Shifted Concepts Separation for Providing the Semantic Sustainability

L.Ismailova[1], S.Kosikov[2], V.Wolfengagen[1], I.Parfenova[2], I.Sleptsov[3]
[1] National Research Nuclear University "MEPhI", 115409, Russia, Moscow, Kashirskoe shosse, 31
[2] Institute for Contemporary Education "JurInfoR-MGU", 119435, Russia, Moscow, Malaya Pirogovskaya str., 5
[3] National Research University MIPT, 141701, Russia, Moscow Region, Dolgoprudny, Institutskiy per., 9

Abstract: The paper considers the problem of supporting the semantic sustainability of the information system in the course of changing its problem domain. The sustainability can be ensured on the base of the coherent semantic behavior of the conceptual constructions in the model of the problem domain. An essential part of such coherence is a separation of the constructions with different behavior. This behavior is connected with the representation of changes in the problem domain. So the separation of the conceptual constructions reflects the semantics of constructions and can be viewed as the semantic separation. Its representation is based of connection of methods of applicative computational technologies and the "functor-as-object" construction by the use of formalism of shifted concepts.

The database of the system is represented as a semantic network. Various mechanisms of the shifted concepts arising are considered, including those for formalizing the change in the scope of the concepts of the subject area, their definitions and recognition functions, as well as the parametric mechanism of shift when the concepts associated with the original ones are changed.

To ensure the manipulation of shifted concepts, a single presentation mechanism is used based on the "functor-as-object" construction. Basic constructions are created to represent a set of situations for the use of the shifted concept, and also for taking into account the connections of situations. The methods of topology and category theory are applied.

The paper discusses possibilities of representation of the network modeling environment for supporting families of shifted concepts in the form of a set of representative constructions of an applicative computing system and solutions for constructing the appropriate tool environment. The following results are presented – of testing the prototype components of the environment while solving cognitive type problems in the field of jurisprudence.

Keywords: Semantic sustainability, shifted concepts, semantic network, functor-as-object, currying, mapping of computation.

I. INTRODUCTION

Modern technologies of scientific research foresee an increasingly intensive use of information resources, especially those presented in the Web environment. The information mining from such resources can be performed manually, but this appears to be a time consuming and inefficient approach. Therefore, the direction of information systems development, oriented to the work with resources, becomes important.

It comes out, however, that information in different resources (and often it might happen within one and the same resource) is organized according to various principles, is described by various (often incompatible) methods, and is classified according to different reasons, etc. [1]. Moreover,

The work is supported by grants 16-07-00912, 17-07-00893 of the Russian Foundation for Basic Research (RFBR).

the indicated characteristics of information may change over time, plus to this those changes can have not only quantitative, but also qualitative nature. Therefore, ensuring the semantic sustainability of the information system in the course of changing its subject area [1], [2] becomes a relevant task.

Simultaneous processing of information, organized according to different reasons, involves performing the agreement of the data models used. Such an agreement is possible only on a single formalized basis, using a conceptually clear and computationally powerful mathematical apparatus. The authors in the present paper follow [1], which suggests an approach to data modeling on a category basis that provides integration of logical and applicative means.

An essential feature of the category approach is the single treatment of stable and changing data on the basis of the concept of a Cartesian closed category. Further specification of the data nature is based on the imposition of additional conditions on the applied categories, for example, the acceptance of the axiomatics of topos. Taking into account the changes within the category theory requires a transition to categories of functors, which allows to formulate the basic concept needed to take changes into account – the concept of a shifted concept [1], [2].

The development of information systems that provide semantically stable work and that are based on a formalized approach to modeling requires the use of tools agreed with the used approach. Such an agreement may involve both the direct development of tools that support the adopted approach, and the use of existing tools. In the latter case, it is necessary to select the capabilities of existing tools agreed with the requirements of formalism, and to offer a set of methods for using tools that do not violate accepted assumptions. This paper uses an approach based on semantic networks [2], [3].

The work is structured as follows. Paragraph 2 briefly overviews the approaches to the taking into account the changes of the subject area when constructing its model. Paragraph 3 clarifies the formulation of the task to support the families of shifted concepts. Paragraph 4 briefly presents the category grounds for modeling the shifted concepts and its connection with the constructions of the supporting environment. Paragraph 5 describes a prototype modeling environment to support the shifted concepts and outlines the paths of further work. Paragraph 6 briefly summarizes the work.

II. APPROACHES TO TAKING INTO ACCOUNT THE CONCEPTS SHIFT

The task of describing changes in the subject area, including changes in the conceptual basis for describing the subject domain, was researched in various scenarios earlier. Within the framework of a purely logical approach the systems were studied, in which the truth of assertions, formulated within the framework of the system, depends on the fulfillment of certain conditions. First of all this is the temporal logic in its various formulations [4], [5] and dynamic logic [6]. The default logic [7] also suggests a description of the subject area, the scope of knowledge about which can change over time. The missing knowledge can be replenished by default. The default logic, however, does not offer means of agreement of the replenishment mechanisms, and this is manifested in the possibility of the absence of fixed points in a number of models of such logic (fixed points represent the agreed state of the system).

However, the mentioned systems, as a rule, are aimed at the identification and formalization of permanent principles, which can be laid as a basis for describing the subject area in the form of a system of axioms of the corresponding logic. Despite the importance of defining such principles, this is not enough to develop a complete system of modeling support. It is also necessary to identify ways of mapping the changes in concepts, classify such changes, etc.

Changes in the domain were also taken into account when developing semantics for databases. For example, the classical definition of a relational database [8] directly contains an indication that the set of relations in it changes with time. The tasks of mapping the incompleteness of the description of the domain in databases, creating temporal databases were also considered.

Within the framework of production rule systems for knowledge representation the task of supporting the description of domain changes was considered in the framework of studying strategies of the operation with work memory. The works related to the logical programming continue this line, and, for example, relate to a controlled resolution [9], to the attempts of linking the capabilities of applicative and logical systems [10], etc.

The mentioned directions of work are of considerable interest, and the identified methods can be partially used to support the presentation of shifted concepts. However, none of them provides an agreed description of the changes in the conceptual model. Therefore, the means declared within the named approaches require, at a minimum, selection and adaptation for joint use.

Besides that, none of the mentioned solutions is aimed clearly at describing changes in the conceptual apparatus of describing the subject area. For example, the possibility of the appearance of new concepts that did not exist before and the transition from descriptions within the framework of old concepts to the description by means of new concepts are not taken into account. The indicated possibility is important for a number of practical applications, for example, in the field of jurisprudence.

This paper proposes an approach to presenting changes (including conceptual ones) in the subject area on the basis of category theory [3]. The basic element of the approach is the notion of a shifted concept, which is an object of the category of functors from the category of *Asg* assignments to the base category D. The objects of the assignment category represent the states of the concept, and the arrows represent the ways of the concept shift. The presented approach is coordinated with the representation of a set of shifted concepts in the form of a semantic network.

III. TASK OF DEVELOPING THE ENVIRONMENT TO SUPPORT THE FAMILIES OF SHIFTED CONCEPTS

The study of approaches to solving the problem of presenting changes in the subject area and revealing their limitations, as well as studying the possibilities of formalisms based on category theory to support shifted concepts, including those in the semantic network environment, makes it possible to specify the task of developing the support tools for representing shifted concepts. The indicated task is the development of the problem of supporting the evolving concepts formulated in [1].

In accordance with the general formulation from [1] in order to support modeling, it is necessary to provide means for a typical description of the domain. This can be achieved by choosing the support tools in the form of a network environment that provides:

- representation of structured types on the basis of typed concepts of the semantic network, the semantics of which are specified by the category construction of the pullback;
- representation of functional types thanks to the possibility of abstracting fragments of the semantic network;
- representation of subtypes based on recognition functions, the semantics of which are specified by mono-arrows of the category model;
- representation of dependent types on the basis of concept families, the semantics of which are specified in the form of functors depending on the parameter.

The support tools are expected to give the ability to provide various types of parameterization, which can be achieved through:

- representation of the assignment points to ensure attribution of the semantic construction of the concept shifting;
- support to processing of fragments of the semantic network, local for assignment points, for representing the dynamics of the concept shifting, in particular, changing its recognition function;
- support to generation of assignment points according to the conditions placed on the

possible attribution of the concepts, which ensures the tracking of the dependence of the concept shifting on the set parameter.

It is also needed to ensure the integration of the modeling and computing capabilities of the semantic network, which is provided by:

- possibility of attributing the semantic network constructions by generating cloned nodes obtained with a substitution system representing the attribution;
- possibility of identifying concepts that are undefined or partially defined at a given assignment point, and providing a computational response to the identification of such concepts;
- provision of various ways of replenishment of undefined concepts, including setting an explicit way of attributing the concept or the way of attributing by default.

The formulated requirements can be provided in the environment of semantic network support, oriented to the modeling of the domain and integrated with the applicative mechanisms of computation. The semantic network structures are assigned with semantics on a category basis within the model formulated in [1]. The applicative mechanisms provide the computation of the attributions of the semantic constructions of the network in accordance with the attributed semantics.

IV. SEMANTICS OF THE NETWORK CONSTRUCTIONS

A. Semantic network structure

The semantic network is considered as consisting of nodes and (named) arcs. The vertices of the network are represented by concepts and predicates. Some nodes of the network (both concepts and predicates) can be defined through other ones, and the definitions admit a parameterization of the usual form corresponding to the λ-expressions of the applicative environment.

Concepts represent the objects allocated in the domain in the course of its examination, the classes of such objects and various abstract entities. The common concepts, constants and variables are distinguished among the concepts. The arcs of the semantic network represent the connections that are allocated in the subject domain when it is examined. The assignment points are presented to display the intensional component of the model in the semantic network.

When linking the semantic network constructions to a computational model, each vertex of the network is associated with a construction of a category model, an object of the functors category is associated with the vertex of the semantic network. The arc connecting the nodes corresponds to the arrow of the category of functors.

B. Description of the semantics of network

A description of structured objects of the domain by semantic network can be performed on the basis of the construction of the Cartesian product in the category. At the same time, however, the expression of conditions imposed on the connection of objects requires additional category constructions. The description based on the construction of a pullback is more convenient.

A pullback is used to represent the conditions imposed on objects and the arrows that connect them. The pullback is defined as follows. Suggest $a, b \in Ob(C), f: b \to a, g: c \to a$. Then the pullback is the object d together with arrows $f': d \to c, g': d \to b$, such, that for any $d' \in Ob(C), f'': d' \to c, g'': d' \to b$ there is the only arrow $h: d' \to d$ such, that $f'' = h \circ f'$, $g'' = h \circ g'$.

Graphically it will look like it is shown in the diagram below.

One should note that the pullback is the limit cone over a diagram consisting of two convergent arrows f and g. The diagram representing a pullback is named the Cartesian square.

Let us see how that works. Suggest $f: b \to a$ and $g: c \to a$ are mono-arrows. In the category C these mono-arrows represent subsets of the object a. Then the Cartesian square

$$\begin{array}{ccc} d & \xrightarrow{f'} & c \\ {\scriptstyle g'}\downarrow & & \downarrow{\scriptstyle g} \\ b & \xrightarrow[f]{} & a \end{array}$$

specifies a set of elements that simultaneously get into the subsets f and g, that is, a crosscutting of subsets f and g. The square above expresses that f ∘ g' = g ∘ f'. So, in this case the pullback is used to represent conjunction.

The pullback is unique up to isomorphism. Let us formulate this more accurately. Suggest $m : d_2 \to d_1$ and $n : d_1 \to d_2$ specify the isomorphism d and d' (that is, $m \circ n = 1_{d1}$ and $n \circ m = 1_{d2}$). Then the left square of the diagram

$$\begin{array}{ccc} d_1 & \xrightarrow{f_1'} & c \\ {\scriptstyle g_1'}\downarrow & & \downarrow{\scriptstyle g} \\ b & \xrightarrow[f]{} & a \end{array} \qquad \begin{array}{ccc} d_2 & \xrightarrow{f_2'} & c \\ {\scriptstyle g_2'}\downarrow & & \downarrow{\scriptstyle g} \\ b & \xrightarrow[f]{} & a \end{array}$$

where $f_2' = f_1' \circ m$, $f_1' = f_2' \circ n$, $g_2' = g_1' \circ m$, $g_1' = g_2' \circ n$, is Cartesian when and only when the right square is Cartesian one.

Let us single out some essential properties of the pullback. An arrow f : a → b is a mono-arrow when and only when the square

$$\begin{array}{ccc} a & \xrightarrow{1_a} & a \\ {\scriptstyle 1_a}\downarrow & & \downarrow{\scriptstyle f} \\ a & \xrightarrow[f]{} & a \end{array}$$

is Cartesian.

Suggest f : a → c, g : b → c, h : a → b, and f = g ∘ h. then the square

$$\begin{array}{ccc} a & \xrightarrow{1_a} & a \\ {\scriptstyle h}\downarrow & & \downarrow{\scriptstyle f} \\ a & \xrightarrow[g]{} & a \end{array}$$

is Cartesian.

Suggest f : b → a. A kernel pair of the arrow f is named such a pair of arrows g, g' : c → b, that the square

$$\begin{array}{ccc} c & \xrightarrow{g} & b \\ {\scriptstyle g'}\downarrow & & \downarrow{\scriptstyle f} \\ b & \xrightarrow[f]{} & a \end{array}$$

is Cartesian. Thus, the kernel pair is the result of the ascent of the arrow along itself.

In the category Set the kernel pair of the function f : A → B is the set of pairs (a_i, a_j) such, that $f(a_i) = f(a_j)$. It is obvious that the set is a subset of the Cartesian product A × A. The similar property takes place in an arbitrary category (having pullbacks).

C. Semantic separation

A semantic separation of concepts suggests checking the conditions for ensuring behavior consistent with the dynamics of the data domain. In an applicative computing system the consistency can be expressed as a property of an estimating mapping. Parameterization of mappings is expressed with an exponential, which is a universal parametric mapping.

The exponential in the category is the abstraction of the set of functions. The definition is given below.

The exponential of the objects a and b in the category C is such object d together with an arrow ev : d × a → b, that for every object c and arrow f : c × a → b there is the unique arrow h : c → d, for which

$$f = ev \circ \langle h \circ p, q \rangle. \tag{1}$$

The object d will be denoted as a → b. The arrow h built by f, similar to the case of Cartesian product, is the unique arrow with this property, so it can be considered as the function on f. This function will be denoted Λ(f). The arrow Λ(f) is named a currying of the arrow f.

In the new notations the properties of the exponential can be rewritten so.

$$ev \circ \langle \Lambda(f) \circ p, q \rangle = f, \tag{2}$$

$$\Lambda(ev \circ \langle h \circ p, q \rangle) = h, \tag{3}$$

for arbitrary h : c → (a → b).

The notion of exponential uses the Cartesian product of objects. So the category must be Cartesian for the existence of exponentials. The Cartesian category where for every two objects there is an exponential is named Cartesian closed category. Not every category is Cartesian closed.

Despite of the impossibility of the approach to the construction of the exponential by analogy with the Cartesian product, the category $Set^{C^{op}}$ is still Cartesian closed. But successful exponential construction is a little more complicated.

Let U and V be two functors of $Set^{C^{op}}$. We define a functor U → V in the following way. The value of the object mapping of the functor on the object A is, according to D. Scott [11], the family of mappings $U_B \to V_B$, indexed by the arrows f : B → A. That is, elements of $(U \to V)_A$ are mappings φ from the set of arrows f : B → A to the corresponding functions $U_B \to V_B$.

The values of the functions corresponding to the different arrows f : B → A must be coordinated. Namely, if we consider an arrow g : C → B, then the composition f ∘ g is an arrow C → A. This composition is also a possible index in the family φ and, if $\varphi_f : U_B \to V_B$ then $\varphi_{f \circ g} : U_C \to V_C$.

The condition of the coordination requires

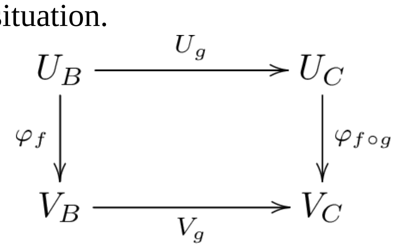
$$\varphi_{f \circ g} \circ U_g = V_g \circ \varphi_f. \tag{4}$$

For representing this condition now in terms of restriction mapping we apply both arrows to the element $b \in U_B$. We get

$$\varphi_{f \circ g}(b \uparrow g) = \varphi_f(b) \circ g, \tag{5}$$

where $b \uparrow g \equiv U_g(b)$ when U is implicitly given.

The diagram below clarifies the situation.



The required condition is a variant of naturality. Below we consider it in detail.

An arrow mapping for a functor U → V must match each arrow f : B → A to the function transforming the mappings φ from arrows C → A to the functions $U_C \to V_C$ to the mappings ψ from arrows C → B to the functions $U_C \to V_C$. Symbolically:

$$\begin{aligned} &(U \to V)_A = \{\varphi : (h : C \to A) \to (U_C \to V_C)\} \\ &(U \to V)_B = \{\varphi : (h : C \to B) \to (U_C \to V_C)\} \\ &(U \to V)_f : (U \to V)_A \to (U \to V)_B, \text{ where } f : B \to A. \end{aligned} \tag{6}$$

So the input for our task is the arrow f: B → A and the mapping φ which transforms each arrow h : C → A to the function $U_C \to V_C$ (it is a set-theoretical function because the functors U and V have their values in the category Set). The output is the mapping ψ, which transforms each arrow g : C → B to the function $U_C \to V_C$. The natural way to define this mapping is to convert the arrow g : C → B to the arrow h : C → A and then apply the mapping φ. For the conversion g to h it is enough to assume h = f ∘ g.

Now we formalize the construction. We denote

$$((U \to V) f)(\varphi) = \psi. \tag{7}$$

Then the value ψ on the arrow g : C → B can be defined as

$$\psi_g = \varphi_{g \circ f}. \tag{8}$$

This definition can be represented formally as

$$((U \to V) f(\varphi))_g = \varphi_{f \circ g}. \tag{9}$$

This formula defines a restriction mapping for the functor U → V: φ ↑ f = ψ where φ ϵ $(U \to V)_A$. Here $\psi_g = \varphi_{f \circ g}$, that is,

$$(\varphi \uparrow f)_g = \varphi_{f \circ g}. \tag{10}$$

This is the very construction that can not be generalized to the arbitrary category D. But there is rather wide class of categories allowing such generalization.

So we have defined the object and arrow mappings for the functor. Now we check that this is really a functor. We must check the composition preservation property

$$(U \to V)(f \circ g) = (U \to V) f \circ (U \to V) g \tag{11}$$

and the unit preservation property

$$(U \to V)(1_A) = 1_{(U \to V)_A}. \tag{12}$$

We begin with the composition. Let f: B → A and g: C → B. Then

$$(U \to V)(f \circ g) : (U \to V)_A \to (U \to V)_C. \tag{13}$$

The elements of $(U \to V)_A$ are the families φ of mappings. For the comparison of these families we apply them to the arrow h : D → C. Then

$$(U \to V)(f \circ g)(\varphi) = \psi, \quad \psi_h = \varphi_{(f \circ g) \circ h} \tag{14}$$

and

$$((U \to V) f \circ (U \to V) g)(\varphi)_b = (U \to V) f((U \to V) g)(\varphi)_h = (U \to V) f(\varphi)_{g \circ h} = \varphi_{f \circ (g \circ h)}. \tag{15}$$

The property of the unit preservation can be checked in the similar way.

Now we define the arrow of the evaluation mapping ε: (U → V) × U → V. Then ε_A: $(U \to V)_A \times U_A \to V_A$ and

$$\varepsilon_A(\varphi, a) = \varphi_{1_A}(a). \tag{16}$$

As usual we have to check the natuality of the given construction.

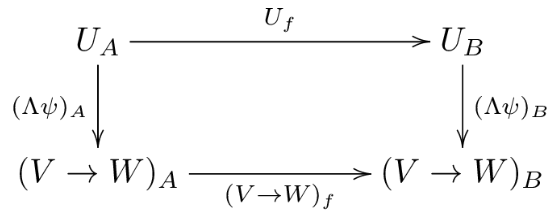
Now we consider currying. Let ψ : U × V → W, then

$$\psi_A : U_A \times V_A \to W_A, \quad \psi_B : U_B \times V_B \to W_B. \tag{17}$$

Carrying of ψ is an arrow Λψ : U → (V → W) with (Λψ)A : UA → (V → W)A. We are going to define $(\Lambda\psi)_A a = \varphi$ where $\varphi_f : V_B \to W_B$ for f: B → A. Let b ϵ V_B be an element of the domain of φ_f. Then φ_f (b) = ψ_B (Ufa, b), that is,

$$((\Lambda\psi)_A)_f b = \psi_B(a \uparrow f, b) \tag{18}$$

We check the functor character according to the diagram.



We have

$$(\Lambda\psi)_B \circ U_f = (V \to W)_f \circ (\Lambda\psi)_A$$
$$((\Lambda\psi)((U_f)a))_g(b) = \psi_C(U_f a \uparrow g, b) = \psi_C(a \uparrow (f \circ g), b) \qquad (19)$$
$$((V \to W)_f \circ (\Lambda\psi)_A a)_g(b) = ((\Lambda\psi)_A a)_{f \circ g}(b) = \psi_C(a \uparrow (f \circ g), b)$$

V. COMPUTATIONAL ABILITIES TO SUPPORT THE CONCEPTS SHIFT

The computational abilities of the semantic network environment include means for obtaining designations for semantic network constructs. To get designation with respect to the semantic network representing the domain model, it is necessary to specify a fragment of the semantic network, which is to be designated (corresponds to the request to the network) and the assignment point, in which the designation is computed. Since the definitions of the network nodes may contain intensional operators, it is possible to pass to one or more other assignment points when computing.

The intensions and extensions are considered in accordance with the general capabilities of the category model for the nodes of the semantic network, corresponding to the concepts. The extensions are computationally interpreted fairly in a standard way as sets of constants corresponding to the elements of the concept extension. More interesting is the interpretation of intensionals, which can include both sets of constants, and fragments of the semantic network, which should be indicated to get the intensional concept.

Thus, with respect to a set of assignment points that determine the parameterization of the concept shift, two independent shift mechanisms are implemented: (1) the transition from one assignment point to another, performed by intensional operators; (2) the possibility of specifying various fragments of the semantic network for computation at different points of assignment. The second mechanism can be considered as an extension of the method of specifying constants, whose value is functions of higher order (as one of the arguments of these functions is the semantic function of the semantic network fragment), depending on the assignment point. The shifted concepts are defined by this method, and for designation of these concepts include different fragments of the semantic network at different points of assignment.

The activation of included fragments is performed when computing the context, i.e., the set of the assignment point specifying the definitions of intensional expressions (both of the first and of the second type), and also, possibly, the assignments for nested fragments of the semantic network that specify the values of non-local variables in accordance with the general applicative strategy of computation. The activated fragments may contain basic nodes, whose semantics are specified by objects of base category D, the nodes, for which definitions are given (in this case, the fitting is done to take into account the parameterization method), as well as the nodes, whose definitions at the current assignment point are not specified. In the latter case, an exceptional situation is fixed, requiring the concept shift.

The concept shift can be implemented in various ways. The direct specification of a fragment of the semantic network is possible; the fragment should be designed to obtain the designation of shifted concept. It is also possible to set the default reaction, for example, such that the concept recognition function is considered to be identically true or identically false for all constants coordinated with the concept by the type. It is also possible to set a more complicated function that depends directly on a shifted concept or its parameters.

The assignment point, in which the designation is performed, can be generated. For this purpose the semantic characteristics are attributed to the shifted concepts by means of the semantic network. As such the key words in the subject area and the key-value pairs may be applied as well as more complicated characteristics. When performing the designation in the generated assignment point only those nodes of the semantic network are involved in it that have the required characteristics. It is also possible to define a fragment of the semantic network that specifies the conditions for involving vertex definitions in the generated assignment point.

As a whole the proposed mechanism ensures the following:

- way to define concepts taking into account the possible shift and the definition of two basic shift mechanisms;
- way of computing the values of shifted concepts, providing an explicit and implicit specification of the shift method;
- generation of an assignment point for computations that take into account the nature of the shift of concepts.

The environment of network modeling is at the stage of prototype implementation. Some separate environmental mechanisms were tested when solving the problems of supporting the training system in the sphere of the best available technologies implementation in the Russian Federation. In view of the rapid change in the domain, its modeling is associated with the allocation and support of the shifted concepts, and the proposed methods have proved their applicability.

At the same time, during the approbation a number of features are identified, related to the prototype nature of the system and making its application difficult. Thus, syntactically the network is partially specified by a set of programming language constructs, and partially by using the XML dialect. The continuation of the work seems to be necessary to determine the set of syntactic representations that ensure an expressive and succinct description of the semantic network of support for shifted concepts.

VI. Conclusion

The paper considered the problem of supporting the families of shifted concepts to render support to the semantic sustainability of the information system in the course of changing its subject area. The paper suggests the representation of the shifted concepts within the semantic network, which provides a representation of the concept transformations when the semantic characteristics of the presented situation change, as well as the separation of concepts depending on their behavior under such a change.

The following suggestions are made:

- basic mechanism of the concepts shift representation, based on the definition of families of local interpretations of concepts;
- approach to describing the shift of concepts within the framework of intensional logic using a mechanism similar to the continuation mechanism in the lambda calculus;
- technique for implementing the shift of concepts based on the mechanism of partially defined nodes of the semantic network (in particular predicates);
- technique of determining the method of shift based on semantic features, ensuring the generation of families of shifted concepts.

A prototype environment is also proposed for supporting shifted concepts in the form of a network modeling environment that supports the declared abilities. The environment was tested in the presentation of dynamic information for the training system in the sphere of environmental law.

References

[1] Wolfengagen,V.E. Ismailova,L.Y. et al Evolutionary Domains for Varying Individuals Procedia Computer Science, 10.1016/j.procs.2016.07.447

[2] Cuzzocrea A., Sellis T. Semantics-Aware Approaches to Big Data Engineering - Journal on

Data Semantics June 2017, Volume 6, Issue 2, pp 55#56.

[3] Larisa Ismailova. Criteria for computational thinking in information and computational technologies. Life Science Journal, 11(9s):415-420, November 2014.

[4] Gabriella Castro Barbosa Costa. Using data provenance to improve software process enactment, monitoring and analysis. In Proceedings of the 38th International Conference on Software Engineering Companion, ICSE `16, pages 875-878, New York, NY, USA, 2016. ACM.

[5] V. Wolfengagen et al. Migration of the Individuals Procedia Computer Science, Volume 88, 2016, pages 359-364, http://dx.doi.org/10.1016/j.procs.2016.07.449

[6] Conceptual Modeling. Proceedings of 35th International Conference by ed. Comyn Wattiau, I. et al, ER 2016, Gifu, Japan, November 14-17, 2016, Lecture Notes in Computer Science, Volume 9974 2016, 2016, Springer

[7] Population Modeling Working Group. Population modeling by examples (wip). In Proceedings of the Symposium on Modeling and Simulation in Medicine, MSM'15, pages 61#66, San Diego, CA, USA, 2015. Society for Computer Simulation International.

[8] Wolfengagen,V.E., Ismailova,L.Y., Sergey V. Kosikov Computational Model of the Tangled Web Procedia Computer Science, 10.1016/j.procs.2016.07.440

[9] Scott, D. "Advice in modal logic", in Philosophical Problems in Logic, ed. Karel Lambert. Reidel, 1970

[10] Scott D.S. Relating theories of the lambda calculus. # Hindley J., Seldin J. (eds.) To H.B.Curry: Essays on combinatory logic, lambda calculus and formalism.- N.Y. & L.: Academic Press, 1980, pp.403-450.

[11] Scott D. The lattice of flow diagrams. In Symposium on Semantics of Algorithmic Languages, 1971, pp. 311-366, Springer-Verlag.