The Ontological Decision Support System Composition and Structure Determination for Commanders of Land Forces Formations and Units in Ukrainian Armed Forces

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Abstract

The subject of the article is the ontological decision support system in automated military control systems. The primary purpose of the work is to determine the composition and structure of the decision support system by commanders of formations and units of the Land Forces of the Ukrainian Armed Forces using an ontological approach. The objective is development:

- A decision support system based on the ontological knowledge base;
- A prototype of software, mathematics and information support for it;
- Offers for an algorithm of functional activities of the Land Forces of the Ukrainian Armed Forces from the battalion and above according to US Armed Forces standards (MDMP) at each stage (steps) of the military decision-making process.

The essential features of the decision support system for commanders of formations and units of the Land Forces of the Armed Forces of Ukraine is a central component of an ontological knowledge base. Described the possible use of ontologies to represent structured constituent decision-making and related components domains that describe this process. The subject area ontology built to describe and explain the decision-making process of MDMP according to the standards of NATO member countries based on knowledge formalised in guiding documents for information exchange, database structure, and software implementation of models, methods and algorithms of individual modules of the decision support system. A prototype software and mathematics and information management are developed, which can be used as a prototype for future automated subsystem management of the Land Forces of the Armed Forces of Ukraine. It is for simulating the formation and ontological decision support system for commanders of buildings and units of the Land Forces of the Armed Forces of Ukraine. According to the US Armed Forces (MDMP) standards, the work of officials' work algorithm of the battalion and above is proposed. Automation of each stage (step) of MDMP gives the chance to reduce the time for decision-making. The algorithm can be used to implement the educational process of training officers and cadets of higher military educational establishments in the centre of simulation and subsequently for use in decision-making in warfare and the army training centres.

Keywords 1

Decision support system, ontology, knowledge base, software-mathematical and information support, decision making, armed force, land force, decision making process, subject area, military decision making process, decision support, military decision making, intelligent system, ontological decision support system, NATO member country, making process according, combat mission, combat operation, NATO standard, information support, multi agent system, Ukrainian armed force, automated control system, intelligent decision support system, information exchange, game method

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1. Introduction

The trend towards creating automated control systems (ACS) for the army and weapons is to integrate intelligence, communications, automation, geographic information systems (GIS) and navigation, combat destruction, and comprehensive support. Functionally, this means combining into a single system of the above subsystems, which should include a subsystem for decision support - the algorithm of management, special software, automated methods of information processing, situation assessment, preparation of management decisions with the choice in the process of comparing the most effective of them [1].

However, the implementation of the decision support system (DSS) as a component of the ACS of the Land Forces (LF) of the Armed Forces (AF) of Ukraine, which has not yet been established, with the gradual increase of its capabilities, is a complex scientific and technical problem. The difficulties that commanders have in making decisions and planning in conditions of the conduct of hostilities are:

- The presence of uncertain factors and insufficient knowledge about values of the characteristics of objects in critical situations, about the goals, algorithm and management resources;
- The need to analyse a large amount of information with the existing shortage of time spend on working off combat documents, bringing tasks (commands, signals, orders) to subordinates, etc. [2].

New methods/algorithms Improvement and development for commanding bodies actions in the Ukrainian Armed Forces LF from the battalion and above should be supported by relevant information and basic knowledge. It is in the field of facility management, taking into account the US Armed Forces standards (MDMP - Military Decision - Making process), which are identical to NATO standards (OPP [3-19]. The knowledge base created based on the ontological approach will provide at each step of the process military decision-making to apply methods and algorithms for finding solutions and models and methods of optimisation and data mining presented in it. [20]. Therefore, rational presentation of knowledge about the tasks and the decision-making process is one of the main problems of building any intelligent system. In addition, an important task is the composition and structure development for ontological DSS commanders of Ukrainian Armed Forces formations and units at Land Forces.

2. Recent research and publications analysis

The scientific and technical literature does not pay enough attention to the development of methodological aspects related to the construction of specific ontologies for DSS of combat operations and their management, taking into account the standards of NATO member countries. Still, several scientific studies emphasise the relevance of this topic.

The article [21] presents the ontology of the field of knowledge "Support for decision-making in poorly structured areas". The author considered this ontology as a conceptual basis of an intellectual, scientific Internet resource, which contains systematised information about this area of knowledge, presents meaningful access to information, processing and solving typical problems. The article shows that the field of learning described by ontology extends the classical theory of decision-making. Still, the theoretical knowledge of the subject area is not enough to work off methodological aspects related to the construction of specific ontologies for DSS of governing bodies.

The integration of various information resources in the management system of military technologies in [22] is based on the procedures of transdisciplinary ontologies. An approach to the construction of an information-analytical system (IAS) is proposed, which provides the solution of cognitive meta-tasks: "structuring", "analysis", "synthesis", "rational choice" in the processing of text documents, databases and knowledge bases. This approach advantage is the IAS focuses on processing large amounts of unstructured and spatially distributed information. In addition, it is built as a modern management system of network information arrays of different size and knowledge systems based on ontological management and analytical component, creating a functional model. However, the solutions implemented by the author do not allow to entirely building an effective decision support system in the field of technology management for military purpose.

The article [23] considers the main provisions of the ontological approach to integrating heterogeneous information resources underlying the information interaction of heterogeneous

automated special-purpose systems. It proposes the ontological approach to combining heterogeneous computerised techniques based on a hybrid method of ontology interaction. As for the disadvantages of this method, it is worth noting the lower performance of calculations on ontologies compared to relational database management systems. This circumstance can lead to negative consequences, which can be expressed in the violation of semantic connections of concepts and classes. Thus, it will allow considering the ontological model of the description of the subject area of the information task inadequate.

3. The article purpose formulation

The purpose of the article is to determine the composition and structure of the decision support system by commanders of compounds and units of the Land Forces of the Ukrainian Armed Forces based on structuring the characteristic features of knowledge. One of the means of implementing such an approach to the presentation of knowledge is the ontological approach. Therefore, it is necessary to develop a prototype of the software, mathematics and information support for the functioning of ontological DSS with proposals for the algorithm of functional activities of governing bodies of the LF Ukrainian Armed Forces from the battalion and above by the standards of the US Armed Forces (MDMP) at each stage (steps) of the process military decision-making.

4. Presenting main material

Ordering and effective use of the necessary information for the preparation and conduct of hostilities by commanders of formations and units of the LF of the AF of Ukraine is possible under conditions of building an ontology of military decision-making, orderly and structured knowledge using specific conceptualisation. Conceptualisation involves the description of many objects and concepts, learning about them and the relationship between them. Today, the task of forming conceptual "transparent" representations for weakly structured subject areas (SA), which are characterised by the lack of strict mathematical models, is relevant. The leading paradigm of structuring information flows are ontologies - knowledge, formally reflected based on conceptualisation or hierarchical conceptual structures formed by the analyst based on the study and structuring of information flows, documents, knowledge protocols and other sources [24-25]. There are three types of ontologies [26]:

1. ***Domain-oriented.*** The SA ontology contains concepts taxonomy, other relations, instances of classes and various types of constraints (axioms). Axioms set semantic rules for the system of relations.
2. ***Task-oriented***. Describe the solution of specific problems, the source of knowledge of the specifications of structures (databases) and data processing methods.
3. ***Top-level***. The general ontology describes the categories - the concept of the upper level. Examples are physical, functional, behavioural concepts and relationships that relate to general scientific concepts and relationships.

Recently, it has accepted to build a single ontology, which contains three types of ontologies. Hierarchically, it looks like this: the general ontology is at the top of the hierarchy, and the ontologies of the subject area and tasks are connected to it. This approach allows you to consider all the functions within the subject area holistically and the knowledge described in the ontology - to use in other programs, databases, etc. Significantly increases the efficiency of intelligent decision support systems. The set of axioms (constraints) that make up the ontology has a first-order logic theory. The dictionary terms are the names of unary and binary predicates, called concepts and relations, respectively. In the simplest case, an ontology describes only a hierarchy of concepts related to inheritance and aggregation. In addition, appropriate axioms are added to express other relationships between concepts and to limit their interpretation. Given the above, the ontology is a simplified basic model (base) for the organisation of knowledge storage, which describes the facts that are always true within a particular community based on the generally accepted meaning of the dictionary used.

Usually, the formal model scheme for ontology O by three of this kind is described [27-33]:

$$O = \langle C, R, F \rangle, \tag{1}$$

where C is a finite set of concepts (concepts, terms) of the subject area, which is set by the ontology O;

R is a finite set of relations between concepts (concepts, terms) of a given subject area;

F is a finite set of interpretation functions (axiomatization, constraints) given on ontology concepts or relations O.

In general, the structure of the ontology is a set of elements of four categories [34]:

1. ***Concepts (classes, concepts, categories).*** They are considered conceptualisations of all representatives of an entity or phenomenon. In addition, they are general categories that can be arranged hierarchically [35-37]. Each class describes a group of individual entities that are combined based on the presence of common properties. They can store all concepts (types, concepts, categories) in the knowledge base in open and extended form can be stored, both formalised or not.
2. ***Relation.*** Represent the type of interaction between the concepts of the subject area, connect the classes, and describe them [38-41]. The most common type of relation used in all ontologies is the categorisation relation, i.e., assigning an object to a specific category.
3. ***Axioms***. They set the conditions for the correlation of categories and relations; they express obvious statements that connect concepts and references [42-47]. Allow communicating the information that cannot be expressed in the ontology by building a hierarchy of concepts and establishing different ideas. Hypotheses can be included in an ontology for various purposes: to verify information's correctness, derive new information, or define complex constraints.
4. ***Instances (individuals).*** Individual representatives of a class of entities or phenomena, i.e. specific elements of a particular category [48-52].

Thus, the components of the ontology are subject to a kind of hierarchy. At the lower level of this hierarchy are specific individuals; higher are the concepts, i.e. categories. At a higher level are the relationships between these concepts [53]. Rules and axioms unite all these elements.

Within the proposed subject area MDMP, a prototype of software-mathematical and information support (SMaIS) was developed, which is the basis for the development of ontological DSS of commanders of formations and units of the LF of the AF of Ukraine (Fig. 1) [54].

When creating SMaIS ontological DSS, it is proposed to use a modular approach, which allows developing basic modules. The model's functionality is divided into modules, the expansion of the functionality of which occurs by adding a new module to the system. According to NATO standards, the module "Military decision-making process" is built using an ontological approach, a functional addition through the addition of new stages in which will adapt the core of the ontological model to a specific subject area. The basis for the formation of such DSS is the formalisation of algorithms (order) of work of commanders, namely the process of military decision-making MDMP, for which the program is formed a hierarchical structure. The upper level of this structure includes the known seven stages (steps) of the MDMP decision-making process (first level of the hierarchy), with the corresponding sub-stages (second level of the order), the tasks performed in these sub-stages (third level of the scale), and the actions of commanders (fourth level hierarchy) (Fig. 1).

Among the stages of MDMP, the top level of the hierarchy of algorithms are as follows:

- Obtaining a combat mission;
- Analysis of the combat mission;
- Development of probable options for combat operations;
- Analysis of possible options for action and conducting a war game;
- Comparison of possible options for action;
- Choice of action option and its approval;
- Issuance of plans and orders.

The specified hierarchical structure that in detail defines algorithms of work of commanders at decision-making on conducting military operations is supplemented with additional functionality, namely:

- Information and information-calculation tasks for:
    a. The organisation of management, interaction and surveillance on the ground;
    b. Collection, processing and accounting of data on their troops, the enemy and physical and geographical conditions;

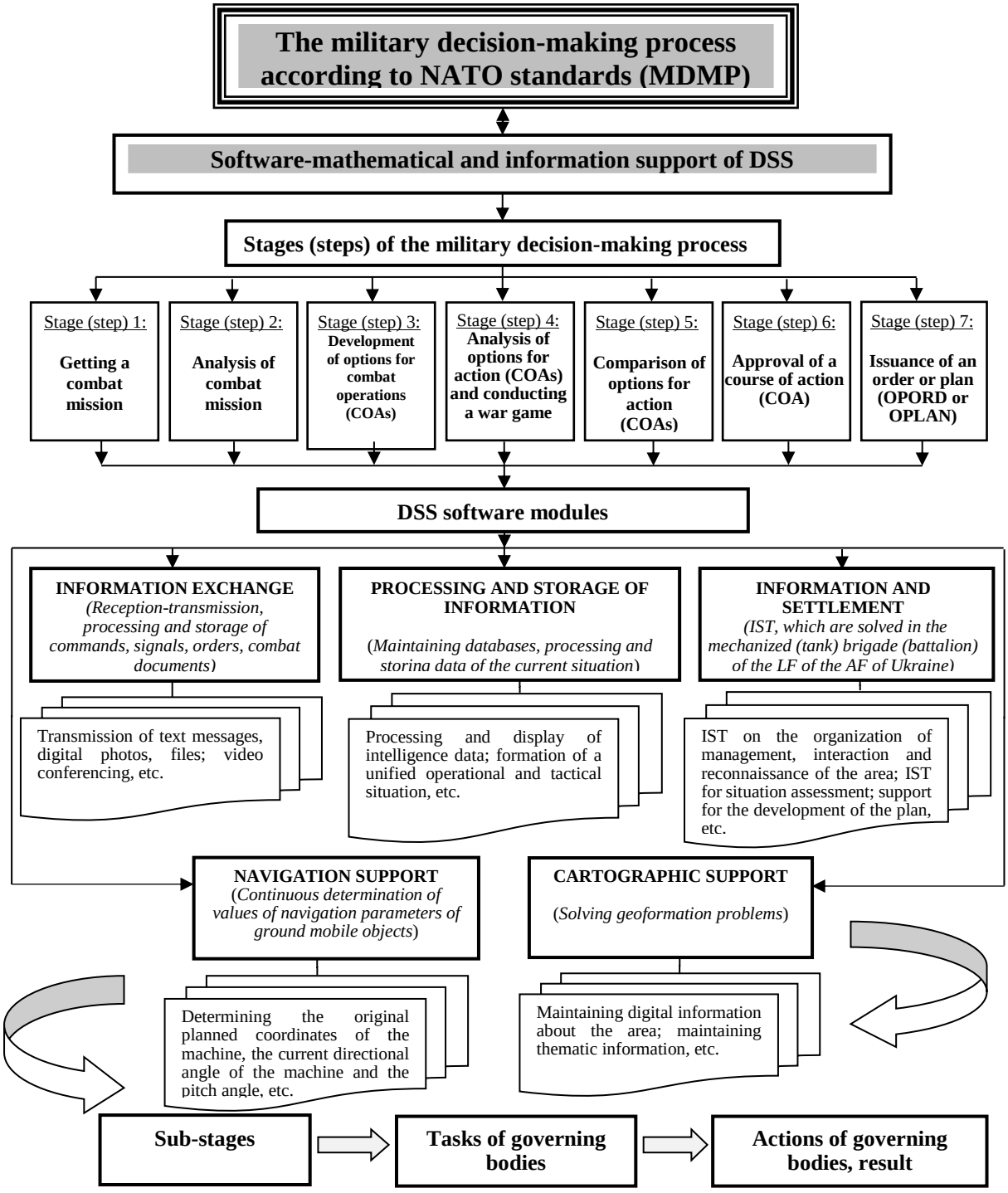

Figure 1: Structure of SMaIS of ontological DSS of commanders of formations and units of the LF of the Armed Forces of Ukraine

c. Assessment of the situation;
d. Marching opportunities;
e. Manoeuvrability;
f. Combat, shock, fire capabilities;
g. Operational support;
h. Technical support and combat service support [55];

- Electronic forms of combat documents, which are worked out at the appropriate stages (sub-stages);

- Reference data used in the relevant stages of work, tips on how to perform specific tasks of commanders (based on the requirements and recommendations of the relevant sections of NATO standards);
- Tactical examples;
- References to guiding documents or their sections (chapters, paragraphs), which regulate the implementation of specific tasks, etc.

Thus, the ontology is built to describe the algorithm of work of commanders in decision-making for combat and to explain the abbreviation of the MDMP decision-making process according to NATO standards based on knowledge formalized in the legal and regulatory framework for information exchange, database structure. This ontology is used to implement models, methods, and operation of individual DSS modules. In turn, such automation of each stage (step) of MDMP gives the chance to reduce the time for decision-making as a whole. An example of automated design of ontologies (tasks and SA), which was built during the work, is shown in Fig. 2 (fragment of SMaIS).

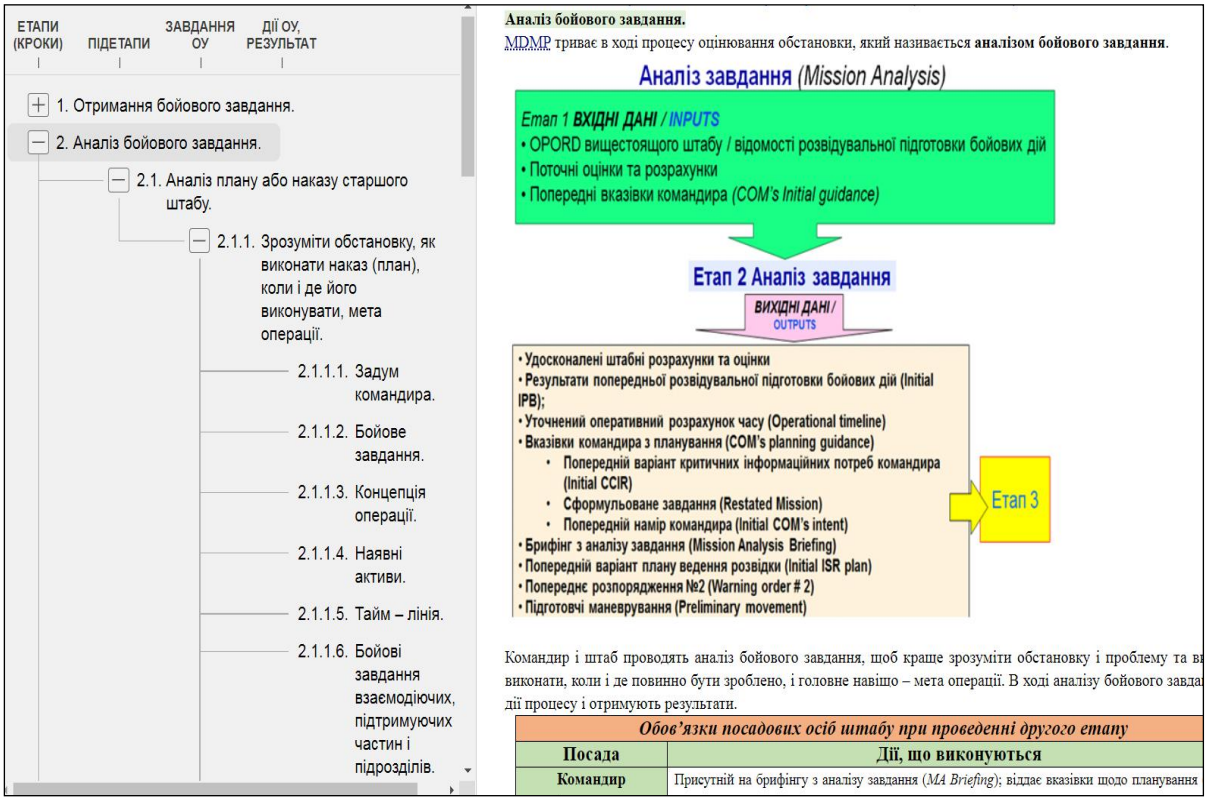

Figure 2: Hierarchy of the decision-making process by the commander (fragment)

The menu on the left displays the ontological model of the process work of commanders in decision-making for combat (hierarchy of the commander's decision-making process). The figure also shows the use of the built ontology to explain and describe the MDMP decision-making process according to the standards of NATO member countries (menu on the right). The given ontology of planning the work of commanders in decision-making for combat operations integrates the activities of the commander, staff, subordinate, attached and interacting staffs in order:

- Understand the situation and combat mission,
- Develop and compare combat options (COAs - Courses of Action),
- COA selection and development of a plan (OPORD - Operation Order);
- An order to perform a combat mission, other documents.

The structure of DSS ontology determines the methods and algorithms that are necessary for commanders of formations and units of the LF of the Armed Forces of Ukraine in the decision-making process to solve the formal system [56-68].

The developed ontology of the process of commanders' decision-making in combat operations can be considered as a component of the knowledge base of complex DSS for the LF of the AF of Ukraine.

It is a template for building a dynamic element in the knowledge base of such DSS, which changes from one specific task in the military to another.

5. Conclusions

1. The main features of building a decision support system for commanders of formations and units of the Land Forces of the Armed Forces of Ukraine, the central component of which is the knowledge base, are considered. The core of such a knowledge base is the ontology of the subject area.
2. The article is described the possible use of ontologies for a structured presentation of decision-making and relevant components from the areas that represent such a process.
3. It is established that the SA of ontology is built to describe and explain the decision-making process of MDMP according to the standards of NATO member countries. It is based on knowledge formalised in guiding documents for information exchange, database structure, and software implementation of models, methods and algorithms of individual DSS modules.
4. For model and form, an ontological decision support system by commanders of formations and units of the Land Forces of the Ukrainian Armed Forces, a prototype of software, mathematics and information support is developed. They can be used as a prototype of the future subsystem of ACS of the LF of the Armed Forces of Ukraine.
5. The work algorithm process for the LF officials in the Ukrainian Armed Forces from the battalion and above according to the US Armed Forces (MDMP) standards is proposed. Automation of each stage (step) of MDMP gives the chance to reduce the time for decision-making. This material can be used during the introduction into the educational process of training officers and cadets of higher military educational institutions in the centre of simulation and later for use in decision-making for combat operations in training canters and troops.

6. References

[1] L. I. Polishchuk, O. K. Klimovich, S. M. Bogutsky, O. D. Pashchetnyk, Protses pryynyattya rishennya na vedennya boyovykh diy v sukhoputnykh viys´kakh zbroynykh syl krayin NATO, volume 4(20) of Weapons and military equipment: scientific journal, 2018, pp. 3-8. doi: https://doi.org/10.34169/2414-0651.2018.4(20).3-8.

[2] S. Khmelevskiy, M. Pavlenko, O. Petrov, Information analysis method about current situations in ACS of special operations, volume 4(1) of Advanced Information Systems, 2020, pp. 103-106. doi: https://doi.org/10.20998/2522-9052.2020.1.15.

[3] O. D. Pashchetnyk, V. L. Zhivchuk, Analiz shlyakhiv zabezpechennya informatsiynoyi sumisnosti avtomatyzovanoyi systemy upravlinnya taktychnoyi lanky sukhoputnykh viys´k z avtomatyzovanoyu systemoyu upravlinnya krayin-chleniv NATO [Analysis of ways to ensure information compatibility of the automated control systems of the tactical unit of the Land Forces with the automated control systems of NATO member countries], in: The latest technologies - for the protection of airspace: materials of the XV scientific conference of the Kharkiv NU of the Air Force named after Ivan Kozhedub, 2019, p. 63.

[4] FM 3-0 Operation, Headquarters Department of the Army Washington, DC, 2017. URL: https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN6687_FM%203-0%20C1%20Inc%20FINAL%20WEB.pdf.

[5] FM 5-0 The operation process, Headquarters Department of the Army Washington, DC, 2010. URL: https://fas.org/irp/doddir/army/fm5-0.pdf.

[6] STANAG 2199, Command and Control of Allied Land Forces, ATP-3.2.2, Edition B, Version 1, 2016.

[7] FM 1-0, Human Resources Support, Headquarters Department of the Army Washington, DC, 2014. URL: https://fas.org/irp/doddir/army/fm1-0.pdf

[8] FM 1-02, Operational terms and graphics, Headquarters Department of the Army Washington, DC, 2010. URL: https://www.globalsecurity.org/military/library/policy/army/fm/1-02/fm1-02.pdf.

[9] ADP 2-0, Intelligence, Headquarters Department of the Army Washington, DC, 2019. URL: https://fas.org/irp/doddir/army/adp2_0.pdf.
[10] ATP 2-01.3, Intelligence Preparation of the Battlefield (Battlespace), Headquarters Department of the Army Washington, DC, 2019. URL: https://fas.org/irp/doddir/army/atp2-01-3.pdf.
[11] FM 2-91.4, Intelligence support to urban operation, Headquarters Department of the Army Washington, DC, 2008, https://fas.org/irp/doddir/army/fm2-91-4.pdf.
[12] FM 3-06, Urban Operations, Headquarters Department of the Army Washington, DC, 2006 URL: https://fas.org/irp/doddir/army/fm3-06.pdf.
[13] FM 3-09, Fire Support and Field Artillery Operations, Headquarters Department of the Army Washington, DC, 2020. URL: https://armypubs.army.mil/epubs/DRpubs/DRa/pdf/web/ARN21932FM3-09FINALWEB.pdf.
[14] ATP 3-21.10, Infantry Rifle Company, Headquarters Department of the Army Washington, DC, 2018. URL: https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN8519_ATP%203-21x10%20Final%20Web.pdf.
[15] FM 3-21.20, The Infantry Battalion, Headquarters Department of the Army Washington, DC, 2006. URL: https://fas.org/irp/doddir/army/fm3-21-20.pdf.
[16] ADP 3-90, Offense and Defense, Headquarters Department of the Army Washington, DC, 2019. URL: https://fas.org/irp/doddir/army/adp3_90.pdf.
[17] FM 4-0, Sustainment, Headquarters Department of the Army Washington, DC, 2009. URL: https://www.globalsecurity.org/military/library/policy/army/fm/4-0/fm4-0_2009.pdf.
[18] ATTP 5-0.1, Commander and Staff Officer Guide, Headquarters Department of the Army Washington, DC, 2011. URL: https://fas.org/irp/doddir/army/attp5-0-1.pdf.
[19] FM 6-0, Commander and Staff Organization and Operations, Headquarters Department of the Army Washington, DC, 2015. URL: https://www.milsci.ucsb.edu/sites/default/files/sitefiles/fm60.pdf.
[20] V. Lytvyn, V. Vysotska, D. Dosyn, Y. Burov, Method for ontology content and structure optimization, provided by a weighted conceptual graph, volume 15 of Webology, 2018, pp. 66-85.
[21] G. B. Zagorulko, Razrabotka ontologii dlya internet-resursa podderzhki prinyatiya resheniy v slaboformalizirovannykh oblastyakh [Development of ontology for intelligent scientific internet resource decision-making support in wearkly formalized domains], volume 6(4/22) of Ontology of Designing, 2016, pp. 485-500. doi: https://doi.org/10.18287/2223-9537-2016-4-485-500.
[22] O. Holovin, Ontolohichna informatsiyno-analitychna pidtrymka protsesiv funksionuvannya systemy upravlinnya tekhnolohiyamy viys´kovoho pryznachennya, volume 2(22) of Weapons and military equipment: scientific journal, 2019, pp. 16-28. doi: https://doi.org/1034169/2414-0651.2019.2(22).16-28.
[23] A. Brunilin, V. Kuvaev, I. Saenko, Ontologicheskiy podkhod k organizatsii informatsionnogo vzaimodeystviya raznorodnykh avtomatizirovannykh sistem spetsial´nogo naznacheniya [An ontological approach to information interaction organization of heterogeneous automated systems for special purposes], volume 2 of T-Comm, 2015, pp. 69-73.
[24] V. Lytvyn, V. Vysotska, D. Dosyn, O. Lozynska, O. Oborska, Methods of Building Intelligent Decision Support Systems Based on Adaptive Ontology, in: Proceedings of the International Conference on Data Stream Mining and Processing, DSMP, 2018, pp. 145-150.
[25] V. Lytvyn, V. Vysotska, P. Pukach, M. Vovk, D. Ugryn, Method of functioning of intelligent agents, designed to solve action planning problems based on ontological approach, volume 3/2(87) of Eastern-European Journal of Enterprise Technologies, 2017, pp. 11-17.
[26] L. V. Massel, Fraktal´nyy podkhod k strukturirovaniyu znaniy i primery yego primeneniya [Fractal approach to knowledge structuring and examples of its application], volume 6(2/20) of Ontology of Designing, 2016, pp. 149-161. doi: https://doi.org/10.18287/2223-9537-2016-6-2-149-161.
[27] M. Davydov, O. Lozynska, Mathematical method of translation into Ukrainian sign language based on ontologies, volume 871 of Advances in Intelligent Systems and Computing, 2018, pp. 89-100.
[28] A. Getman, V. Karasiuk, Y. Hetman, Ontologies as a Set to Describe Legal Information, volume Vol-2604 of CEUR workshop proceedings, 2020, pp. 347-357.
[29] Y. Burov, V. Vysotska, P. Kravets, Ontological approach to plot analysis and modelling, volume Vol-2362 of CEUR Workshop Proceedings, 2019, pp. 22-31.

[30] P. Kravets, Y. Burov, V. Lytvyn, V. Vysotska, Gaming method of ontology clusterization, volume 16(1) of Webology, 2019, pp. 55-76.
[31] N. Kunanets, H. Matsiuk, Use of the Smart City Ontology for Relevant Information Retrieval, volume Vol-2362 of CEUR Workshop Proceedings, 2019, pp. 322-333.
[32] S. Sachenko, S. Rippa, Y. Krupka, Pre-Conditions of Ontological Approaches Application for Knowledge Management in Accounting, in: Proceedings of the International Workshop on Antelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 2009, pp. 605-608.
[33] O.H. Lypak, V. Lytvyn, O. Lozynska, R. Vovnyanka, Y. Bolyubash, A. Rzheuskyi, D. Dosyn, Formation of Efficient Pipeline Operation Procedures Based on Ontological Approach, volume 871 of Advances in Intelligent Systems and Computing, 2019, pp. 571-581.
[34] S. O. Dovgy, V. Yu. Velichko, L. S. Globa, et al., Komp´yuterni ontolohiyi ta yikh vykorystannya u navchal´nomu protsesi. Kyiv, Institute of Gifted Children, 2013.
[35] P. Kravets, V. Lytvyn, V. Vysotska, Y. Burov, Promoting training of multi-agent systems, volume Vol-2608 of CEUR Workshop Proceedings, 2020, pp. 364-378.
[36] O. Bisikalo, O. Kovtun, V. Kovtun, V. Vysotska, Research of Pareto-Optimal Schemes of Control of Availability of the Information System for Critical Use, volume Vol. 2623 of CEUR Workshop Proceedings, 2020, pp. 174-193.
[37] V. Vysotska, A. Berko, V. Lytvyn, P. Kravets, L. Dzyubyk, Y. Bardachov, S. Vyshemyrska, Information Resource Management Technology Based on Fuzzy Logic, volume 1246 of Advances in Intelligent Systems and Computing, 2020, pp. 164-182.
[38] P. Kravets, The game method for orthonormal systems construction, in: Proceedings of the The Experience of Designing and Application of CAD Systems in Microelectronics, 2007, pp. 296-298.
[39] P. Kravets, R. Kyrkalo, Fuzzy logic controller for embedded systems, in: Proceedings of the International Conference on Perspective Technologies and Methods in MEMS Design, MEMSTECH, 2009, pp. 58-59.
[40] P. Kravets, The control agent with fuzzy logic, in: Proceedings of the Perspective Technologies and Methods in MEMS Design, 2010, pp. 40-41.
[41] P P. Kravets, Game methods of construction of adaptive grid areas. In: Proceedings of the The Experience of Designing and Application of CAD Systems in Microelectronics, 2003, pp. 513-516.
[42] P. Kravets, Adaptive method of pursuit game problem solution. In: Proceedings of the Modern Problems of Radio Engineering, Telecommunications and Computer Science Proceedings of International Conference, 2006, pp. 62-65.
[43] P. Kravets, Game methods of the stochastic boundary problem solution, in: Proceedings of the Perspective Technologies and Methods in MEMS Design, 2007, pp. 71-74.
[44] P. Kravets, O. Prodanyuk, Game task of resource allocation. In: Proceedings of the Experience of Designing and Application of CAD Systems in Microelectronics, 2009, pp. 437-438.
[45] P. Kravets, V. Lytvyn, V. Vysotska, Y. Ryshkovets, S. Vyshemyrska, S. Smailova, Dynamic Coordination of Strategies for Multi-agent Systems, volume 1246 of Advances in Intelligent Systems and Computing, 2020, pp. 653-670.
[46] . Kravets, Game method for coalitions formation in multi-agent systems, in: Proceedings of the International Scientific and Technical Conference on Computer Sciences and Information Technologies, 2018, pp.1-4.
[47] R. Kaminskyi, N. Kunanets, A. Rzheuskyi, Mathematical support for statistical research based on informational technologies, volume 2105 of CEUR Workshop Proceedings, 2018, pp. 449-452.
[48] N. Shakhovska, R. Kaminskyy, E. Zasoba, M. Tsiutsiura, Association rules mining in big data, volume 17(1) of International Journal of Computing, 2018, pp. 25-32.
[49] R. Kaminskyi, N. Kunanets, V. Pasichnyk, A. Rzheuskyi, A. Khudyi, Recovery gaps in experimental data, volume 2136 of CEUR Workshop Proceedings, 2018, pp. 108-118.
[50] H. Dmitriv, R. Kaminsky, Two algorithms median filtering to identify the time series trend, volume 512 of Advances in Intelligent Systems and Computing, 2017, pp. 283-292.

[51] N. Shakhovska, L. Nych, R. Kaminskyj, The identification of the operator's systems images using the method of the phase portrait, volume 512 of Advances in Intelligent Systems and Computing, 2017, pp. 241-253.
[52] O.I. Kuntyi, V.T. Yavorskyi, V.R. Ivashkiv, R.M. Kaminskii, I.V. Saldan, Four-factor optimization for electrochemical conversion of WC-Ni pseudo alloy in sulfuric acid solutions, volume 199(7) of Chemical Engineering Communications, 2012, pp. 838-848.
[53] O. Klymovych, V. Hrabchak, O. Lavrut, T. Lavrut, V. Lytvyn, V. Vysotska, The diagnostics methods for modern communication tools in the Armed Forces of Ukraine based on neural network Approach, volume Vol-2631 of CEUR Workshop Proceedings, 2020, pp. 198–208.
[54] O. D. Pashchetnyk, V. L. Zhivchuk, L. I. Polishchuk, Rezul´taty rozrobky systemy pidtrymky pryynyattya rishen komandyriv taktychnoyi lanky Sukhoputnykh viys´k za standartamy NATO [Results of the development of the decision support system of the commanders of the tactical unit of the Land Forces according to NATO standards], in: Proceedings of the International Scientific and Technical Conference on Prospects for the development of armaments and military equipment of the Land Forces, 2019, p. 224.
[55] R. V. Guminskiy, E. V. Ryzhov, O. V. Korolova, Avtomatyzatsiya diyal´nosti komandyra, shtabu pry pryynyatti rishen´ na operatsiyu [Automation or commander and staff's activities in the process of decision making for operation (combat actions)], volume 3 of Military-technical collection, 2010, pp. 75-81. doi: https://doi.org/10.33577/2312-4458.3.2010.
[56] E. R. Lloyd, Spatial Decision Support Systems Use in Peacekeeping and Stability Operations Analysis: Spatial Analysis for US Army Civil Affairs Civil Information Management, 2019.
[57] A. Gricius, Democratic control over the armed forces in Lithuania, in: Lithuanian annual strategic review 2002, 2003, pp. 233-253.
[58] A. Dodonov, A. Nikiforov, V. Putyatin, V. Dodonov, Modeling Complexes of Organizational Management Automated Systems-a Means to Overcome the Management Crisis, 2019.
[59] G. Razma, A modern warfare paradigm: reconsideration of combat power concept, volume 8(3) of Journal of security and sustainability issues, 2019, pp. 435-452.
[60] M. Sengöz, The Framework of Military Leadership. Cambridge Scholars Publishing, 2020.
[61] Y. Pashchuk, Y. Salnyk, Implementation of ISTAR in Ukrainian armed forces, volume 1 of Viys′kovo-tekhnichnyy zbirnyk, 2013, pp. 64-71.
[62] V., Tyurin, V., Mirnenko, A., Salii, P., Open′ko, O. Avramenko, Reviews on the development of the theory of logistic support of the Air Force of the Armed Forces of Ukraine, volume 4(4) of VUZF Review, 2019, pp. 58-67.
[63] T. Vitalii, M. Volodymyr, S. Anatolii, O. Pavlo, A. Oleksandr, Reviews on the development of the theory of logistic support of the Air Force of the Armed Forces of Ukraine, volume 4(4) of VUZF Review, 2019, pp. 58-67.
[64] V. Mirnenko, P. Openko, V., Tyurin, O. Martyniuk, Methodological Basis of Logistic Support of the Air Force of the Armed Forces of Ukraine, volume 5(2) of Safety & Defense, 2019, pp. 47-53.
[65] P. F. Tushev, On the extreme need of scientific foundations for the organizational development of Russian Armed Forces, volume 13(3) of Military Thought, 2004, pp. 198-212.
[66] E. S. Zakiev, S. V. Pankov, K. B. Kalabay, Application of geoinformation systems in the armed forces and other military formations in the Republic of Kazakhstan, volume 68(2) of Vojnotehnički glasnik, 2020, pp. 356-382.
[67] S. Pokhnatiuk, O. Sovhar, Y. Ryzhov, Multiple integrated laser engagement system its employment in the armed forces of Ukraine, volume 1 of Viys′kovo-tekhnichnyy zbirnyk, 2013, pp. 72-76.
[68] I. Sutyagin, J. Bronk, II. Equipment, Organisational and Doctrinal Reforms of Land Forces, volume 89(1) of Whitehall Papers, 2017, pp. 43-88.