmed, manned and unmanned drones for various military operations. The Queen Bee itself inspired drones. Initially, robots were unmanned and used only for surveillance and reconnaissance. Nonetheless, since bees can sting, the drones were armed with missiles. This is how the first generation of 'Queen Bees' (Predators and Global Hawk) started stinging with Hellfire missiles. [42] Bees always work in coordination and share tasks, a principle now applied to drone swarming and operational coordination.

Military innovation in drone swarming, task sharing, and coordination of different system units on the battlefield is redefining the combat dynamics. These natural characteristics of living things are already being applied to conventional drones and programmed into replica drones and robots. In the biomimicry of robots, swarming has emerged as a tactic that reinvigorates the traditional concept of massiveness or quantity of force, with added advantages of network resilience, autonomy, innovation, self-adaptation, and self-organization.[43] Integrating biomimetic strategies can lead to unconventional warfare tactics that challenge traditional notions of military engagement. The swarms, flocks, Packs, and shoals of bio-inspired robots, equipped with added camouflage, deception, morphology, surprise, and shock, can be detrimental to tactical-level operations with strategic impact, even when used as standalone conventional tools.

Experts have already referred to the ongoing Russia-Ukraine war as the "Drone War" because of the crucial role that drone technology has played throughout the conflict.[44] The Israeli military, in 2021, used swarms of Artificial Intelligence drones, which were capable of functioning on "their judgment" to geolocate, target, and strike against Hamas fighters in Gaza, in coordination with every other unit of the swarm.[45] Recently, China tested a swarm of around a thousand drones linked to a single network, which can serve as a force multiplier and overwhelm defense systems, rendering them ineffective. A notable fact about these resilient swarms is that a single unit embodies the characteristics of the entire system, meaning that even if a single unit is lost, the mission can still be continued by the remaining units. The resilience and flexibility of these swarms are noteworthy. They function as amorphous groups where no member is essential for survival and effective operations. Military swarms offer more adaptable and survivable forces, as well as new offensive and defensive tactics better suited to contemporary battlespaces.[46]

Previously, drones have played a significant role in conflicts because they can perform "dull, dusty, and dangerous tasks" in counterterrorism and counterinsurgency operations, and offer ideal tools for warfighting. These robots are not mere tools of convenience but redefine the rules of engagement through a unique blend of operational efficacy, reduced risk, and precision in contested environments.[47] However, drones are one form of robotic replication, and the list includes various others. A range of living things replicas can help enhance situational awareness through real-time data collection, processing, and integration, facilitating better decision-making and task sharing, just as living things do instinctively for collective objectives. Miniature drones, some as small as bugs, mimic insects and offer significant advantages: they are less detectable and can be deployed in tight spaces. These can gather intelligence in urban areas, monitor enemy movements, or even deliver payloads.[48]

Small states and non-state actors may also be able to utilize these robots to inflict disproportionate attrition. These developments lead to new forms of warfare, such as decentralization and autonomous AI-enabled decision-making in military operations. This evolution can amplify the power of asymmetric warfare, where smaller, agile forces utilize biomimicked technology to counter traditional military powers. For instance, swarming drones in shared brain systems or robots can facilitate collective action and shared objectives, leveraging natural networking between living things to provide a greater force multiplier for disruptive impact.[49]

In terms of "fire ant" warfare, swarms composed of millions of sensors, emitters, microbots, and micro-missiles, and deployed via pre-positioning, burial, airdrops, artillery rounds, or missiles, can saturate the terrain of conflict. The proponents of innovations in the application of force, particularly regarding the tactical use of swarms, argue that instead of charging at the enemy in waves, such forces, when deployed to converge from all directions for coordinated offensive bursts, may produce maximum shock effect.[50]

The characteristics of these resilient systems can revolutionize maneuverability, shock, surprise, and force multiplication, and have significant implications for future conflicts.

These robots can evolve their behaviors based on battlefield conditions, much like organisms adapt to survive in their respective environmental conditions. When unleashed in large numbers, they can cause severe disruption. Because quantity has its quality, with innovation in robotics, the numerical and massive use of force may return to the battlefield, altering the odds of conflict.[51] Similarly, as the importance of critical connectivity, information gathering, and processing increases, it will become increasingly necessary to "disrupt, degrade, and disable" the highly connected and information-dependent systems and infrastructure of adversaries.

International Humanitarian Law (IHL) Perspective

Introducing bio-inspired robotics in warfare creates a thorny trilemma of legal, moral, and ethical challenges. These challenges are primarily related to distinction and misidentification, autonomy, lethality, accountability, and attribution.[52] Among these, the most critical challenge is the right to kill or a life-and-death decision over humans given to a machine or robots.[53] The general concerns regarding legal, moral, and ethical considerations primarily pertain to actors who use force, the weapons they employ, their actions, and the consequences of those actions.

IHL, as the law of armed conflict, broadly deals with 'weapons law', which refers to the means and methods used, and the 'targeting law, meaning the lawful *use* of weapons. Ambiguities in the application mar the legal qualifications for a ban or regulation, providing weak grounds for morality and ethics in the regulation. Certain tenets of IHL, such as the need for greater care in precision, mitigation of human suffering, and accuracy in target identification, to some extent, justify the use of dual-use technologies as means and methods of warfare.[54] The resultant dilemma also limits the scope of IHL in terms of its legal applicability, moral strength, and ethical grounds for banning emerging lethal and semi-autonomous technologies. The IHL defines specific qualifications regarding the use of force and weapons, but leaves many aspects undefined, thus making it challenging to apply to emerging technologies.

The autonomy of bio-inspired robots used in combat can complicate and blur the lines of accountability, challenging existing legal frameworks governing warfare. The life-like attributes of bio-inspired robotics blur the lines between autonomy, agency, and the sanctity of animal life, making the moral calculus far more complex than conventional robots. Human or animal-like replication may influence the threat response and affect anthropomorphism regarding bio-inspired robotics.[55] Besides the unpredictable and uncontrollable nature of robotic designs and functioning, these robots can cause physical harm and infringe on other fundamental rights of the people, such as privacy, even when deployed for unrestricted reconnaissance and surveillance.

There is a long history of animals being found guilty of causing harm, which is often considered tantamount to committing a crime or violating specific social and legal norms; for this reason, they have also been tried and punished. The subjects of accountability, attribution of responsibility, and retribution are currently under discussion regarding robots at international forums. However, the militarisation of nature and weaponisation of animals through biomimicry sets an unprecedented shift in warfare and may challenge the existing legal frameworks. Moreover, these developments further widen the gap between technological innovation in warfare and the legal frameworks designed to regulate it. The scope and interpretation of the existing legal frameworks are further complicated by general principles of Law, such as "anything not explicitly prohibited is permitted"[56] or "prohibitions have to be clearly stated or otherwise do not apply".

Another similar principle is not to anthropomorphize robots, meaning they cannot be given human-like rights or characteristics, or robots cannot be given personhood. The anthropomorphizing of pet animals has moral, psychological, and ethical implications. The development of bio-inspired robotics would complicate the principle of IHL; if robotics cannot be anthropomorphized, can bio-inspired robotics be? Similarly, Robots cannot get human-like characteristics, but can they have life-like characteristics? Difficulty in addressing these challenges also creates an anthropocentric bias. It raises moral and ethical concerns regarding animal identity and suffering, blurred by their biological look-alike robots.[57]

Thus, while the future promises enhance tactical efficacy through bio-inspired robots, it simultaneously demands rigorous ethical scrutiny to ensure that deploying such technologies does not undermine fundamental humanitarian principles. As advancements in bio-inspired robotics evolve, military applications will become increasingly sophisticated. The prospect of deploying robots that mimic biological systems raises significant questions regarding their strategic advantages, such as enhanced surveillance capabilities and improved adaptability in unpredictable environments. The proliferation of cheap and readily available bio-inspired robots could also empower non-state actors, posing new threats to global security. Therefore, integrating these technologies also necessitates carefully examining ethical implications by balancing innovation with moral responsibility, which will be crucial as nations navigate this complex landscape.

Conclusion

The 21st century has witnessed significant technological strides. Military biomimicry, also known as bio-inspired robotics, has made considerable progress. Historically, animals played a crucial role in warfare. Now, their unique characteristics are being incorporated into advanced robotics, transforming the conduct of warfare. Nature-inspired robots are best suited for asymmetric and decentralized force applications, which can have disproportionate impacts or multiplier effects, as well as force multiplication across different domains for targeted operations.

This technological development may give bad actors new power to carry out their missions without moral, legal, or ethical constraints. These tactics mainly favour the attacker and pose significant challenges for defenders using traditional approaches to defence. The tactical use of drones and robots by the state, as well as non-state actors such as terrorist organisations, with simultaneous air and land attacks, can saturate enemy defence systems and render them obsolete.

As warfare increasingly integrates biotechnology, the implications for future armed conflict will be profound. Using bio-inspired robots, which have been employed in a manner similar to animals and insects historically, could lead to new war-fighting paradigms where the lines between the biological and technological domains become increasingly blurred. This evolution will require military strategists to adapt their tactics and consider new forms of engagement, threat perception, and defence measures. Exploring natural systems as a means of weaponisation and bio-inspired robotics is an interconnected development that could significantly shape and reshape future warfare. The emphasis on understanding biological systems to enhance military capabilities with the help of artificial intelligence could be a game-changing approach to warfare. However, this rapid advancement raises critical ethical concerns, highlighting the urgent need for comprehensive international legislation and regulation. International agreements and legally binding instruments need time for the responsible and ethical use of autonomous systems in warfare. Such frameworks are essential to govern the use of animal replications, ensuring that their deployment adheres to ethical standards and prevents potential abuses.

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