device. Moreover, such a high-priced technology will be removed from old and damaged models for reuse (green planet!). Furthermore, there is a need to radically increase hardware reliability. However, this need contradicts the tendency to reduce the reliability of integrated circuits while reducing their design norms in the latest information system technology. The only way out is the specialization of architecture for such artificial intelligence.

Summary

The development of the universal Artificial Intelligence architecture and hardware components for it is futile.

Computer engineering of Artificial Intelligence will advance in the direction of finding new effective algorithms and specialized structures for their implementation. Moreover, more attention will be paid to the improvement of efficiency of common architectures programming adapted to the tasks of artificial intelligence, such as TensorFlow.

V. I. Slyusar

To Subsection 7.1. Artificial Intelligence and National Security

The tendency of shifting to robotics, which covers a wide range of areas, is especially discernible in the military sphere. The world's leading countries are making significant efforts to equip military units with robotic systems for various purposes and increase the effectiveness of their military use. The experience of military cooperation with the NATO member countries demonstrates that military analysts consider Artificial Intelligence (AI) to be a breakthrough technology for improving military readiness. The introduction of artificial intelligence is an important trend in the development of battlefield management systems and fire-control systems, including robotic platforms. [Stanley-Lockman and Hunter 2021].

As for controlling military affairs, artificial intelligence technologies are considered an important addition to the workforce in a range of directions, including expanding situational awareness and data exchange; coordination of divisions; distribution of goals; control of sensors and weapons; detection and identification of threats, reduction of reaction time; assessment of intentions; semi-autonomous weapons system; resource management, partial replacement of human decision-making, etc. In the long run, the optimal choice of a combination of sensors and weapons, depending on the threats, should be made with artificial intelligence, which is becoming more important both in solving problems of situational awareness and decision-making support.

In 2017-2018, NATO started the process of AI standardization. For now, several stages have been passed through. The first stage concerned terminology. At the initial stage, NATO experts used two alternative definitions of Artificial Intelligence (NIAG StudyGroup SG-238 GBAD Operations against the 21st Century Peer Nation Cruise Missile and Unmanned Aerial Systems (UAS)):

"AI is the capability provided by algorithms of selecting optimal or suboptimal choices from a wide possibility space, to achieve goals by applying strategies which can include learning or adapting to the environment";

"Artificial Intelligence (AI) refers to systems designed by humans that, given a complex goal, act in the physical or digital world by perceiving their environment, interpreting the collected structured or unstructured data, reasoning on the knowledge derived from this data, and deciding the best action(s) to take (according to pre-defined parameters) to achieve the given goal. AI systems can also be designed to learn to adapt their behavior by analyzing how the environment is affected by their previous actions".

The Bilateral Strategic Command (BI-SC) final report on Joint Air Power Capabilities (JAPC) turned to the definition of the NIAG SG-231: "Artificial intelligence (AI) is an ability of a non-biological system to achieve any complex goal through processes comparable to human cognitive processes such as perception, deduction, recognition, memorization, and learning".

The first of NATO's official definitions (NATO adopted) was included in the AJP-3.10 Ed. B, Ver. 1. Allied Joint Doctrine for Information Operations. In the project proposal dated May 2021 artificial intelligence is defined as a branch of computer science dedicated to the development of data analysis systems that perform functions commonly associated with human intelligence, such as reasoning, learning, and self-improvement.

Simultaneously with the approval of AI definitions, NATO experts have begun the process of agreeing on relevant acronyms. For instance, in the *Allied Joint Doctrine for Close Air Support and Air Interdiction, Study Draft 1*, it was decided to stop using AI for *Air Interdiction*, so that it remains an abbreviation for *Artificial Intelligence*. Nevertheless, the harmonization of acronyms is not completed yet.

Experts' views on possible military application of AI is a gradually expanding cluster of standards, which reflects certain aspects of the role and function of artificial intelligence in specific missions. It is noteworthy that these standardization documents already cover all domains of multi-domain operations – land, air, maritime, and cyberspace.

Moreover, the integration of relevant AI regulations gradually extends to all components of DOTMLPFI (Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, Interoperability). For instance, in the ATP-49. Use of Helicopters in Land Operations Doctrine Ed. G, Ver. 1 it is suggested to integrate AI technology in ground control stations for controlling unmanned vehicles (UAV) (Fig. 2), as well as a part of MUM-T, integrated with the helicopter team.

The ASCP-01 Ed. A Ver. 1 NATO Stratcom Training Standards (Annex F, page F-5) standardized requirements for the general competencies of information environment assessment specialists who have to be capable of understanding and applying artificial intelligence and machine learning technologies to assess the information environment: *Understand and apply Artificial Intelligence/Machine Learning in IEA.*

The roadmap for the implementation of the Federated Mission Networking spirals in the 2019 edition determined the goal of the 6th FMN spiral to improve the processes of analysis and decision-making by integrating AI. The 6th spiral implementation schedule envisages the formation of utilization and safety requirements that will begin in November 2022 and come to an end in 2024 with final specifications, including technical ones. The beginning of relevant artificial intelligence technologies utilization within the framework of FMN is planned for 2027 with their mass operational use in 2028-2029.

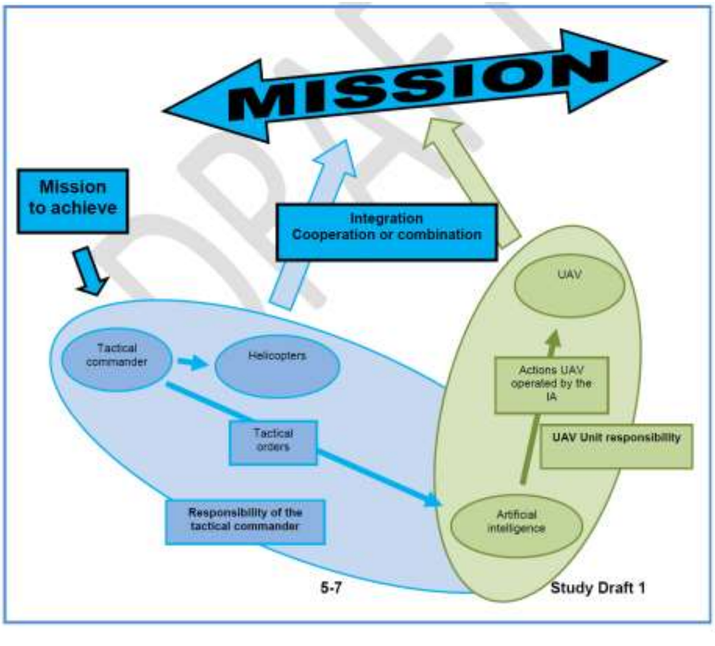

Fig. 2. AI in MUM-T (ATP-49(G)

Expectations for AI in medicine are reflected in *the AJMedP-5 Ed. B, Ver. 1 Allied Joint Doctrine for Medical Communications and Information Systems.* In particular, the paragraph "Automation and Artificial Intelligence" states that the automation of procedures and the use of current and future Artificial Intelligence will better enable command and control, particularly in Mass Casualty situations whether in combat or on humanitarian missions.

The fact that Artificial Intelligence can already significantly influence land activities is stated in *the ATP-3.2.1.1 Conduct of Land Tactical Activities, Annex D Considerations on countering UAS threat*.

However, the most radical approach is introduced in the AJP-3.10.2 Allied Joint Doctrine for Operations Security and Deception, Ed. A Ver. 1, which provides direction and guidance for the planning, execution, and assessment of operations security (OPSEC) and deception. For the first time, AI is on a par with human experts when it comes to decision-making. For the purposes of AJP-3.10.2, a decision-maker is understood to be a person or artificial intelligence responsible for decision-making within an adversary or population's hierarchy. Moreover, AI as a decision-maker may be at any level in any environment and may be capable of creating the required behavioral response.

The next step is the beginning of technical standardization of artificial intelligence tools, in particular, safety requirements for the use of AI in weapon systems, etc. NATO's first technical standard, which considers the use of AI, maybe the AOP 4452.

According to the presentation of the head of *the NATO AC326 SG/B: Ammunition. Systems Design and Assessment* at the meeting of *the CNAD Ammunition Safety Group (AC/326)* in June 2021, in the updated version of these guidelines it is planned to consider AI safety requirements in ammunition systems. The fact of the matter is, that the integration of AI modules into smart ammunition is considered an important trend in the development of arms. Such modules will be able to analyze combat areas, detect and identify the target in a specific area and opt for the effect specific to the identified target. In particular, AI-powered ammunition should distinguish an armored fighting vehicle from infantry, and create a cumulative effect in the first instance (HEAT, High-Explosive Anti-Tank), and shrapnel or nonlethal effect in the second instance (powerful electromagnetic pulse). A loitering munition or unmanned combat aerial vehicle (UCAV) equipped with the specified AI module will increase the ability to suppress or neutralize the enemy to reduce the number of volleys, and minimize vulnerability to enemy counter-battery fire, maximize the effectiveness of ammunition with minimal collateral damage.

Nevertheless, the analysis of the current NATO standardization mechanism reveals that the standardization of the military applications of AI should be carried out as part of the formation process of the System of Systems of Standards, S3 [Slyusar 2017]. S3 should be a hierarchical, multidimensional and multifunctional, consensual integration of the system-forming clusters of regulatory documents. The necessity for such a structure of the system of standards stems from the need to ensure the development, testing, and maintenance of the entire life cycle of the system of systems of weapons and military equipment through the use of AI, and to be a reflection of it. In this instance, the concept of NATO cross-domain standards [Slyusar 2018], which implies these standards to combine the descriptions of AI applications specificity for the benefit of the ground force, the air force, and the navy, for instance, in the form of separate sections or annexes, in a single document merits consideration.

Alternatively, some of the standards may be applied without changes in the armed forces, which must also be safeguarded and approved by the main groups of the Conference of National Armaments Directors (CNAD). This approach aims to avoid duplication in standardization, harmonize the AI standards in the armed forces, and provide an opportunity to coordinate the work of expert communities of the NATO's Conference of National Armaments Directors in related areas of the AI technologies standardization.

Key areas of the AI standardization in the security and defense:

- operational scenarios and common AI use cases;
- minimum requirements for AI-enabled systems;

- AI-enabled systems modes;
- a software architecture, main technical characteristics of AI-based systems, and big data transfer protocols;
- human-AI interfaces.

Considering common AI application scenarios, AI can perform several typical functions to aid an armored vehicle driver:

- improving stability and finding a safe path;
- detecting threats that impede movement;
- providing visual notifications for marking areas that call for closer observation;
- analyzing hyperspectral images of the territory to detect changes on its surface, which is a sign of concealed improvised explosive devices or landmines;
- detecting camouflaged targets in natural scenes, etc.

A comprehensive list should be created for all possible military applications of AI.

In terms of interface, it is important to note that as a means of interactions between humans and Artificial Intelligence, it is reasonable to consider AR technology, since the results of the information processing performed by the Artificial Intelligence are the most convenient to transfer to the operator through the use of visual, auditory and tactile symbols of the Augmented Reality. Correspondingly, it is also reasonable to set tasks for the AI system, especially since it is much easier to standardize AR symbols than to achieve full technical compatibility of systems developed by different manufacturers. In particular, the reverse interaction between a human and AI-based on augmented reality may be carried out by assigning zones to AI that are subject to analysis, using various variants of the graphical interface to input the source data, converting voice messages into commands for moving three-dimensional AR objects, their orientation, etc.

It is possible to establish interactions between several AI systems through the use of AR, in particular cloud services. For instance, a specially designed AI system can synthesize a three-dimensional terrain model based on contour two-dimensional images obtained from multiscopic images taken by scattered AI platforms. To maximize the potential of AR as an AI system interface, it is important to determine the requirements for appropriate functionality. In addition to that, it is necessary to standardize the design of AR symbols for the interoperability of the results of interactions between AI, operators, and other AI systems.

It is important to note that AI should be integrated into the generation of contour symbols of targets in targeting processes by transferring only the shells of targets as AR symbols, which will be superimposed on the real-world environment. It requires the deployment of large-scale work on the formation of appropriate datasets. Correspondingly, three-dimensional AR symbols should be formed, animated, and the effects of occlusion in the process of visualizing the color AR symbols on the display should be reduced through the use of AI. It is important that the optimal luminosity of AR symbols for different background objects is a rather urgent task. Depending on the position and spatial orientation combined into a network of combat platforms, the background may be different and quite often coincides with AR symbols in brightness and color. It leads to a partial or complete loss of AR systems' functionality.

With the aid of AI, this issue can be resolved by adaptively selecting the color and brightness of the AR symbol when applying it to the background image. AI tools should evaluate the background and assign the optimal color to the AR symbol, enable a dynamic change in brightness and color during visualization, or activate pulsation, rotation, and other animation effects. Correspondingly, the use of AI prompts the introduction of an auxiliary, translucent color layer, which would serve as a transitional buffer between the color palette of the background and the data visualization symbol. In this case, the adaptive choice of combining the colors of the auxiliary layer, background, and symbols of the AR should also be powered by AI.

AI algorithms can not only build the contour symbols of targets but also visualize models of their vulnerabilities, which are currently used for modeling and simulation. These visualized vulnerability models segment enemy objects into multiple hitting areas, providing a more efficient choice to maximize the likelihood of neutralization or destruction of the target. The information about such hitting areas can be distributed as AR symbols between networked combat vehicles within the unit for the collective bombardment of the complex target. The level of segmentation of AR contour symbols varies according to the distance to the target. The state of such segmentation should be used as additional information about the current distance to the object of fire impact.

Available AI technologies are capable of generating images from the audio or text description, converting text reports and messages into annotations and AR symbols, or, if necessary, synthesizing audio or transforming them into audio symbols. In this instance, a top national priority is to develop

The Ukrainian language model will enable to develop intelligent assistants, generate realistic military exercise scenarios with enemy consistency, greatly facilitate data collection from unstructured texts, etc. In the future, on this basis, it will be possible to synthesize AR and the synthetic virtual environment through the use of AI, which will significantly improve the quality of training and military exercise.

Moreover, the synergy between AI and autonomy in the military creates several security challenges for the use of AI-based autonomous weapons systems, which is a major concern for NATO experts and all countries around the world. In particular, the real threats to the emergence of AI-enabled lethal autonomous systems on the battlefield and possible risks to the civilian population prompted a comprehensive review of the United Nations Office for Disarmament Affairs (UNODA) policy. Consequently, the activities of the United Nations Institute for Disarmament Research (UNIDIR) were also modified, and a The Group of Governmental Experts (GGE) on Lethal Autonomous Weapons Systems (LAWS) was established as a part of the United Nations Office for Disarmament Affairs [Slyusar 2021].

UNIDIR's series of regional table-top exercises were conducted to discuss different scenarios for the possible use of AI-enabled autonomous weapons systems. The main findings of this series of exercises are important for the formation of strategic approaches and therefore merit careful consideration.

The project brought together experts and diplomats to discuss the technical, military, and legal implications of introducing autonomy. The created scenarios serve as a tool to develop a more comprehensive understanding of the relevant operational and tactical context. Moreover, two methodological approaches were applied regarding the following:

- targeting process, including the different layers of autonomous weapons systems involved;
- the study of the impact on the decision-making process of different levels of human control over autonomous weapons systems depending on the type of targets, geographical and other conditions, taking into account potential threats to civilians.

Special attention was paid not to AI-enabled fully autonomous systems, which feature all steps of the targeting process without any human intervention, but to the grey zone when autonomy is used to perform a limited number of specific tasks that can be carried out technically. Furthermore, a number of issues that require consideration and regulation have been revealed.

Several assumptions were applied:

- technological developments were considered to be evolutionarily based on the uncertainty about the potential capabilities of revolutionary technologies (for example, in the long run, the introduction of quantum computing will drastically affect the development of AI), so it was important to focus on the current state of technology and realistic assessment of the gradual development of technologies;
- experts focused exclusively on AI-enabled physical autonomous weapons systems (AWS) capable of being deployed that achieve the kinetic effect, so the cyberweapons were out of scope; moreover, multidimensional systems used for intelligence, surveillance, and reconnaissance tasks were out of scope;
- AI-enabled decision-support systems that may be used for planning purposes were out of scope;

- the exercise focused on decisions to deploy LAWS, while political decisions to acquire or develop such technology were out of scope.

The analytical basis of the research is the infographic which illustrates the human element in decisions about the use of force published by UNIDIR in 2020 [Human element 2019]. This infographic is only the visible part of the iceberg since the decision-making process that leads to the use of force is complex and starts well before the actual use of force. First of all, this process starts with the political leadership that makes the decision that military intervention is required, then it goes through several phases of planning and evaluation, and results in the deployment of the weapons system.

Despite the attempt to speed up the exercises, a broad approach has been applied throughout the exercise. Beyond the visible part of the iceberg remained important decisions and key parameters that have a critical impact on the use of force. For instance, at the strategic level, the establishment of rules of engagement and the selection of targets, permissible or non-permissible use cases. At the operational level, the use cases are detailed, carefully analyzed, and approved. Decision-makers determine the best type of weapons systems to achieve the desired effect. Moreover, they assess the collateral damage by considering other critical factors. This data is further transmitted to the tactical level, where the mission is executed with the detailed planning of all necessary steps. Throughout all phases, the context is of paramount importance, taking into account parameters, circumstances, and constraints.

The tactical mission execution phase consists of the following steps:

– Find – navigate and maneuver on the battlefield to find the target based on available information, intelligence, and data collected in real-time.
– Fix and Track – once the target is detected, sensors will be used to determine and maintain positive identification of the target and to monitor the environment.
– Target – final checks before the engagement takes place include risk assessment, compliance check for rules of engagement and international law, and international humanitarian law.
– Engage – the attack is executed, and weapons are released. (An attack can also be suspended or canceled).
– Assess – the effectiveness of the attack is evaluated and decisions on future action are taken (including re-attack if necessary).

In addition, the exercise presented four different options for human control or involvement in a weapon’s execution of each of the above steps:

– Full direct control – the system has no autonomy and remains under the full and direct control of the operator for the execution of the given task.
– Human in-the-loop – the system implements the given task with autonomy but requires human intervention to validate and implement specific actions.
– Human on-the-loop – the system implements the given task in autonomy under the supervision of human operator(s) who can intervene if necessary to correct or abort a specific behavior or action.
– Human off-the-loop – the system implements the given task with full autonomy, without supervision or intervention by a human operator(s).

In the course of the exercises, experts were asked to create an ideal control configuration in the form of a table for each of the scenarios (Tab. 1). The given version of Table 1 serves as an example. Moreover, 1 indicates the suitable level of control for each of the steps, and the lack of control is 0.

In the course of the exercises, while filling out the table, technical experts draw a conclusion, based on their understanding of the technical feasibility of applying possible levels of control for various tasks in different contexts. Military experts stressed a point of military expediency or achieving military superiority. However, legal experts focused on legal implications or legal considerations of the permissibility of lethal actions in each particular case.

Table 1. Control configuration

Step	Options for human control			
	Full direct control	Human in-the-loop	Human on-the-loop	Human off-the-loop
Find	0	0	1	1
Fix and Track	0	1	1	1
Target	1	1	1	0
Engage	1	1	1	0
Assess	1	1	1	1

Finally, experts were asked to reflect on and assess the relative relevance and influence of a range of factors in their decisions for each scenario:

– type of target (fixed or mobile, manned or unmanned, pre-planned/on-call/not planned, etc.);
– environment (e.g., urban or open, mountain, desert or forest, etc.);
– domain (e.g., air, land, maritime);
– type of mission and mission parameters (e.g., time of the attack, desired effect);
– assessment of risks to civilians or own forces;
– technical characteristics of the system (e.g., understandability, predictability, reliability); and
– other factors (which experts were asked to specify in their inputs).
– Four scenarios were used in the exercise:

Scenario 1

– Unmanned missile launcher.
– No military or civilian personnel.
– Launcher armed and ready to fire.
– Effect: destroy launcher.

Scenario 2

Armed UAVs.

– Active 24/7.
– Last known position from 12h before the mission is launched.
– Effect: neutralize UAVs.

Scenario 3

– Line of Communication (Road) used by enemy forces for re-supply of weapons and ammunition.
– Road also used by civilians and civilian houses in proximity.
– Effect: destroy LOC.

Scenario 4

– Enemy convoy in transit.
– Position unknown.
– Road also used by civilians.
– Effect: destroy convoy before it reaches city boundaries.

These scenarios were not intended to be representative of all the possible operational and tactical contexts. They were just a tool that was supposed to trigger discussion on something more specific and measurable. Analysis of scenarios shows that in two of them the position of the targets was known (Scenario 1 and Scenario 3), and in the other two, the position was unknown.

In addition, the scenarios proposed different combinations of other critical factors such as:

Target

- Fixed or mobile.
- Inhabited or uninhabited.
- Location known or unknown.
- Collateral damage and risk to civilians.
- Low risk or high risk of civilian casualties.
- Low risk or high risk of damage to civilian or dual-use infrastructure, some of which were included in no-strike lists (e.g., civilian housing).

The views of three categories of experts (technical, military, and legal experts) on the different scenarios provide enough evidence to conclude that when provided with a range of options for control, most experts converged towards options that would allow humans to retain a form of involvement. Experts rarely opt for full direct control or human off-the-loop configuration. Nevertheless, certain regional aspects and regional variations were identified. Experts from different countries had diverse views. Although, according to the aggregated data, it should be highlighted that there are many options and variations within and among expert communities. Therefore, it is very difficult to distinguish one specific trend that can be applied exclusively to one expert community.

Another important characteristic is the distribution of expert opinions on the permissible level of autonomy of AI-enabled weapons across the steps of the targeting cycle displayed as a dependency graph. Notably, for each of the steps, if the curve is plane, more variants of disagreements appear within the same group of experts. If there are peaks, more experts converge toward shared options. The analysis shows that in fact, the results of the exercises allow specifying multiple differences between the approaches of technical, military, and legal experts. However, for Scenario 2 in connection with the steps of Find, the distribution of opinions of different types of experts is very similar and is mainly reduced to the expediency of full autonomy of search systems.

O. Ye. Stryzhak

Introduction

The economic development of any country in the 21st century largely depends on the degree of representation of knowledge systems in the global market, which spread across socio-economic relations. This phenomenon manifests itself in the form of the knowledge economy, which is based on interdisciplinary processes of creation, processing, storage, distribution and use of knowledge. Consequently, the cognitive and communicative scenarios of interaction in all spheres of socio-economic activity of the country also depend on its ability to effectively process existing knowledge and comprehensively use already accumulated information resources. However, information resources that represent knowledge systems by the totality and nature of presentation belong to the big data. All of them are also characterized by multidimensionality, multiple latent connections, etc.

As evidenced by the global experience, tackling the issue of development and effective use of knowledge systems in various fields lies in the application of modern information technology implemented on the basis of AI as one of the key technologies of our time.

The Defense Advanced Research Projects Agency (DARPA) has stated that the 21st century marks the beginning of the transdisciplinary research age. It is possible to ensure the full implementation of this mega direction of scientific and technical development as a component of the knowledge economy on the basis of the use of all AI means. Thus, the formation of logical meta-frames is ensured, through which knowledge reflecting the results of transdisciplinary research may be integrated into various sectoral directions of the information society development and, as a result, will contribute to the development of the knowledge economy.

Such features of the modern stage of the knowledge society formation determine the relevance of the problem of creating intellectual tools and means capable of taking on at least part of the basic cognitive functions of a human. Therefore, the further development of the knowledge economy, especially in our country, largely depends on how effectively the achievements in the field of Information Technology and Artificial Intelligence will be implemented and used.

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