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THEORY OF DATA CENTRIC OPERATIONS. REFERENCE MODEL OF ONTOLOGY AND JUSTIFICATION OF THE CONCEPTUAL APPARATUS

The article discusses the issues of developing the theory of data-centric operations (DCO). The peculiarities of changing the ontological model of describing reality in the evolutionary transition from the concept of network-centric warfare to the theory of data-centric operations are analysed. The emphasis is placed on the shift of emphasis from gaining access to information to generating knowledge based on information, i.e. to data centric. The innovations and technologies that serve as the basis for creating the theory of DCO are considered. The article focuses on the definition of the DCO theory, formulation of the main hypothesis and conceptual framework. The use of the IDEAS data model as an upper ontology is determined. The scheme of formation of an ontological description and the scheme of formation of possible actions in the course of DCO are developed. The formation of the DCO ontology is proposed to be carried out using the BORO methodology. A reference model of the data centre operation ontology is proposed.

Keywords: *polyergic systems, data centric, data centric systems, theory of data centric operations, ontology, IDEAS, BORO.*

INTRODUCTION

The introduction of network technologies, the widespread use of gadgets and personal computers are leading to the emergence of the neocortex in people. Modern people are beginning to think differently from the way people did at the end of the 20th century. And just as the mechanistic model of systemic thinking gave way to the biological model and paternalistic culture, so now there is a paradigm shift and a transition to socio-cultural models of building organisations and multi-intelligent systems. A change in the socio-cultural model necessarily leads to a change in the ontological model of describing reality [1, 2]. A term is always just a word. What this word denotes in the real world is a «concept». Concepts have their own concept for different semantic communities of people who understand the essence of the surrounding objects and phenomena in the same way [3]. People's knowledge significantly affects their representation of reality. Fig. 1 shows the ontology-knowledge model. The use of data-centric technologies has required a common understanding of different entities not only by specialists in different fields, but also by artificial intelligence (AI) systems, which has inevitably led to a close look at the issue of ontology. A problem arose: how to describe the world so unambiguously that even a computer could interpret these descriptions [2, 4].

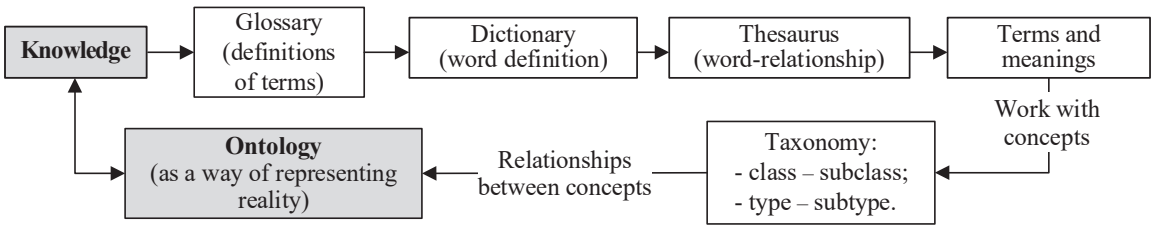
The theory of DCO is the result of the evolutionary development of the concept of network-centric warfare (NCW) [1]. The development of network technologies has brought the world into the «information age», while society is developing at the same time. Competitive advantage is increasingly shifting from gaining access to information to generating knowledge based on information, i.e. to data centric. The innovations and technologies that serve as the basis for creating the theory of data centre operations are shown in Fig. 2 [1].

As a way of representing reality, the ontological model has undergone significant changes in the process of evolution. For example, the NCW ontological model describes the relationship between the subjects of the battlespace, focusing on the processes that transform raw data into information and information into knowledge [1]. Data are individual facts, measurements, or observations that may be sufficient to make a specific decision. Information is obtained when data elements are collected, reconciled, merged and placed in an operational context. Knowledge is the result of the ability to use information to build and apply an explanatory model based on an understanding of a situation or phenomenon.

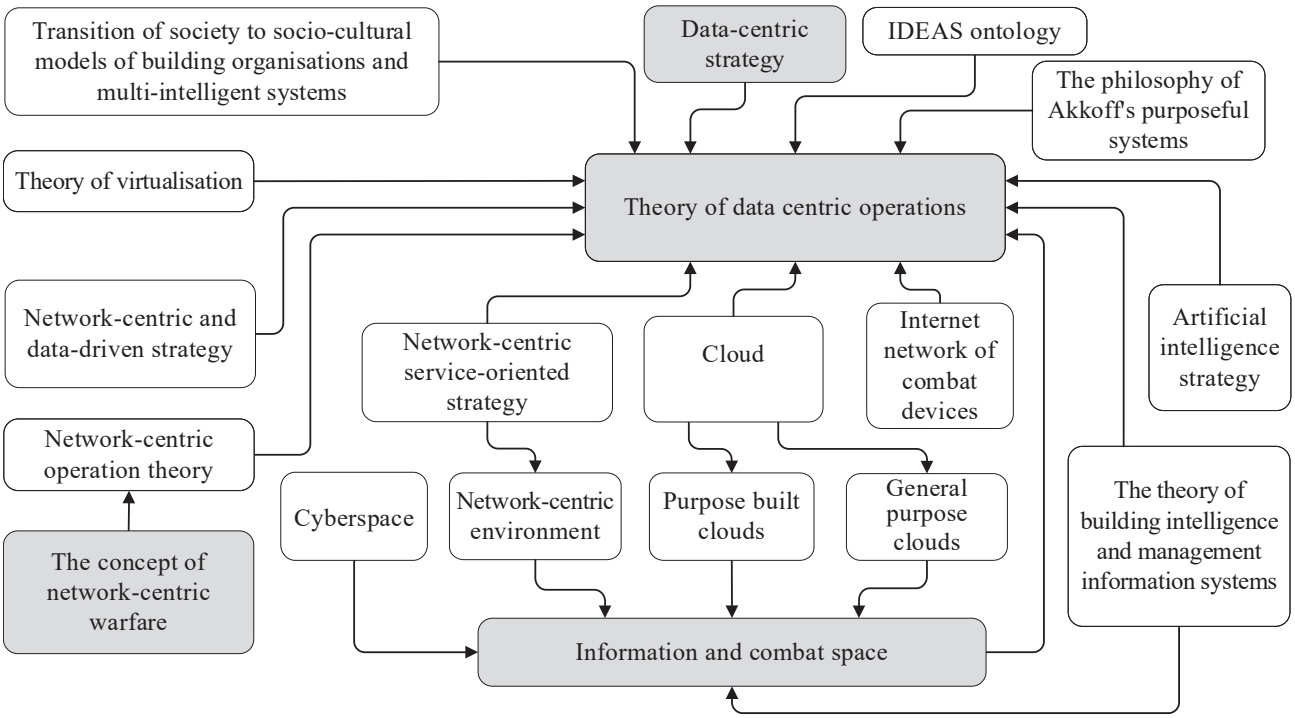
The NCW ontological model is now considered to be outdated, so when creating a theory of data centric operations, one of the key problems was the creation of a new reference model of the ontology and the justification of the conceptual apparatus.

ANALYSIS OF THE LATEST RESEARCH AND PUBLICATIONS

Modern views on the development of the theory of data centre operations are given in [1, 2]. A special class is made up of data-centric systems described in [4, 5]. A special place in the modern vision of the provisions of the systems



F i g . 1. Ontology – knowledge model



F i g . 2. Innovations and technologies that serve as the basis for creating a theory of data centre operations

approach is occupied by the provisions of the systems engineering standards given in [6]. A significant contribution to the development of data centre systems is made by the views on the general theory of systems set forth by Ackoff in [7–9], J. Gharajedaghi [10] and Levenchuk [3]. The most significant issues of using polyergatic control are presented in [11]. The Boyd method and its modification are given in [5, 12]. Materials on the mathematical theory of virtualisation are given in [13]. Particular attention should be paid to the works on data centre ecosystems [14] and the theory of network-centric warfare [15].

The purpose of the article is to develop the theory of data-centric operations based on the development of a method and model for polyergetic management of the life cycle of missile systems.

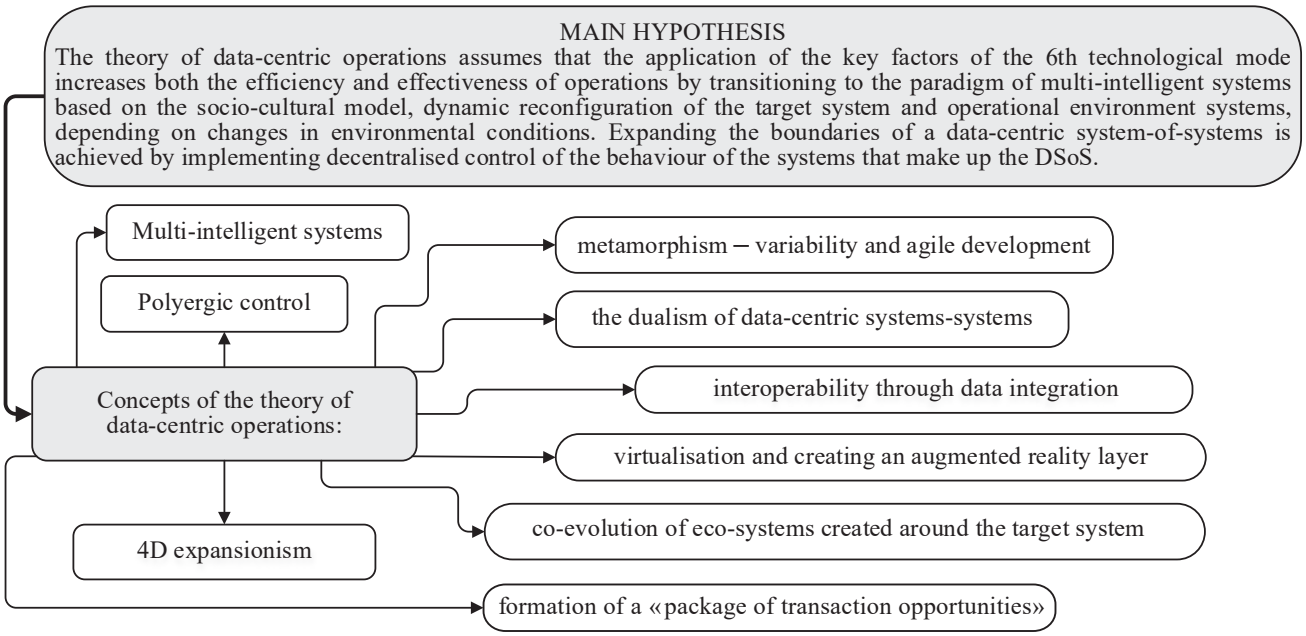
RESEARCH RESULTS

Theory (from the Greek θεωρία – consideration, study) is a doctrine, a system of scientific knowledge that describes and explains a certain set of phenomena and reduces the natural relationships discovered in this area to a single unifying principle. The theory acts as an information model of synthetic knowledge, within which individual concepts, hypotheses and laws lose their former autonomy and become elements of an integral system [8–10]. A theory is also «a hypothesis accepted for the sake of argumentation or research, an unproven assumption, a statement of obvious relationships or the basic principles of certain observed phenomena that have been tested to some extent» [11].

The theory of data-centric operations reflects the global transition from the concept of building mono-intelligent systems to a multi-intelligent socio-cultural model, addresses the creation and operation in 4D space (3D coordinates / time) of data-centric systems-of-systems (DSoS) [11]. This is a new vision of the behaviour of combat systems, the transfer of 4D expansionism to the operational level, metamorphism, cloud computing and service-oriented architecture not only in virtual networks but also on the battlefield.

Data-centric systems of systems are «metamorphic» systems that do not have a permanent «body» (structure), are constantly changing, the heart of which (command posts) is difficult to detect and inaccessible to the enemy, some of which may be in virtual structures – clouds. Such combat systems are difficult to destroy with conventional (aerial) weapons. The main hypothesis and concepts of the theory of data-centric operations are shown in Fig. 3.

The concept of multi-intelligence implies that a data centre system consists of purposeful entities (systems) that can perform the same task, but in different ways in different conditions, or can perform different actions in the same



F i g . 3. Conceptual framework of the data centre operation theory

conditions. Purposeful elements in such a system have the ability and right to make their own choices. In multi-intelligent systems, their elements are connected by information, united into a system by common goals and common ways of achieving them, while working on the basis of common values that are the basis of their own culture (socio-cultural systems) [10].

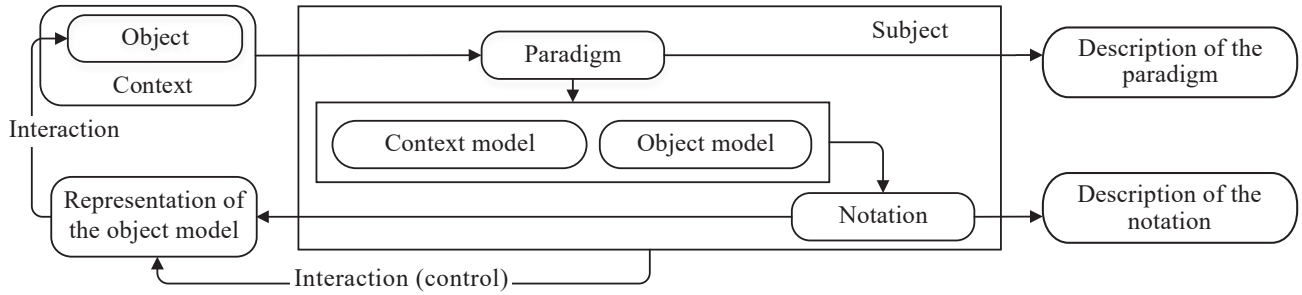
The concept of polyergic management implies that the subject (person) interacts with (manages) the object not as some mechanistic entity, but indirectly, through the information model (see Fig. 4), i.e., the formation of the conceptual environment in which our knowledge of the data-centric system of systems is formed, and the transactional environment that primarily determines the interaction of stakeholders.

In model-based data centre systems, classical ergatic management (human – machine) is replaced by polyergatic management (human – technology). The main idea underlying the polyergic management system is the assumption that the management hierarchy, which was previously largely formed on the basis of hierarchical access to information, is transformed into a hierarchy of competences in data-centric systems [12].

The concept of 4D-extensionism. An individual is an individual, unique object existing in the physical world. There are objects that exist in space-time (4D approach, four-dimensional space according to Einstein). Such an object has a certain extent in space (i.e. size, length, width, height, radius) and in time (i.e. it has a moment when it began to exist and a moment when it ceased to exist). The place of an individual in 4D is called «extent», and the corresponding view of the world is called «extensionalism». A four-dimensional object exists in time as well as in space. At the same time, there is only one object, but other objects are distinguished in it – its temporal parts. This approach is enshrined in the ISO 15926 standard, where all entities/objects are divided into physical (individuals) and functional, or abstract (classes and relationships).

Abstract objects are those that are not individuals – they do not have a length in 4D, they do not have an extent. The models and data required to solve a certain task are abstract objects, but they are stored in the network in the form of programs and databases on some physical media. Moreover, the storage locations of programmes and data, the location of the user and the data processing device may not coincide.

The concept of metamorphism, which means an adaptive spatio-temporal synthesis and reconfiguration of the structure of a data centre system of systems, providing DSoS with the greatest efficiency of the operation in specific conditions. At the same time, the time scale of the operation is not limited. It can be an anti-aircraft warfare that lasts a few minutes or a certain stage of the DSoS life cycle that lasts



F i g . 4. The concept of polyergic control

for decades. In the case of anti-aircraft warfare, the metamorphosis is manifested in the fact that, with comparable awareness of air and space forces and air defence missile systems, the former have significantly greater manoeuvrability. The latter, having much less mobility, parry this ability of the enemy by manoeuvring with fire, for which, in accordance with the firing cycle (Boyd cycle [13, 14]), they constantly rebuild their spatial and temporal structure. The methodology of adaptive spatio-temporal synthesis and reconfiguration of the DSoS structure is directly related to the concept of 4D expansionism.

The target system is assembled over time. At the same time, the relations between objects that arise in the process of carrying out certain activities act as another abstract object. This approach allows us to consider a data centre system of systems as a single object with different temporal parts. A set of equipment systems connected by a network occupies a certain 3D space. DSoS reconfiguration is tied to the tasks being solved at the current time. In other words, we can say that the current DSoS structure is defined as the intersection of 4D space with the time plane. Events are three-dimensional «slices» of the DSoS at a certain point in time, like three-dimensional photographs. Before the event, there was one state of the DSoS, and after the event, there was another state. The current structure (a time slice of 4D space) is determined by the capabilities required for the current time interval.

The concept of dualism of data centric systems-systems is determined by the dual nature of DSoS, which can be considered both as a fit-to-purpose system and as network resources. A new quality of DSoS is configuration management through the optimal use and distribution of network resources over time, with the structure changing not only at the expense of its own resources, but also through the dynamic linking of network resources within the framework of the task performed by the system at a given time. Individual systems/resources can be used simultaneously in different DSOS.

The concept of interoperability through data integration is the ability to share information and resources between components of a distributed system. There are three aspects of integration:

- infrastructural integration, which is typical for systems that are closely connected at the physical level. It may require the use of the same hardware, operating system, etc;
- information integration is necessary for the implementation of data exchange, usually based on the use of a single ontological model;
- process integration implies that the underlying systems from which the system-systems are created are not interdependent (free systems) and often rely on flexible information presentation (e.g., internet browsers) and provide support for collaboration, workflow.

The concept of virtualisation and the creation of an augmented reality layer. According to the mathematical theory of virtualisation [13], a distinction should be made between replication models – virtual models that simulate physical reality – and transposition virtual models that can not only simulate physical reality but also effectively replace physical reality with virtual reality. The use of virtual reality technologies makes it possible to use virtual systems (abstract objects) to control physical devices. For example, using virtual reality helmets and glasses, an augmented reality layer is created that displays a virtual control panel for an unmanned aerial vehicle.

The concept of co-evolution of eco-systems created around the target system has been transferred from biological systems to data centre systems. The concept envisages the joint evolution of the target system, life cycle support systems and operational environment systems, and the consideration of these systems as a single eco-system created around the target system [14].

The concept of forming an operation's capability package was inherited from the theory of network-centric operation [15]. The operational capability package consists of the operational concept and related concepts of command, doctrine, organisational arrangements, personnel, information flows, systems, material, education, training and logistics (Fig. 5). That is, everything that is needed to make this concept work in an operational environment. Like network-centric systems, data-centric systems always start as ideas about how something can be done or as a concept. The main concept processes are shown in Fig. 5.

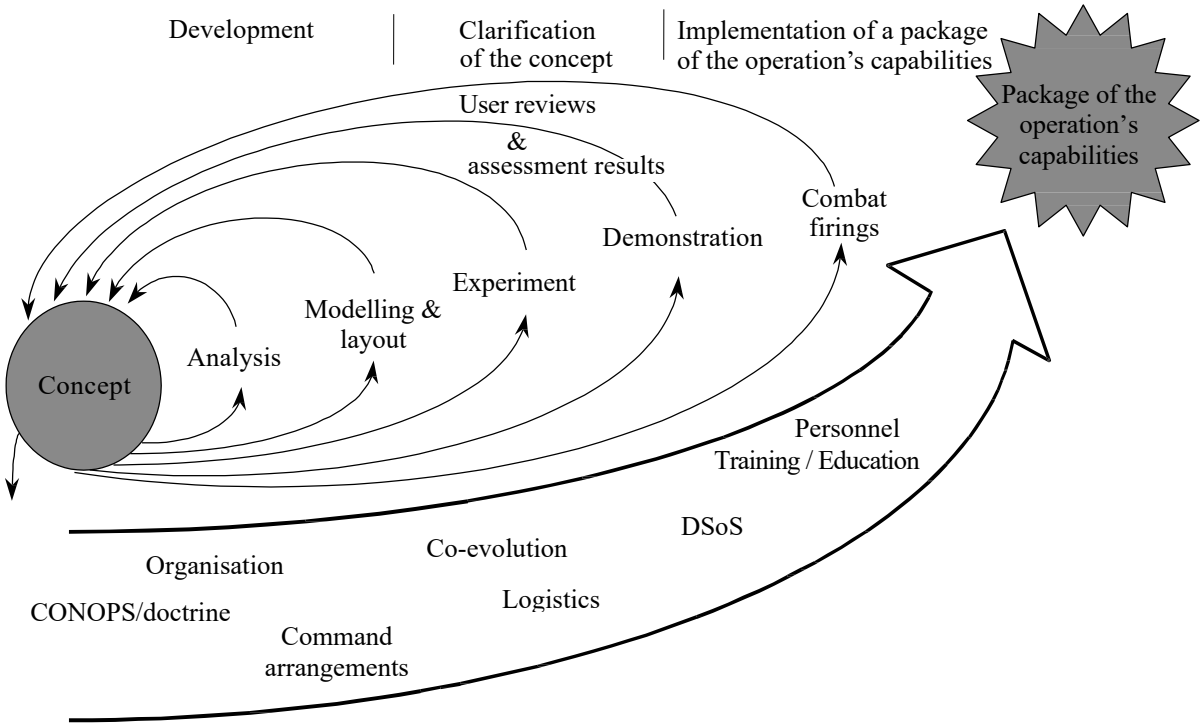
Data centricity arose from the need for many people to work together on complex projects. But this inevitably raises the problem of how to describe the world so unambiguously that different people and even computers can interpret these descriptions unambiguously. And this brings us to «ontology». The term «ontology» is used in various disciplines, from philosophy to knowledge engineering, where an ontology consists of concepts, conceptual properties, relationships between concepts, and constraints. Ontologies are defined independently of factual data and reflect a common understanding of the semantics of a discourse domain.

When creating data-centric system-of-systems, the main problem is not to develop the architecture of the systems that make up the SoS, the main problems are to develop an integrated organisational architecture of the DSoS.

The solution to the integration problems was found to be possible within the framework of a logical (semantic) approach to data modelling based on an ontological description of the world. In general, ontological data modelling proved to be much more effective than the taxonomic «classification» approach. But the real breakthrough came when modern data modelling solutions formed the basis for creating a neutral data model of the IDEAS ontology in relation to individual engineering systems.

The International Defence Enterprise Architecture Specification (IDEAS) group has proposed a formal ontology to facilitate interoperability of enterprise architecture models. The IDEAS ontology is the basis for the DM2 data metamodel, an ontological representation for NATO engineering architecture descriptions.

The need to integrate domestic enterprises into the processes of creation and production of weapons in NATO countries makes it expedient to use the IDEAS ontology as a basic ontology when creating an ontology of the theory of data-centric operation. Different ontologies are required



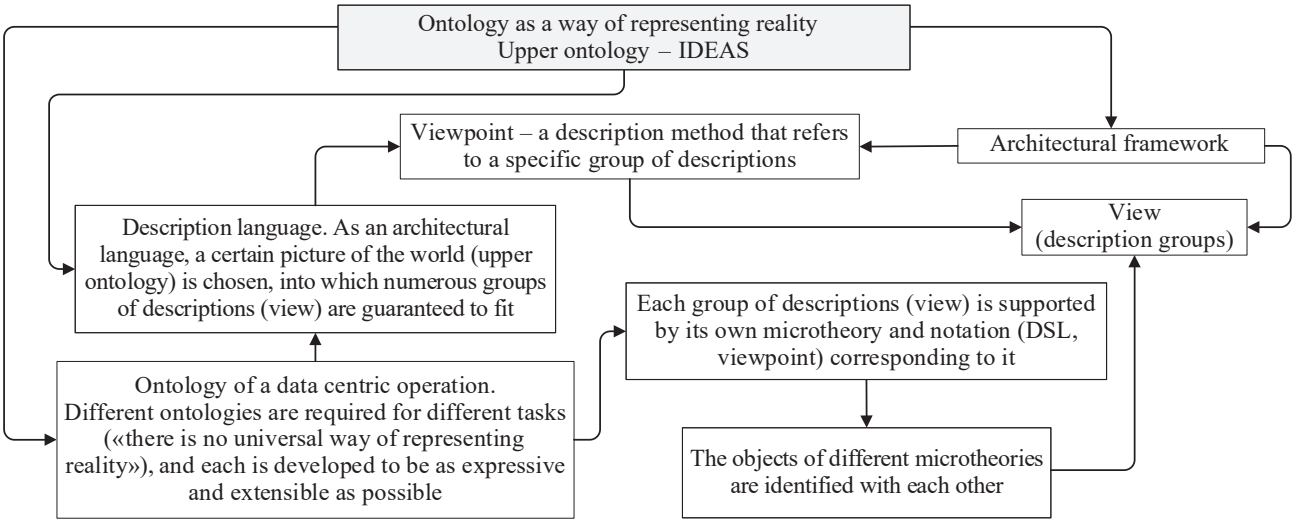
F i g . 5. Basic processes of the concept of forming a package of the operation's capabilities

for different tasks (there is no universal way of representing reality), and each of them was developed with the aim of maximum expressiveness and extensibility. The formation of an ontology is an extremely complex and resource-intensive procedure that cannot be carried out within the development cycle of a single system, even a large one. For this purpose, special scientific research is organised, the results of which are recorded in international standards containing ready-made formal ontology descriptions. The general scheme of forming an ontological description is shown in Fig. 6.

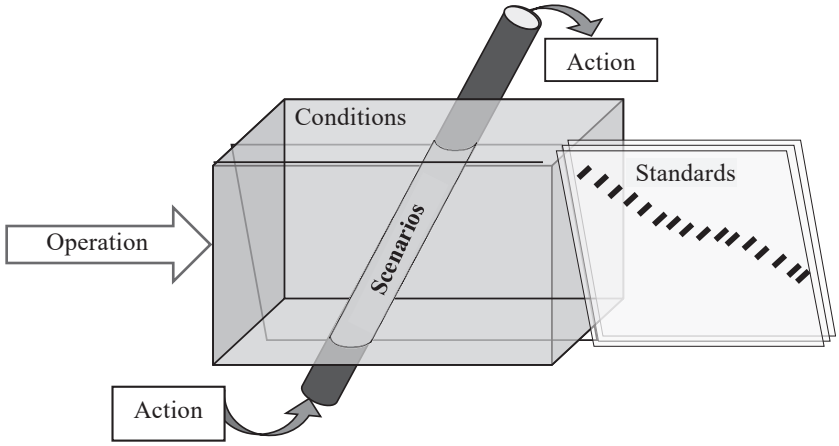
The ontological model of a data centre operation is built on the basis of the implementation of the connection of such meta-concepts as «needs» (needs, motivation, purpose, requirements), «opportunity» (as the ability to achieve the desired result, effect) and «service» (as a mechanism for accessing opportunities). The general scheme of formation of possible actions during a data centric operation is shown in Fig. 7.

The formation of the data centre operation ontology is carried out by adding objects to the base ontology using the BORO (Business Object Reference Ontology) methodology [16]. The scheme of using Boro processes to form the DCO ontology is shown in Fig. 8.

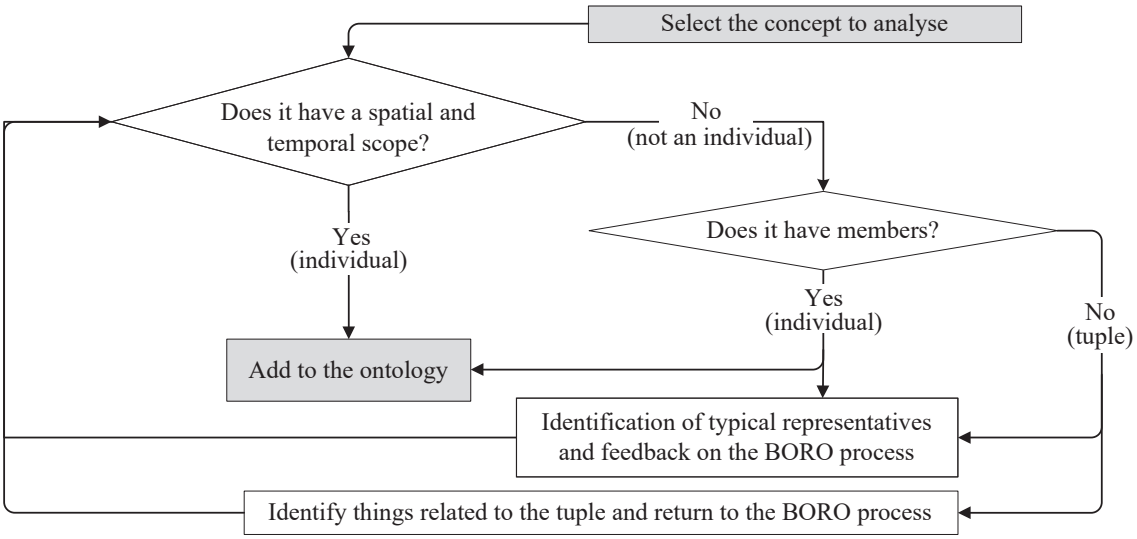
The reference model of the data centric operation ontology is shown in Fig. 9. A reference model is a structured set of concepts and their relationships for a certain subject area, which provides a conceptual structuring of this area and has a fairly generalised description. In essence, a reference model is a form of meta-knowledge that defines the fundamental decomposition or architectural specification of a particular subject area. The reference model of the DCO



F i g . 6. General scheme of forming an ontological description



F i g . 7. General scheme of possible actions during a data centric operation



F i g . 8. Scheme of processes of Boro-analysis of objects during ontology formation

ontology is terminologically the same as the IDEAS ontology and ISO/IEC/IEEE 42010:2022 «Software, systems and enterprise – Architecture description» [6].

A new ontology, as well as a theory, is developed primarily when a paradigm shift is needed. It turned out that a paradigm shift is primarily accompanied by a switch in our perceptions of an object, which is accompanied by an evolution from logical semantics to object semantics. In this case, different perceptions correspond to different description semantics, due to which the semantics of objects changes. The existing paradigm imposes one view of the world. The transition to a new paradigm leads to a radically different way of seeing the same world. It should be borne in mind that we can only see the world through one paradigm at a time. But a paradigm shift is usually one of the ways to move from the old to the new. The introduction of networks, the emergence of network-intensive systems caused a paradigm shift, required a new understanding of the concept of system, the formation of a new system-system view and the philosophical justification of these views.

CONCLUSIONS

1. Competitive advantage is increasingly shifting from gaining access to information to generating knowledge based on information, i.e. to data centricity.

2. During the evolutionary development from the concept of network-centric warfare to the theory of data-centric operation, one of the key problems was the creation of a new reference model of ontology.

3. The theory of data-centric operations reflects the global transition from the concept of building mono-intelligent systems to a multi-intelligent socio-cultural model.

4. In data-centric systems based on the model, classical ergatic control (human − machine) is replaced by polyergatic control (human − technology). The main idea underlying the polyergic management system is the assumption that the hierarchy of management, which was previously largely formed on the basis of hierarchical access to information, in data-centric systems is transformed into a hierarchy of competences.

5. The general scheme of forming an ontological description involves the use of an upper ontology, which is advisable to use the IDEAS data model.

6. It is advisable to add objects to the basic ontology using the BORO methodology.

7. The Reference Model of the data centre operation ontology coincides in terminology with the IDEAS ontology and ISO/IEC/IEEE 42010:2022 «Software, systems and enterprise — Architecture description» [6].

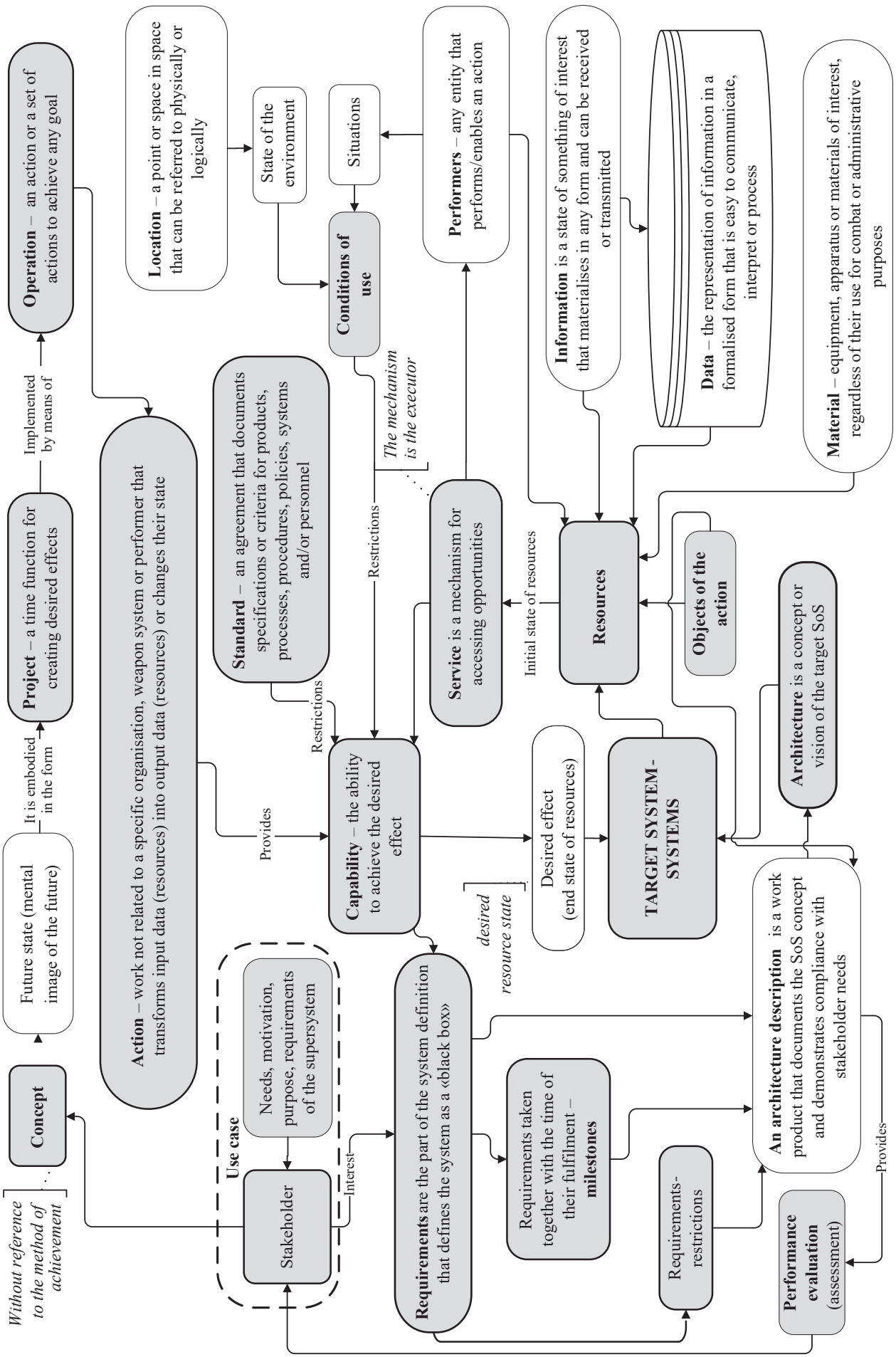


Fig. 9. The reference model of the data centric operation ontology

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ТЕОРІЯ ДАТА-ЦЕНТРИЧНИХ ОПЕРАЦІЙ. ЕТАЛОННА МОДЕЛЬ ОНТОЛОГІЇ І ОБҐРУНТУВАННЯ ПОНЯТІЙНОГО АПАРАТУ

В статі розглядаються питання розбудови теорії дата-центричних операцій (DCO). Проаналізовано особливості зміни онтологічної моделі опису дійсності при еволюційному переході від концепції мережево-центричної війни до теорії дата-центричних операцій. Наголошується, що конкурентна перевага все більше зміщується від отримання доступу до інформації в сторону генерування знань на основі інформації тобто до дата-центрики. Показано, що при еволюційному розвитку від концепції мережево-центричної війни до теорії дата-центричної операції, однією з ключових проблем стало створення нової еталонної моделі онтології. Також наголошується, що теорія дата-центричних операцій відображає глобальний перехід від концепції побудови монорозумних систем до мультирозумної соціокультурної моделі. Показано, що в дата-центричних системах, основаних на моделі, класичне ергатичне керування (людина – машина) змінюється на поліергатичне керування (людина – технологія). В якості основної ідеї, що покладено в основу поліергатичної системи керування, розглядається припущення, що ієрархія керування, яка раніше у значній мірі формувалася на основі ієрархічного доступу до інформації, в дата-центричних системах трансформується в ієрархію компетенцій. Розглянуті інновації та технології, що служать основою для створення теорії дата-центричних операцій. Основна увага в статті приділяється визначенню теорії DCO, формулюванню основної гіпотези і концептуальних основ. Визначено використання моделі даних

IDEAS як upper ontology. Розроблено схему формування онтологічного опису і схему формування можливих дій при проведенні DCO. Формування онтології DCO пропонується здійснювати з використанням методології BORO. Запропоновано еталонну модель онтології дата-центричної операції.

Ключові слова: *поліергатичні системи, дата-центрика, дата-центричні системи, теорія дата-центричних операцій, онтологія, IDEAS, BORO.*

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