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Future of Biotechnology in AI: Vision of 2028 and beyond

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Abstract

Biotechnology is referred to as one of the world's most innovative and dynamic sectors, with technological and scientific advancements transforming the energy, agriculture, healthcare, and environmental sustainability industries. Meanwhile, the convergence of artificial intelligence (AI) and biotechnology is believed to revolutionize warfare, defense, and military interventions. By the year 2028, this union/ fusion might offer beneficial outcomes such as superior biosensors, neural interfaces, and bioengineered organisms capable of redefining the dynamics on the battlefield. The development of biotechnological innovations, along with the use of artificial intelligence in soft robotics, presents tremendous benefits for military enhancement such as neural warfare, increased surveillance, and bio-engineered soldiers. This evolution/ advancement has specific associated challenges, such as ethical, operational, and security concerns. This paper intends to present a comprehensive analysis of the future of biotechnology driven by AI, with a vision extending to 2028 and beyond, most notably the associated positive and negative influence of widespread A-driven biotechnological advancements that have been explored. In other words, the expected role of biotechnology integrated with AI in military and defense strategy is being analyzed in this study.

Keywords: Future of Biotechnology in AI, Defense Technology, Vision of Biotechnology in 2028 and beyond in military enhancements, Convergence of biotechnology and AI, and future of Warfare

I. INTRODUCTION

Biotechnology is a field of technology that integrates cellular and biomolecular processes in the development of food, healthcare, and fuel products. In terms of industrial biotechnology, AI improved the efficiency levels of industrial processes by the optimization of biofuel production, fermentation, and waste management (Khan, 2020). Meanwhile, by evaluating complex biological systems, AI algorithms not only demonstrate bottlenecks and suggest improvements but are also crossing over in fields such as warfare and defense (Rashid et al., 2023). The ongoing AI development guarantees that the field not only stays current but also drives innovation in the development of dependable, user-friendly, and practical solutions that advance warfare experiences (Deshmukh et al., 2023, Araya and King, 2022). Most significant advancements in Biotechnology, when combined with artificial intelligence, include neural interfaces, biosensors, and soft robotics; these innovations are believed to play an active role in reshaping modern warfare (Chakraborty et al., 2023, Zhang et al., 2022). For example, biosensors effectively monitor soldiers' and environmental conditions in real-time and support performing medical responses on time for the efficient execution of the mission (Thakre et al., 2022). Neural interfaces can make it easier for military individuals to communicate with machines as they be able to control drones and robotics more effectively. Additionally, well-designed soft robotics for exploring new terrains can substitute fixed aerial vehicles offering better reconnaissance and infiltration capabilities (Wu, 2022). Hence, these technologies promote a military that is more flexible, quick to adapt and makes better decisions while reducing the risks to humanity (Das and Pandit, 2021).

Meanwhile, from 2028 onward, Biotechnology and Artificial intelligence integration is expected to bring revolutionary changes in all the fields (Özbay, 2024). For example, big data analytics provides researchers with knowledge to get results from large biological databases that improve military aspects (Bibi and Ahmed, 2020). The new potential in military strategies arises from the possibility of interfacing with neural signals, augmenting physical and cognitive abilities, and enabling the use of

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soft robotic agents for reconnaissance; such integration is not only an enhancement of the capabilities of the soldier on the battlefield but also facilitates the evolution towards autonomous systems that can function in extreme conditions with lesser human intervention (Sherani et al., 2024, Paul, 2023). However, there are profound specific issues, such as privacy, ethics, and the use of biological systems for offensive purposes, that come with these advances (Sahu et al., 2022). Meanwhile, personal freedoms may be abridged by the surveillance aspects of biosensors, while the threat of autonomous robot weapons driven by artificial intelligence and biology may escalate the conflict further without the need for it; this ensure innovations are embraced but with ethical constraints that inform the military initiatives of the future (Hendrycks, 2024, Hossain, 2023). Thus, biotechnology and artificial intelligence should be integrated into military operations to promote military capabilities (Xu et al., 2021). This paper intends to explore the future of AI-driven biotechnology in military operations, emphasizing the impacts of neural networks, biosensors, and soft robotics in warfare. Meanwhile, not only the positive effects, such as improved military capabilities and surveillance, but the associated risks, such as potential misuse and relevant ethical issues, are also being highlighted; the following are the main objectives of this study;

- To explore the critical advancements in AI-driven biotechnology.
- To evaluate the potential positive and negative impacts in warfare, defense, and military reinforcement.
- To demonstrate the security and ethical risks associated with innovative technologies.

II. LITERATURE REVIEW

a. Overview of Biotechnology and AI

The study by van Weerd and Lassche (2021) evaluated that biotechnology and AI fields began to intersect in different areas, such as healthcare and defense. For example, one of the most common and well-known applications of AI in healthcare or medicine is drug discovery (Agu and Obulose, 2024). AI models seek through large databases to look for potential drug compounds, evaluate their interactions, and decide the suitable molecular structures (Rane et al., 2024). AI technology brings faster the discovery of potential drugs for different diseases, decreasing dramatically the time and the costs of a conventional drug discovery process(Deng et al., 2022). Besides the medical field, which is dominated by prescriptions, AI has also achieved much in the field of genomics (Singh et al., 2024). The learning algorithms process the sequences and patterns of the DNA, enabling us to find out the variations in the genes and the likelihood of rising diseases. For instance, image and speech recognition systems in machines can constantly analyze next-generation sequencing data to identify biomarkers that are necessary for individual treatment (Paolanti and Frontoni, 2020, Tripathi et al., 2021). Hence, AI improves treatment outcomes and reduces risks since therapies are chosen according to the patient's genetic makeup. In addition, data analysis by AI is more extensive than human researchers' data analysis because it can find correlations in large data sets of genomes (Sahu et al., 2022). In these ways, in healthcare, AI fostered the development of personalized treatment plans and drug discovery and promoted diagnostic accuracy through predictive modeling and data analysis.

In addition to this, in defense, AI-powered biotechnology allows the creation of bio-inspired technologies and advanced surveillance systems (Iqbal et al., 2023). For example, some of these innovations include soft robots successfully designed to imitate animal behavior and allow for the performing of stealthy missions in challenging environments. Meanwhile, AI-enabled advanced surveillance systems optimize the time taken for analyzing varied threat types with the aid of varying sensors, such as biosensors, and drones, amongst others (Sharma et al., 2022). In this case, farming biotechnology and artificial intelligence made it possible to really evaluate conditions on the battlefield or unit's movements of the enemy in real time (Ahmed and Echi, 2021). Furthermore, AI systems can compensate and change more quickly than what is possible with today's technology, thus improving the effectiveness of the dynamic defense over the static defense (Bonfanti, 2022). Hence, the active development of biotechnologies, allowing new methods to improve the physiological attributes of humans, has opened further prospects, and the active processing of massive biological databases, studying their dynamics, and making decisions in real-time, AI has been integral to biotechnology-associated tasks (El Kafhali et al., 2022).

b. Current Applications of Biotechnology in Defense and Military Operations

The current applications of AI in biotechnology have transformed the industry by fostering development, research, and production procedures (Clarke and Kitney,

2020, Garouani et al., 2022). A widely known use case is in biosensors, where AI models are used as a new, innovative frontier for gathering intelligence; biosensors help in faster identification, detection, and diagnosis, providing a technological revolution (Xu et al., 2021). With AI having the potential to scale and automate data mining and interpretation for prediction effectively, the time consumed in the throughput process decreases vastly, allowing researchers to approach appropriate therapeutics with relative ease quickly (Ortseifen et al., 2020). Biosensors are used in soft robotics or other AI-driven systems to collect intelligence as they can detect biological signals like brain activity. Meanwhile, biosensors can also be placed behind enemy lines in soft robotic flies to monitor physiological indicators, brain waves, and even emotional states. Hence, these modern sensors can collect real-time data on enemy individuals, offering armed forces a competitive advantage in battle intelligence. The military usage of brain-computer interfaces reflects that these systems enable soldiers to effectively control the drones with different commands that are being directly issued to the weapon systems by the brain (Li et al., 2023). Through brain interfaces, this biosensing technology may also be utilized to control drones or other military hardware, giving warriors the ability to handle complicated machinery with just their minds (Hendrycks, 2024, Arinez et al., 2020). Therefore, Biosensors have the potential to be the most valuable tools in contemporary military strategy due to their capacity to access and modify human brain signals (Sherani et al., 2024).

A valuable innovation for military operations is soft robotics, which is designed to mimic living organisms and can be reduced to the size of small animals or insects (Ghosh et al., 2022). In the context of military operations, AI-powered soft robots equipped with biosensors can present a valuable advancement. These versatile machines can address challenging terrains and arrive at enemy territories stealthily, and these flexible, soft designs support minimizing detection. With the help of technological advancements such as AI, robots can efficiently and in real-time process information from the field, and acquire important information such as the position of the enemy troops, their fortifications, and lots of other information (Ghazizadeh et al., 2024). Furthermore, these robots can be programmed for direct operations that involve spy or demolition tasks, which increases operativity and, at the same time, decreases the likelihood of endangering the human life of a soldier. Hence, they are an essential component in today's warfare, especially due to the devolving nature of battlefields. Meanwhile, unlike ordinary drones or stiff robots, biohybrid soft robots are able to conceal themselves within the immediate environment, thus improving their efficiency in intelligence, sabotage, and reconnaissance-related activities (Boldt and Orrù, 2022). For example, using soft and natural materials, the designer can hide in their environment or blend with its elements, reducing the chances of detection by eyesight or electronics; such versatility permits their use in different contexts, including desert and city environments, without being noticed. Moreover, their budding operations allow them to silently traverse challenging environments on potential targets; hence, in this regard, they assume essential roles in most of the recent stealth missions (Hendrycks, 2024).

c. Ethical, Legal, and Social Implications

The application of AI-powered biotechnology in armed conflict raises specific moral or legal concerns. For example, apart from telepresence, where biosensors monitor the cognitive performance of soldiers, such a monitoring technique serves governments' information concerns, which can lead to abuse of private data (Carlo, 2021). In as much as these technologies have their benefits in assessing soldier preparedness and evaluating their psychological status, they also carry the potential for abuse. There is a potential for the abuse of sensitive information by governments, which may result in the loss of trust from the personnel in the military authorities; such observation may also result in prejudice or wrongful treatment due to cognitive evaluation towards career development and social. Hence, it is imperative to maintain a solid legal base that prohibit such misuse and protect the privacy rights of soldiers in all aspects of these modern technologies (Ali et al., 2024). Moreover, mind-machine interfaces for information exchange may also be used for warfare purposes with emerging new horizons. Hence, the associated issues must be acknowledged by the worldwide community, and political measures should be taken, including laws restricting the deployment of bioweapons in combat (Boldt and Orrù, 2022).

III. METHODOLOGY

A secondary analysis is conducted, and research information is drawn from existing reports and literature related to artificial intelligence (AI) and biotechnology in defense applications. The qualitative approach is used, focused on collecting insights from defense publications,

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peer-reviewed journals, and government reports published in the last five years (such as between 2018 and 2023). A comprehensive understanding of the impacts and risks of AI-driven biotechnology in terms of military settings has been acquired using a secondary qualitative approach.

IV. IMPACTS OF AI-DRIVEN BIOTECHNOLOGY IN MILITARY OPERATIONS

a. Positive Impacts

The study by Raska and Bitzinger (2023) evaluated that there is little or no sphere of warfare that AI cannot influence, including, but not limited to, defense innovation, military industry integration, civil-military affairs, battle management, simulation, and training, prediction, movement, intelligence, information, and protection of force. Meanwhile, in weapons, sensors, navigation, aviation support, and surveillance warfare, systems such as these can incorporate AI to minimize human interaction with operations. Meanwhile, this added efficiency due to AI means that such systems need less maintenance (Ertan, 2022). In a similar context, the study by Anh and Hieu (2024) revealed that one of the potential benefits of AI-driven biotechnology is increased surveillance and intelligence gathering. It is explored that AI-associated biosensors and neural interfaces can continuously relay information, not only about the location of enemy targets but also about their forces and environmental conditions. In this way, military structures are able to obtain and process information more effectively in order to make more rational decisions.

According to Termanini (2022), active implementation of biotechnology can be helpful in conducting stealthy missions like spying and targeted assaults. For example, flies that are made in the shape of miniature robots can carry out surveillance in an enemy's location without being noticed and bring back valuable information to the military. Moreover, by the plugin of neural interfaces, traditional soldiers can directly associate with computer intelligence systems, which significantly influences the response time in various situations. It is revealed that AI is capable of not only interpreting neural activity patterns but also predicting possible actions of the soldier, thus reinforcing their decisions through the interaction of human and artificial intelligence.

b. Negative Impacts

There is a potential for AI to be manipulated or hacked by adversaries, and sensitive information can be exploited and stolen due to the invasion of these systems (Carlo, 2021). The study by Ghazizadeh et al. (2024) revealed that the increasing incorporation of biosensors and neural interfaces in military applications may lead to intrusion into the basis of soldiers' privacy. It is explored that including a diagnosis using brain activity monitoring to monitor cognitive strategies has implications regarding the ethics of obtaining data from people and how the data acquired can be abused. In addition, De Haro (2024) revealed that biotechnology driven by AI brings new biosecurity challenges, especially in regard to the biowarfare use of such biotechnological systems, as well as possible exploitation by competitors. There is a possibility of using advanced biotechnology for the construction of bioweapons or disturbing the operational capacity of vital military installations.

Similarly, a study by Abaimov and Martellini (2020) revealed that with increasing reliance on AI-powered biotechnology in modernizing various militaries, there is a risk of vulnerability to cyber-attacks, system breakdowns, or technological incapacitations. Hence, performances perceived to be subordinate would undermine human soldiers' tactical aspects and consequently compromise a nation's security.

V. RISKS AND CHALLENGES OF AI-DRIVEN BIOTECHNOLOGY IN DEFENSE

The study by Boldt and Orrù (2022) revealed that one of the main concerns when it comes to AI-supported biotechnology is privacy invasion. For example, using extracts of neural activity monitoring in the course of military activity or extraction of cognitive such as memory raises moral issues on the issue of consent and also the functional constraints of the private data. In these ways, there are also fears about the potential of these kinds of technologies being put to use in warfare by altering the cognitive attributes of soldiers directly or indirectly.

According to Ali et al. (2024), the reliance on AI-driven biotechnology raises operational concerns, such as system breakdowns or cyberattacks that deactivate critical military equipment. If these systems become too crucial to military strategy, a single failure might have catastrophic implications. There is also the possibility of unintended consequences, which occur when AI systems make judgments that are not in line with human aims, resulting in combat miscalculations (Abaimov and Martellini, 2020). Additionally, the study by Hendrycks (2024) revealed that there are certain biosecurity risks

associated with AI-powered biotechnology. For example, AI-powered biotechnology can be weaponized to develop biological agents that are difficult to counteract or detect. Meanwhile, adversaries can also hack into AI-driven biosensor systems, compromising operations and attaining control of vital military infrastructure (Hendrycks, 2024).

VI. BIOTECHNOLOGY AS A GAME-CHANGER IN DEFENSE BY 2028

Biotechnology undergo drastic changes and innovations regarding health care, defense, agriculture, and ecosystems by the year 2028 (Husaini and Sohail, 2023, Differding, 2023). In terms of healthcare, gene editing technologies such as CRISPR revolutionize treatment for genetic diseases and improve the ability of crops to withstand climate conditions; this further promoted the growth of Precision Medicine, which is a solution that is based on the patient's genetic makeup in order to enhance patient's outcome (Khan, 2020, Rane et al., 2024). Additionally, biomanufacturing approaches facilitated new process designs, which are more efficient and economical (Das and Pandit, 2021, Delen, 2020).

The importance of biotechnology in military activities is expected to keep increasing with technological advances (Ghazizadeh et al., 2024). Biosensors be capable of constant supervision of the comprehension of the battlefield aided with AI, while the neural interfaces allow the union of the warrior and the machine in an effective flow; such developments have a considerable edge estimate advantage to the armed forces (Ali et al., 2024). There are indications that there be a further progression of biotechnology by types of AI of biosensors and neural interfaces, some of which produced by the year 2028. These technologies probably be smaller, more independent, and more effectively synergy with traditional military equipment, making it possible to improve the movement and decision-making. Meanwhile, the permitted solutions offered by AI for defense operations are less demanding (Carlo, 2021). AI systems are used to detect and identify signals of interest, as well as to build the technology needed to turn off the signal or intercept the risk it poses. AI can also help detect and intercept approaching threats (Chakraborty et al., 2023). Hence, all these trends of applying biotechnology promoted military operations (Holzinger et al., 2023).

VII. RESEARCH LIMITATIONS AND FUTURE IMPLICATIONS

The impacts and risks of AI-driven biotechnology are comprehensively explored in this paper, most notably in the context of military operations, but there are certain limitations of this analysis. One of the fundamental limitations is that this study relied on secondary data sources, so it may not capture the most recent innovative advancements in biotechnology and AI. In addition, the qualitative approach used in this analysis restricts the capability of generalized findings across diversified technologies and contexts.

Future research focused on primary data collection methods would be advantageous for attaining deeper insights into chosen research phenomena. Meanwhile, the exploration of societal and technological implications, such as ethical considerations and public perceptions, would also be essential. Hence, a deeper comprehensive analysis of evolving AI-driven biotechnology aspects is vital to ensure the responsible integration of military strategies.

VIII. CONCLUSION

In conclusion, the integration of AI and biotechnology is poised to revolutionize military operations or strategies by 2028 and beyond. While specific innovations such as neural interfaces, biosensors, and soft robotics promise to increase operational effectiveness and capabilities, they also raise specific operational, ethical, and privacy concerns. It is explored that misuse potential and surveillance technologies implications require a careful strategy for their deployment. Hence, for evolving military strategies, it is essential to balance technological advancements with relevant ethical considerations in order to ensure that these powerful tools and technologies are used responsibly. Moreover, the continued dialogue among stakeholders would also be vital for the navigation of concerns or complexities associated with AI-driven biotechnology in defense.

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