ISSN 0005-1055, Automatic Documentation and Mathematical Linguistics, 2020, Vol. 54, No. 2, pp. 105–112. © Allerton Press, Inc., 2020.
Russian Text © The Author(s), 2020, published in Nauchno-Tekhnicheskaya Informatsiya, Seriya 2: Informatsionnye Protsessy i Sistemy, 2020, No. 4, pp. 10–17.

An Analysis of the Role and Structure of Information (Conceptual) Systems

S. I. Matorin[a], * and V. V. Mikhelev[b], **

[a]*ZAO SoftKonnekt, Belgorod, 308023 Russia*
[b]*Belgorod State National Research University, Belgorod, 308015 Russia*
**e-mail: matorin@softconnect.ru*
***e-mail: keeper121@ya.ru*

Received February 24, 2020

Abstract—The nature of information (conceptual) systems is studied using a system–object approach. The conclusion is made that the hierarchies of conceptual and material systems are an object-oriented system, whose conceptual systems are external systems (class systems) that determine the properties of specific objects, and objects–material or internal systems (systems–phenomena) that perform real interactions. The results of a formal description of the hierarchy of conceptual systems are considered, taking their interconnection into account by formalization using descriptive logic of some provisions of the system–object approach. The syntax and semantics of the ALCOIQ descriptive logic and its extension to the SHOIQ logic are described. The SHOIQ logic is introduced; it formally describes the concepts of the volume and content of a conceptual system that expand system theory based on a system–object approach.

Keywords: information systems, system–object approach, conceptual systems, class systems, material systems, phenomenon systems, functional query, external determinant, descriptive logic

DOI: 10.3103/S0005105520020077

INTRODUCTION

The concept of *Information Systems* occurs in various spheres of human activities. Such systems are designed to store, search for, and process information. They include relevant organizational resources (human, technical, financial, etc.) and provide the dissemination of information (ISO/IEC 2382: 2015 “Information technologies. Vocabulary). In our study, information systems are understood as material systems (that is, real and objectively existing systems) that organize, store and transform information, in which the main subject and product of labor is information. Thus, information is a resource with which an information system works.

There are many definitions for the concept of *information*. Starting from the definition of N. Wiener: “Information is not matter and not energy, information is information.” and ending with definitions in international and Russian standards: knowledge about objects, facts, ideas, etc. that people can exchange within a specific context (ISO/IEC 10746-2: 2009: Information technology. Open distributed processing. Reference model: Foundations. Part 2); knowledge regarding facts, events, things, ideas and concepts that in a certain context have a specific meaning (Information technologies. Vocabulary); information perceived by a person and (or) special devices as a reflection of the facts of the material or spiritual world in the process of communication (GOST 7.0-99 2000: Information and library activities, bibliography. Terms and Definitions).

Moreover, information itself can also be a system (naturally informational and not material), for example, a set of data under certain conditions, classification, knowledge model, including ontology. *Conceptual schemes* as semantic networks of concepts and concepts interconnected by certain rules, or *conceptual systems*, which consist of non-physical objects, i.e., ideas or concepts are an important example for our study of such information systems [1].

The importance of studying such systems and developing principles that are applicable to both material and conceptual systems for constructing a general theory of systems, as well as for overcoming the gap between the natural sciences and the humanities, was substantiated in [2, 3]. In addition, researchers identify information (i.e., conceptual) systems with theoretical objects introduced by scientific theories, as well as with mental entities or ideal constructs. In [4], it was noted that mental entities (ideal constructs) have referents in the world, and these referents are the fundamental unobservable properties of objects in the real world. At the same time, it was stated in [5] that fundamentally not observable referents are not just constructions of our consciousness, but objectively existing properties of material objects of the World; moreover, they make up its backbone, as it were, and "it's easier to move a mountain than one of them."

However, in [4] it was emphasized that the issues of modern science have not yet been resolved: What is the nature of the referent of an ideal construct (i.e., a conceptual system)? and What, in fact, is it? In this paper, we propose a variant of answers to these questions obtained using information and system–object approaches.

FEATURES OF THE SYSTEM–OBJECT APPROACH

The most significant feature of the system–object approach is the consideration of two fundamentally different types of systems: *internal systems* (material systems according to Ackoff) and *external systems* (conceptual systems according to Ackoff) [6]. We have adopted the terms system-phenomena and system-classes in accordance with [7]. Using the system–object approach, it was shown (for example, in [8, 9]) that both methods of systems formation (internal and external) correspond to the basic dialectical principles of the system approach: *integrity*, *systematic*, *hierarchical,* and *development* principles presented in [10]. In addition, in [11] it was demonstrated that the main well-known system-wide regularities are satisfied both for phenomenon systems and for class systems. Thus, the system–object approach takes the ideas into account of the founders of system studies that "... the role of the general theory of systems in modern science largely consists in expanding the necessary ontological concepts, which allows us to overcome the ontological prejudice of the ontological primitiveness of the world ..." [12, p. 184].

In connection with this feature, a system is considered as *a functional object or class whose function or role is determined by the function or role of an object or class of a higher tier* (that is, supersystems) in the framework of this approach, which clarifies the definition of a system in [13].

As mentioned in this definition, the conditioning of a system function by a function of a supersystem is considered as a functional request of a supersystem to a system with a certain function, which is an *external determinant* system. This is the cause of the system, the purpose of its existence and the main determinant of its structural, functional, and substantial properties. Thus, the external determinant of the system is considered as a *universal backbone factor.*

The functioning of a system is its *internal determinant*, since it directly determines the internal property of this system (a property of subsystems). The correspondence between the internal determinant of a system and its external determinant is established between the system and the *relation of maintaining the functional ability of the whole* supersystem [13].

TRENDS IN THE INTERPRETATION OF THE STATUS OF INFORMATION (CONCEPTUAL) SYSTEMS

The question of the role and status of information (conceptual, non-material) systems in reality is the above-mentioned question about the nature of the referent of an ideal construct, i.e., conceptual system, and what it is. This question has been posed and discussed for many years; one of its forms is the question of the status of consciousness, which in essence is a complex conceptual system.

Representatives of various fields of philosophy, such as metaphysics, in exploring the original nature of reality, dealt with this issue, starting from ancient history. Teleology explains the development of the world using final targeted reasons: an ontology that studies the most general categories and laws of being.

In recent history, philosophy has come to the conclusion that consciousness is associated with types of reality, which are no less fundamental than physical fields. As an example, in [14] it was argued that the reduction of a wave packet requires an appeal to a new reality, irreducible to particles and fields, somehow connected with consciousness. In [15, 16], consciousness was considered not as a derivative of biological matter, but as a full-fledged structural element of physical reality. Thus, philosophy, in fact, concludes that conceptual systems exist as objectively as material ones.

In addition, physicists have expressed similar ideas, for example, in the form of a strong anthropic principle, especially in the formulation of J. Wheeler: "Observers are necessary to achieve the universe of being." Obviously, this refers to conscious observers, i.e., consciousness again, a conceptual system that must exist objectively. Although the anthropic principle in itself has been criticized by many scientists and relates not so much to physics as to metaphysics, its idea in its essence closely echoes the above-mentioned idea of philosophers about the objectivity of conceptual systems.

In systemic studies in accordance with the information approach in A.A. Denisov's concept of information it is considered as a paired category with respect to matter, as a structure of matter that does not depend on its specific properties, which also correlates with the idea of the objectivity of the existence of information, i.e., conceptual systems.

This idea is also in good agreement with V.I. Vernadsky that at the planetary level there is currently a process of the formation and development of the noosphere of our planet as a result of the logical processing of its biosphere with scientific thought, considered as a new geological factor that is unprecedented in terms of its power and generality.

Finally, religious sources, with their categorical nature, claim that "in the beginning there was the *Word*" (in the original, *Logo*) [From the gospel of John]. At the same time, the Logos is understood as the higher power that governs the world, and the law of world development, as well as the most deep, stable and essential structure of life, the most essential laws of the world. In Chinese philosophy, the concept of Tao is used instead of the concept of Logos, which denotes the origin of uniqueness and duality and, at the same time, the beginning of the world and creation. An analysis of these concepts allows us to state that these sources suggest their correspondence to some objectively existing conceptual systems.

Thus, there is a pronounced tendency to consider conceptual systems as objectively existing in reality on par with material systems. Basically, however, we are talking about conceptual systems in the form of a general or individual consciousness. This, in fact, raises many doubts and objections regarding the objectivity of conceptual systems in the form of a certain consciousness. However, from the point of view of the system–object approach, it is possible to consider objectively existing conceptual systems by themselves without using the term consciousness.

THE FEATURES OF CONCEPTUAL SYSTEMS

In addition to the above-mentioned correspondence of conceptual systems that are class systems to systems–phenomena from the point of view of a systematic approach, as well as the justification, for example, in [8, 9, 11] of the possibility of applying all the provisions of a system–object approach to both of them, it is nevertheless necessary to consider some features of conceptual systems as classes, which are systems (i.e., class systems).

The consistency of such class systems is due, in particular, to the fact that each class supports the functional ability of a class of a higher tier. For clarity, we give an example: the classes passenger car and truck functionally support the class of road transport as types of road transport, i.e., they are systems (subsystems of the road transport system). The classes, for example, green car and blue car are formally also types of the same class, but functionally motor vehicles do not support a class and, therefore, are not systems (subsystems). Similarly for systems–phenomena: the engine as part of the car functionally supports the car and is its subsystem. At the same time, a piece cut from a car is also a part of the car, but does not functionally support it and, therefore, is not its subsystem.

From the point of view of this study, it is important to emphasize that class systems form a hierarchical structure that has some feature that distinguishes it from the hierarchy of systems–phenomena. This feature consists in the fact that the hierarchy of systems–phenomena formed by the part–whole relationship does not have an upper boundary in accordance with the well-known principle of infinity, and the hierarchy of systems–classes formed by the genus–species relationship has an upper boundary in accordance with the known logical law the inverse relationship between the volume and content of concepts (classes) [7, 17]. This law requires a reduction in content, i.e., reducing the amount of information that corresponds to the number of features describing the content of the class while increasing the volume of the class, i.e., the number of subclasses that make up the class. In this case, the content, of course, can only decrease to zero. This determines the upper boundary of the hierarchy of class systems (conceptual systems).

These features are essential for our study for the reason that the basic properties of any system (including a class system) are determined by a supersystem (in this case, a supersystem–class), since the reason for the existence of the system in accordance with the system–object approach is a functional query supersystems. The reason for the presence of certain properties of the system is determined by the hierarchy. Moreover, analysis of the hierarchy of systems–phenomena, due to its infinite nature does not allow us to determine the final reason for the presence of system properties, which contradicts the principle of determinism. An analysis of the hierarchy of class systems allows one to determine the ultimate reason for the presence of system properties due to the finiteness of this hierarchy. Thus, the hierarchy of system classes, which does not contradict the provision of the infinity of the world (in terms of the volume of classes), does not contradict the principle of determinism, since it unambiguously indicates the original reason for the existence of a particular system [7, 9].

These circumstances are an additional argument in favor of the ideas mentioned above about the objective existence of conceptual systems. However, from the point of view of the system–object approach, these systems do not exist in the form of any consciousness, but in the form of a hierarchy of class systems (classes that are systems) with one vertex.

In addition, the occurrence of everything that exists in one Supersystem is revealed as a result of a comparison of some well-known system-wide laws studied by A.A. Bogdanov [18]. As an example, the *principle of organizational continuity* states the fact of the presence between any two systems of links that introduce them into one "chain of ingression" and *the principle of monocentrism*. In [19] we proved that the first of the above principles is valid only if the second is fulfilled on a global level.

Therefore, reality is an object-oriented system, whose classes represent external (according to Schrader) or conceptual (according to Ackoff) systems (i.e., class systems) that determine the properties of objects, and objects are internal (according to Schrader) or material (according to Ackoff) systems (i.e., systems–phenomena) that perform real interactions.

Consideration of the features of the hierarchy of class systems (conceptual systems) is necessary, for example, when modeling conceptual knowledge to ensure the adequacy of conceptual models of this knowledge of reality. The models of conceptual knowledge become models that reflect the consistency of reality only in the case of such an accounting, which is essential when solving classification problems and creating classifiers.

These features were studied in detail in [20, 21], from which it follows that at the highest level of the hierarchy of conceptual systems there are two types of class systems: classes (class systems) of system components or *class objects* and classes (class systems) of properties, i.e., *class properties*. Moreover, the latter also exist in two forms: property classes of objects (*object properties*) and property classes of properties (*property properties*) In [22], such a hierarchy was described using the mathematical apparatus of category theory. However, this description does not justify its properties and does not take substantive features into account.

To further study the properties of the hierarchy of class systems in order to improve existing and create new classifiers (classification systems), which are an important type of conceptual model of conceptual knowledge, it is necessary to justify the properties of this hierarchy of class systems by formal means, taking its substantial features into account. Our study uses descriptive logic to solve such a problem.

THE FEATURES OF DESCRIPTION LOGIC

Descriptive logic (DL) is a knowledge representation language for describing the concepts of a subject area in an unambiguous, formalized form. Any descriptive logic has syntax and semantics. The basic syntactic elements of the language of descriptive logic are the atomic concept and role, corresponding to the single and double predicates of the language of mathematical logic. Concepts are used to describe classes, while roles are used to describe the relationship between concepts. Concepts and roles allow one to describe concepts and their properties [23]. One of the basic descriptive logics is the ALC DL [23, 24] Logic Syntax *Alc* presented below in short form.

$$\{\top; \bot; A; A \sqsubseteq C; \neg C; C \sqcap D; C \sqcup D; \exists R.C; \forall R.C\}$$

The characters $\top$ and $\bot$ are concepts (called truth and falsehood). A is an atomic concept, C, D are arbitrary concepts, and R is an atomic role.

The semantics of DL are described using the concept of interpretation, which is a pair $I = (\Delta, .^I)$ that consists of a nonempty set Δ, called the scope of this interpretation, and the interpretive function I that matches:

(1) To every atomic concept $A \in CN$ there is an arbitrary subset $A^I \subseteq \Delta, CN$ that is the set of all concepts;

(2) Each atomic role $R \in RN$ is an arbitrary subset $R^I \subseteq \Delta \times \Delta, RN$ that is the set of all the roles.

Theories that describe knowledge bases distinguish common knowledge about concepts and their relationships, which are expressed using general statements, that is, terminologies, or axioms, as well as knowledge about individual objects, their properties and relationships with other objects—statements about individuals. In DL we distinguish a set of terminological axioms called *TBox*, and a set of statements about the relationships and properties of individuals called *ABox*. Together they form a knowledge base, or ontology $K = TBox \cup ABox$.

We give an example of the subject area described by *ABox* and *TBox*:

$$ABox = \left\{\begin{array}{c} \text{Man}(\text{John}); \\ \text{Woman}(\text{Maria}); \\ \text{Loves}(\text{John}, \text{Maria}); \\ \text{Married}(\text{John}, \text{Maria}); \end{array}\right\};$$

$$TBox = \left\{\begin{array}{c} \text{Bachelor} = \neg\exists\text{Married} \sqcap \text{Person}; \\ \exists\text{Married} \sqsubseteq \text{Happy}; \\ \exists\text{Married.Woman} \sqsubseteq \exists\text{Loves.Woman}; \\ \text{Person} = \text{Man} \sqcup \text{Woman}; \end{array}\right\};$$

Further *TBox*, for clarity, in natural Russian:

$$TBox = \left\{\begin{array}{c} \text{Bachelor is an unmarried person;} \\ \text{All married people are happy;} \\ \text{Married to a woman also loves her;} \\ \text{Man or woman is a person;} \end{array}\right\}$$

The logical expansion *ALC* occurred before *ALCOIQ* was presented in [25]. The following extensions are introduced here:

—the face values (O) are the representation of the individual in the form of a concept. If a is an individual then $\{a\}$ is a concept. Thus, individual names enclosed in braces become full-fledged concepts;

—reverse roles (I) if R is the atomic role then R^- is the inverse role;

—numerical limitations (Q)

Each new symbol of the designation of logic means a certain extension of it. When these extensions are used separately it turns out that a family of logic $ALC \subseteq L \subseteq ALCOIQ$. L is the logic that lies in the interval belonging to this family.

FORMALIZATION OF THE HIERARCHY OF CLASS SYSTEMS USING DESCRIPTION LOGIC

Using descriptive logic (DL), one can define concepts for class objects, while the roles in the DL will correspond to class properties. However, to describe the hierarchy of roles of the expressiveness of logic *Alcoiq* not sufficient. To solve the problem of constructing a hierarchy of conceptual systems, we use DL *SHOIQ* [23]. It expands *Alcoiq* and has axioms for roles *RBox* (by analogy with *TBox* and *ABox*), which allows us to describe the hierarchy of roles as class systems. *Alcoiq* logic is expanded by the following points:

1. Hierarchy of Roles (*H*): axioms of the form are allowed $R \sqsubseteq S$ where R, S are arbitrary roles. Moreover, we say that R is the subrole of S, and S is the upper role above R.

2. Transitive Roles (*S*): axioms of the form $Tr(R)$ or R^* where R is an arbitrary role and R^* is a transitive role are allowed.

In the *SHOIQ* descriptive logic, the axioms *TBox* and *ABox* for roles are supplemented with *RBox R*, i.e., the knowledge base $K = TBox \cup ABox \cup RBox$.

However, to justify the structure of the hierarchy of conceptual systems, it is necessary to expand the *SHOIQ* logic by formally introducing the concepts of the volume and content of a class system in it.

The *Class System Volume* (*Vol*) constitutes the totality of species—systems—classes included in the class—system, which is generic for them.

The *Class System Content* (*Cont*) includes a superclass (generic class), as well as a set of distinctive features (roles in a supersystem) of this class system.

We describe these concepts using DL. The content of the class system is expressed through the role that supports the functional ability of the class supersystem, as well as through the class supersystem itself:

$$Cont\left(S_{ij}^{l}\right) = S_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_j}^{l_j},$$

where $i = \overline{0, N}$, i is the tier number of the hierarchy and l, j, l_j, p_j are numbers within one tier of the hierarchy. Roles are also class systems. Therefore, they also have content (properties/properties):

$$Cont\left(RS_{ij}^{l}\right) = RS_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_j}^{k_j},$$

where $i = \overline{0, N}$, i is the tier number of the hierarchy and l, j, k_j, p_j are numbers within one tier of the hierarchy.

The concept of the volume of a class system can be described using the operation of combining concepts:

$$Vol\left(S_{ij}^{l}\right) = S_{i+1,1}^{j} \sqcup S_{i+1,2}^{j} \sqcup \ldots \sqcup S_{i+1,\bar{N}_{i+1}}^{j},$$

moreover, $S_{i+1,p}^{j} \sqsubset S_{ij}^{l}, p = \overline{1, \bar{N}_i}$. $\bar{N}_i$ are the number of nodes of the i-level hierarchy.

We consider the possibility of creating a formal model of the hierarchy of class systems (conceptual systems) using descriptive logic that describes the system relationships between classes. In accordance with the system (system—object) approach, a system is considered both as a phenomenon (material object) and as a class (conceptual system), whose function or role is determined by the function of the phenomenon or the role of a class of a higher tier (i.e., the supersystem—phenomenon or class supersystem). A formalized description of this understanding of the system using the notation adopted in descriptive logic is as follows:

$$S_i = [S_{i-1}; RS_i \sqsubset RS_{i-1}]. \quad (1)$$

In expression (1), a formal description of the system is presented in accordance with the rules for calculating the objects of Abadi—Kardeli, where $\forall S_i \exists RS_i$ and S_{i-1} is a class system to indicate a class system (node) of a higher tier of the hierarchy S_i; $RS_i \sqsubset RS_{i-1}$ is a method corresponding to the role (function) of the system S_i in the supersystem S_{i-1}. RS_i is a functional role (property—class) that supports the functional ability of a supersystem—class (concept).

The principle of monocentrism, investigated by A.A. Bogdanov claims that a "stable system will be characterized by a single center; if it is a complex chain then it has one higher common center" [18]. This principle is a consequence of the hierarchical ordering of systems, in our case, the hierarchical structure of generic relationships between class systems (conceptual systems).

The following are statements that substantiate this principle, and, in general, the relationship structure of conceptual systems.

Statement 1. If a class system is a type of a class system of a higher tier and properties (class properties) of a class system are also a type of properties (class properties) of a class system of a higher tier, then this hierarchy has one root.

Let class systems S_{ij}^{l} and RS_{ij}^{l} exist where i is the tier number of the hierarchy, j is the serial number of the node in the tier, and l is the serial number of the supersystem in the tier. In terms of the *SHOIQ* descriptive logic that we extended by the concepts of volume (*Vol)* and content (*Cont*) class systems S_{ij}^{l} is a concept and RS_{ij}^{l} is a role (functional role). We assume that there are class systems (descendants) $S_{i+1,p}^{j}$, included in S_{ij}^{l}, i.e., $\exists S_{i+1p}^{j} \sqsubset S_{ij}^{l} : p = \overline{1, N}$. Let class systems exist (property classes) $RS_{i+1,p}^{j}$ included in RS_{ij}^{l}, $\exists RS_{i+1p}^{j} \sqsubset RS_{ij}^{l} : p = \overline{1, N}$. We describe the fragments *TBox* and *RBox* as an expression:

$$TBox = \left\{ \begin{matrix} \ldots \\ S_{i+1,1}^{j} \sqsubset S_{ij}^{l} \\ \ldots \\ S_{i+1,N}^{j} \sqsubset S_{ij}^{l} \\ \ldots \end{matrix} \right\}; \quad RBox = \left\{ \begin{matrix} \ldots \\ RS_{i+1,1}^{j} \sqsubset RS_{ij}^{l} \\ \ldots \\ RS_{i+1,N}^{j} \sqsubset RS_{ij}^{l} \\ \ldots \end{matrix} \right\}. (2)$$

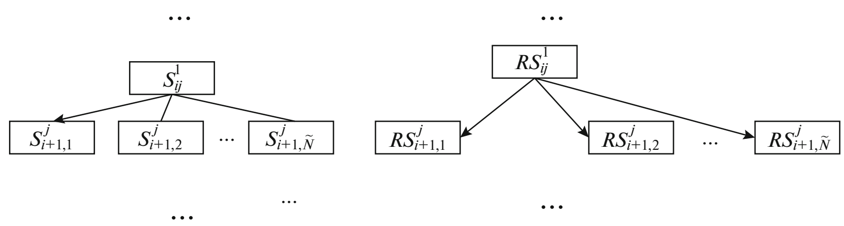

Fig. 1. The hierarchical structure of *TBox* and *RBox*.

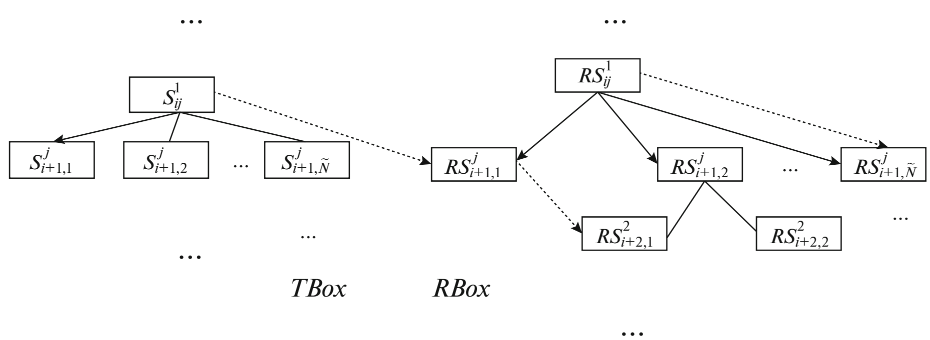

Fig. 2. The hierarchical structure of class systems.

This expression is graphically presented in Fig. 1.

From (1) it is known that class properties (functional roles) support the functional ability of a supersystem S_{ij}^{l}. Therefore, each class system must have supporting functional roles that determine its purpose. In turn RS_{i+1p}^{j} is also a class system and RS_{ij}^{l} is a supersystem class, i.e., it must have supporting features (properties). We describe a class system $S_{i,j}^{l}$ in terms of *SHOIQ* logic. We obtain a composite concept that can be described using the intersection operation:

$$S_{i,j}^{l} \sqsubset S_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_j}^{l_j},$$

where l_j is the serial number of the supersystem class (class property), in relation to $S_{i,j}^{l}$; p_j is the serial number of the class system in the tier, in relation to $S_{i,j}^{l}$.

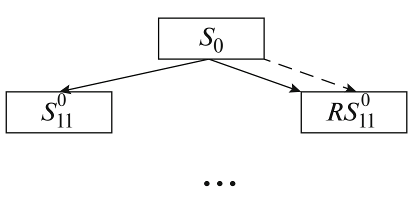

Fig. 3. The root of the class system hierarchy.

We refine the above expression in accordance with the definition of system (1). As a result, we obtain the expression:

$$TBox = \left\{ \begin{array}{c} \ldots \\ S_{i,1}^{l} \sqsubset S_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_1}^{l_1} \\ S_{i,2}^{l} \sqsubset S_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_2}^{l_2} \\ \ldots \\ S_{i,N}^{l} \sqsubset S_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_N}^{l_N} \\ \ldots \end{array} \right\};$$

$$RBox = \left\{ \begin{array}{c} \ldots \\ RS_{i,1}^{l} \sqsubset RS_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_1}^{k_1} \\ RS_{i,2}^{l} \sqsubset RS_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_2}^{k_2} \\ \ldots \\ RS_{i,N}^{l} \sqsubset RS_{i-1,l}^{n} \sqcap \exists RS_{i+1,p_N}^{k_N} \\ \ldots \end{array} \right\}.$$

In Fig. 2 this expression is presented in graphical form.

As noted earlier, class systems must have species characteristics (class properties) that are different from the generic ones, which is necessary for constructing subsequent tiers of the hierarchy and correlates with the logical law of the inverse relationship of volume and content [22] according to which a class system inherited from the current class system should have a large number of species characteristics, i.e., greater content $Cont\left(S_{ij}^{l}\right) \sqsubset Cont\left(S_{i+1,p}^{j}\right)$, but lesser $Vol\left(S_{ij}^{l}\right) \sqsupset Vol\left(S_{i+1,p}^{j}\right)$. When applying the law as a whole, to the entire hierarchy of systems, the following relationships should be satisfied:

$$Vol\left(S_{0,p_0}\right) \sqsupset \ldots \sqsupset Vol\left(S_{i-1,p_k}^{p_{k-1}}\right) \sqsupset Vol\left(S_{i,p_{k+1}}^{p_k}\right) \sqsupset Vol\left(S_{i+1,p_{k+2}}^{p_{k+1}}\right) \sqsupset \ldots \tag{3}$$

$$Cont\left(S_{0,p_0}\right) \sqsubset \ldots \sqsubset Cont\left(S_{i-1,p_k}^{p_{k-1}}\right) \sqsubset Cont\left(S_{i,p_{k+1}}^{p_k}\right) \sqsubset Cont\left(S_{i+1,p_{k+2}}^{p_{k+1}}\right) \sqsubset \ldots \tag{4}$$

From (3) it follows that by moving along the tiers, each parent system—class should have fewer signs than the current one, therefore, it should have a larger volume, and from (4) it follows that the number of signs decreases to the limit state at which the content is the most comprehensive and $k = 0, p_0 = 0$ Moreover, we can talk about the root system—class S_0, which confirms the unity of the vertices of the classification scheme and Statement 1 (Fig. 3).

Statement 2. The root of the hierarchy of class systems is divided into class systems that represent class objects and class properties.

Let there be a root class system S_0 that has no parents. Suppose that it has two descendants (class systems) S_{11}^0 and RS_{11}^0:

$$S_{11}^0 \sqsubset S_0; \quad RS_{11}^0 \sqsubset S_0;$$

with volume $Vol\left(S_0\right) = S_{11}^0 \sqcup RS_{11}^0$ and content $Cont\left(S_0\right) = RS_{11}^0$ where RS_{11}^0 is a class system that includes all the supporting features of the subject area, i.e., a functional role. In [21] RS_{11}^0 was an extremely broad role corresponding to the class "property." In addition, this is consistent with the work of Melnikov [13], which describes the separation of properties into boundary and qualitative, which can be correlated with our reasoning. It is fair to say that in this case relations (3) and (4) will also hold. This confirms the structure of the hierarchy of conceptual systems and Statement 2.

CONCLUSIONS

The initial reason for the existence of systems and the presence of certain properties in them is due to the hierarchy of conceptual or external systems (class systems). Thus, reality is an object-oriented system, whose classes represent conceptual (external) systems—classes that determine the properties of objects, and objects, that is, material (internal) systems—phenomena that carry out real interactions.

The concepts of the system—object approach, "system—class" and "property—class," are unambiguously compared with the concepts of descriptive logic. The syntax and semantics of the *ALCOIQ* descriptive logic and its original extension *SHOIQ* allow us to justify the structure of the hierarchy of class systems and the mandatory implementation of the principle of monocentrism for conceptual systems. The introduction of the concepts of "volume" and "content" of class systems and their description using descriptive logic extends a system theory based on a system—object approach.

Future results will allow us to improve existing classifiers and create new ones (classification systems), which are an important type of model of conceptual knowledge.

FUNDING

This work was supported within the Russian Foundation for Basic Research projects 18-07-00355a, 18-07-00356a, 19-07-00290a, 19-07-00111a, and 19-29-01047mk.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. General Theory of Systems. https://ru.wikipedia.org/wiki/Obshchaya_teoriya_sistem. Accessed February 22, 2020.
2. Ackoff, R.L., General system theory and systems research: Contrasting conceptions of system science, in *Proceedings of the Second Systems Symposium at Case Institute of Technology,* New York—London: Wiley, 1964, pp. 51–60.
3. Dubrovskii, V.Ya., Towards the development of systemic principles: A general theory of systems and an alternative approach. http://gtmarket.ru/laboratory/expertize/6566. Accessed February 22, 2020.
4. Pugachev, N.N., *Teoriya, ontologiya i real'nost'* (Theory, Ontology, and Reality), Voronezh: Izd. Voronezh. Univ., 1991.
5. Lifshits, M., About the ideal and the real, *Vopr. Filos.,* 1984, no. 10, pp. 120–145.
6. Shreider, Yu.A. and Sharov, A.A., *Sistemy i modeli* (Systems and Models), Moscow: Radio i Svyaz', 1982.
7. Matorin, S.I. and Solov'eva, E.A., The determinant model of systems and systemological analysis of the principles of determinism and the infinity of the world, *Nauchno-Tekh. Inf., Ser. 2,* 1996, no. 8, pp. 1–8.
8. Bondarenko, M.F., Matorin, S.I., and Solov'eva, E.A., Analysis of systemological tools for conceptual model-

ing of problem areas, *Nauchno-Tekh. Inf., Ser. 2,* 1996, no. 4, pp. 1–11.

9. Matorin, S.I. and Zhikharev, A.G., A systematic approach to classes of objects, *Sbornik trudov 8-i Mezhdunarodnoi konferentsii "Sistemnyi analiz i informatsionnye tekhnologii (SAIT)"* (Proc. 8th Int. Conf. System Analysis and Information Technologies (SAIT)), Moscow: FITs IU RAN, 2019, pp. 244–249.
10. Gvishiani, D.M., Materialist dialectics: The philosophical basis of system research, in *Sistemnye issledovaniya: Ezhegodnik, 1979* (System Studies: Yearbook 1979), Moscow: Nauka, 1980, pp. 7–28.
11. Matorin, S.I., Zhikharev, A.G., and Mikhelev, V.V., Accounting for system-wide regularities in conceptual modeling of conceptual knowledge, *Iskusstv. Intell. Prinyatie Reshenii,* 2019, no. 3, pp. 12–23.
12. Shreider, Yu.A., The theory of knowledge and the phenomenon of science, in *Gnoseologiya v sisteme filosofskogo mirovozzreniya* (Gnoseology in the System of Philosophical Worldview), Moscow: Nauka, 1983, pp. 173–193.
13. Mel'nikov, G.P., *Sistemologiya i yazykovye aspekty kibernetiki* (Systemology and Linguistic Aspects of Cybernetics), Moscow: Sovetskoe radio, 1978.
14. Grib, A.A., Von Neumann interpretation of quantum mechanics and the problem of consciousness, in *Filosofiya i razvitie estestvenno-nauchnoi kartiny mira* (Philosophy and Development of the Natural-Scientific Picture of the World), Leningrad, 1981, pp. 75–83.
15. Lifshits, M., About the ideal and the real, *Vopr. Filos.,* 1984, no. 10, pp. 120–145.
16. Velikhov, V.P., Zinchenko, V.P., and Lektorskii, V.A., Consciousness: Experience of an interdisciplinary approach, *Vopr. Filos.,* 1988, no. 11, p. 21.
17. Kondakov, N.I. and Gorskii, D.P., *Logicheskii slovar'* (Logical Dictionary), Moscow: Nauka, 1971.
18. Bogdanov, A.A., *Tektologiya: Vseobshchaya organizatsionnaya nauka* (Tectology: Universal Organizational Science), Moscow: Ekonomika, 1989, 3rd ed.
19. Matorin, S.I. and Zhikharev, A.G., Accounting for system-wide regularities in system-object modeling of organizational knowledge, *Sci. Tech. Inf. Process.,* 2019, vol. 46, pp. 388–396.
20. Matorin, S.I., Systemological investigation of the structure of the category system, *Nauchno-Tekh. Inf., Ser. 2,* 1997, no. 3, pp. 3–7.
21. Matorin, S.I., Zimovets, O.A., Shcherbinina, N.V., and Sul'zhenko, T.S., The concept of a formalized theory of systems based on the "NODE–FUNCTION–OBJECT" approach, *Nauchn. Vedomosti Belgorod. Gos. Univ., Ser. Ekon. Inf.,* 2016, no. 16, pp. 159–166.
22. Solov'eva, E.A., El'chaninov, D.B., and Matorin, S.I., Application of category theory to the study and modeling of natural classification, *Nauchno-Tekh. Inf., Ser. 2,* 1999, no. 3, pp. 1–7.
23. Schmidt-Schauss, M. and Smolka, G., Attributive concept descriptions with complements, *Artif. Intell.,* 1991, no. 48, pp. 1–26.
24. Baader, F., Calvanese, D., McGuinness, L., Nardi, D., and Patel-Schneider, P.F., *The Description Logic Handbook: Theory, Implementation, and Applications,* Cambridge University Press, 2003.
25. Baader, F. and Sattler, U., Expressive number restrictions in description logics, *J. Logic Comput.,* 1999, vol. 9, no. 3, pp. 319–350.