A KNOWLEDGE-ORIENTED TECHNOLOGY OF SYSTEM-OBJECTIVE ANALYSIS AND MODELLING OF BUSINESS-SYSTEMS

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Abstract: *A new original method and CASE-tool of system analysis and modelling are represented. They are for the first time consistent with the requirements of object-oriented technology of informational systems design. They essentially facilitate the construction of organisational systems models and increase the quality of the organisational designing and basic technological processes of object application developing.*
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The civilization sustainable development is based on formation of the informational society as a first stage of the noosphere. At the same time, as the transition to the informational society, as economic activity in it become based on knowledge. This knowledge represents the "**informational resource**". It directly influences at the material factors of progress and ensures the "phase transition of knowledge into a power", i.e. efficiency of business, production and any administrative solutions.

The submission about the tendency of knowledge-oriented development of an alive nature is entered into scientific practice by V.I. Vernadskiy under a title "*the Dan's principle*". The knowledge-oriented development should be considered as the universal tendency enveloping not only biological, but also all other complicated systems. The social (organizational) and information systems also develop ***in a direction of increasing of a knowledge role for their sustainable functioning***.

This tendency is exhibited in the unprecedented growth of knowledge and scientific information; increasing of a role of inclusive, depth knowledge; rapid development of methods and means of knowledge processing, analytical activity, acute need of the appropriate experts, influence of informational resources to all sides of the human activity. The technologies and methods of purchase, extraction, submission, processing of knowledge (knowledge management, knowledge engineering) in substantial aspect also develop in the knowledge-oriented direction (data mining, text mining, knowledge discovery, knowledge mining, object

modelling, ontological engineering). In the foreign expert's opinion, the development of these directions is broken by absence of the effective methodologies by the availability of developed technologies.
Accumulated in the given spheres experience and potential even more acutely shows the necessity of the account of depth knowledge, objective factors, system and simultaneously object approach to modelling of complicated systems. Grew the role of the veritable human's resource – "conceptual knowledge", which becomes the core of the informational resources, knowledge bases, and ontology models. In such new spheres of the scientific-practical activity as, for example, business process reengineering, decision support making, object paradigm has appeared the similar necessity, which was already expressed in expediency of the organization's mission definition, context account, systems analysis first of all from the point of view of their functionality, correspondence to requests more high level.
The systemology [1] can become the unique scientific basis of such researches. Systemology is a system approach of the new noospheric stage of science development, which comes to change the differentiation of sciences in analytical paradigm - second in the whole history of science after antique stage.
Systemology allows to work successfully with the complicated systems of the first nature i.e. not human created, and with open systems. At the same time, in difference from other system approaches, is ensured the possibility to consider as a system not only objects, but also classes of objects (systems-classes). The development of the systemology of systems-classes has allowed us to synthesize the system and classification analysis for a solution of problems of conceptual modelling of the low formalized problem areas [2, 3].
Systemology most objectively allows getting the next things for the complicated systems of any nature and with any minuteness:

- to understand the reasons of origin, dynamics of becoming and development;
- to define the influence to other systems;
- to explain the outcomes of adaptation and interaction;
- to predict development in various conditions;
- to make conclusions about necessary measures of stable development;
- to prevent crisis situations and to reduce risks;
- to take into account the main properties and priorities.

Systemology really takes into account system effect, i.e. for the first time considers the system as a qualitatively new essence, instead of reduces it to the sum of component parts. It is ensured owing to the consideration of the system for the first time as:

- integral object, instead of as a set;
- the main properties of a system are explained proceeding from properties of a super system;
- the system is considered as functional object;
- "substation" of a system is taken into account, i.e. "material" from which it is made;
- the shaping and operation of a system of any level is considered from "above" and is determined by the "request" of its super system.

Systemology represents an exposition, oriented on methodological use, of concepts and principles of dialectics, which can be interpreted in terms of any concrete science. Besides, it is a unique system approach, which is agreed at a conceptual level not only with formal logic, object-oriented ideology, but also with a complex of modern scientific-practical disciplines engaging the problems of studying and perfecting of organizational systems (the theory of organization, logistics, and business engineering).
Systemological methods can be applied in cognitive direction of researches, which is major component of knowledge-oriented technologies. It is connected first with the orientation on human is now most necessary for maintenance of harmonic interaction of computer systems with the human.
The development and application of systemology in scientific-educational Knowledge acquisition laboratory (NUL PZ) with the cognitive methods has allowed to decide the fundamental, delivered more than 150 years back, problem of a "natural classification" (NK), to reveal and to formalize its regularities and criterions [3]. NK (systematization) as the ideal of a classification is considered as a privileged system chosen by nature, takes into account the essential properties and relations of objects, the maximum amount of the purposes and can form the basis of the most objective and reality adequate models of knowledge. The features of such classification were studied by many scientists, because it has the greatest value, cognitive and prognostic force and makes a basis of a scientific picture of the universe, but only with the help of systemological approach we succeed in opening its laws. The rules of NK can be taken into account in any problem area and

allows creating the effective methods of knowledge systematization and conceptual classification modelling (systemological classification analysis).
The methods of system analysis and instrumental program CASE-tools of their supporting are widely used at the present time for decision of business, administrative and production problems. However, methods and means of traditional system-structural analysis (SADT, DFD, BPwin, etc.), that are used for business-processes modelling, are historically based on procedure-oriented programming paradigm. Therefore the results of their application can't be immediately used during the developing of object-oriented software.
The most of modern program systems, especially large, at present time are created namely within the frameworks of object-oriented approach. However, the object-oriented analysis (OOA) and language UML are primordial used for software developing. Therefore, they are badly adapted for solution of the problems of business analysis and modelling. At the same time, such problems obligatorily arise, especially during the creation of complex program applications. And what is more, a standard process of object-oriented software developing (Rational Unified Process - RUP) begins with the technological process of business modelling.
A given discrepant situation stipulates the actuality of system and object-oriented methodologies integration. The researches in this direction, carried in NUL PZ, allowed to work up a new original **system-object (systemological) approach and** object-oriented **systemological methodology of analysis and designing (OMSAD)** [4, 5], permitting the marked contradiction. Analytic methods and instrumental means of such approach allow automating the considerable part of analytic work and essentially raising its effectiveness.
Let us consider the basic peculiarities of system-object approach and systemological methodology, and also procedures and possibilities of the new method of system analysis, for the first time consistent with the requirements of object-oriented design.
The traditional system approach (analysis) is peculiar to the *procedure* (functional) system decomposition, and object approach – is peculiar to the *object* system decomposition. At the same time all specialists, as of system analysis, as of object approach consider them as orthogonal. In it's turn, system-object (systemological) approach allows to combine exposure processes of the functional and object structure of analysed system. Thus, the basic peculiarity of the given approach is providing the unity of the decomposition of analysed system, as on functional, as on objective (substantive) sign. This reaches due to the consideration of any system not as a set, but as a *functional «flowing» object [1, 2].* Acknowledgement the status of such an object after the system provides a simultaneous calculation of structural, functional and substantial system existence aspects.
To begin with, any system is a component part of the system structure of higher level (super system), because any system is connected and co-operates with other systems. Herewith any link between systems is the process of mutual *exchange* of elements of definite deep layers of connected systems. Thus, a feature of system is understood as manifestation of it's activity to be included into links, into *exchange flows* with other systems in the super system structure. Consequently, from structural point of view a system is a crossroad of incoming and outgoing links (streams), i.e. <u>unit</u> (node).
Secondly, the functioning (activity, work, behaviour) of any system provides or supports the functioning of the super system, to which this support is necessary. At the same time functioning of the system as a support of the functional ability of the super system consists in the providing of the balance of "influx" and "outflow" on the incoming and outgoing links. Consequently, from the functional point of view the system is a <u>function</u>, which provides a balance of incoming into the system and outgoing from the system streams in accordance to that unit, where this system is in the present moment.
Thirdly, any system is not only a unit and function, but also a substance, which plays a role of definite unit in the structure of the super system and provides its functional balance. Consequently, from the substantial point of view a system is an <u>object</u>, realising a function, set by a unit in the structure of the super system.
Given reasoning allows the representing of any system in appearance of the three elements construction – UFO-element (figure 1) [6], i.e. at the same time:

- as the <u>structural element</u> of the super system – unit, as a crossroad of the relations with the other systems;
- as the <u>functional element</u>, doing a definite role for supporting super system by balancing the given unit – function;
- as the <u>substantial element</u> – object, realising the given function in the appearance of some material formation, having constructive, operational and other characteristics.

The basic peculiarity of the OMSAD methodology is the **formal-semantic adaptive alphabet** of the UFO-elements, and also **categorical principle** that is used during the analysis and designing of systems. Alphabet is a collection of units (crossroads of system links), collection of functions, balancing these units, and collection of objects, realising these functions. At the same time, we use facet classification for units collection, defined by the taxonomic categorical classification of the kinds of system's links (figure 2).

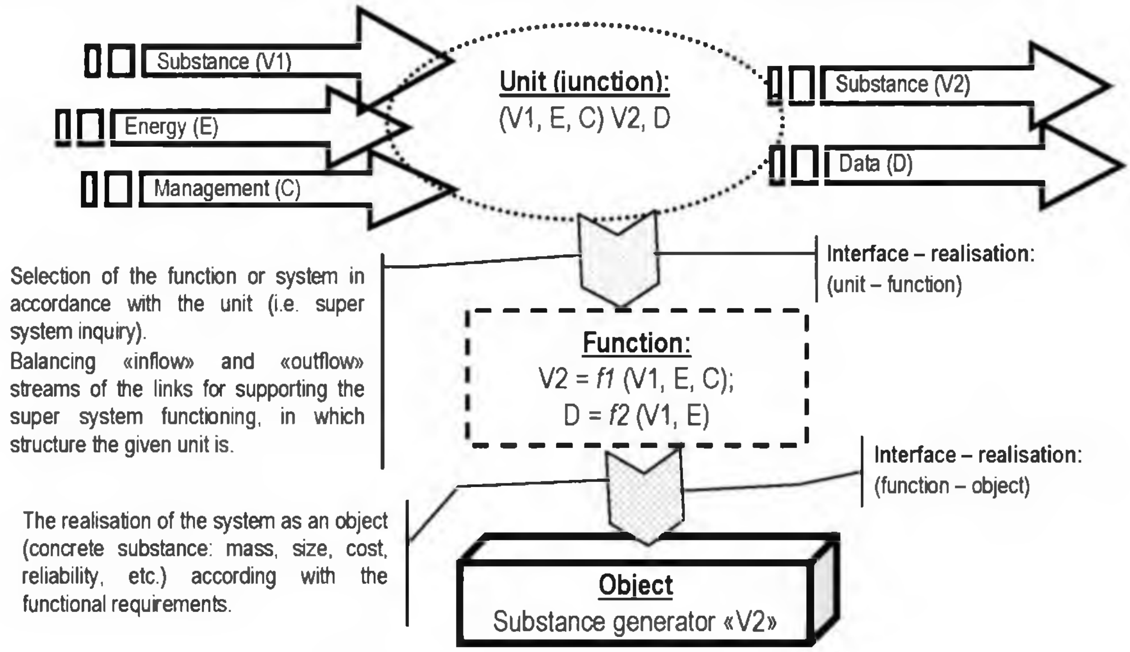

Figure 1. «Unit – Function – Object» approach.

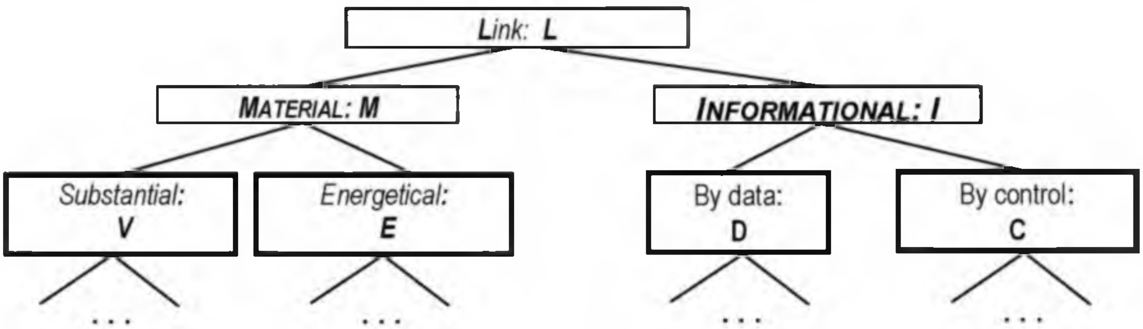

Figure 2. Basic taxonomic classification of system links.

The links classification provides the parametric units classification and constructive determination of symbol semantics of these units. Naturally, the links and units classifications (functions and objects) can be specialised with any degree of accuracy for any concrete domain. The use of classifications for forming the alphabetical collection of the UFO-elements and the possibility of their specialisation turns this collection into the formal-semantic adaptive alphabet.

Parametrical taxonomic classification of UFO-elements represents a classification, in which the objects are systematized depending on functions, which they are realizing, function - depending on what units they are balancing, and the units are determined by that, what crossroad of link they are. This is a conceptual model of application domain in the terms of knots, functions and objects witch plays a role of a " categorical" grid, through which the analyst looks at the domain. The specialization of such a categorical classification model should be carried out in the correspondence with the recommendations of the *systemological classification analysis* offered in the work [3] and directed on the construction of the classifications, witch takes into account the properties and regularities of the natural classification. In the correspondence with these recommendations during the construction and specialization of the classification the good, natural classification will be obtained, if the definite sequence of operations mentioned below is observed.

Any units got by combining of the links from the classification can be considered as alphabetical elements. However with practical point of view it's expediently to consider not all of the possible combinations, but only such ones, which corresponds to the actual physical laws (for example, to preservation laws). Point is that energy does not exist without any material bearer, information does not exist without any material bearer and administration does not exist without any data transmission. This leads to the relatively small number of variants on the level of the links of the base classification (figure 2 In the given tables we use brief markings for data on the material (VD = D) and power (VED = G) bearers, and for control data on the material (VDC = C) and power (VEDC = Q) bearers. This determines that, at present time, only paper (D and C) and electronic (G and Q) information bearers have the wide diffusion.
The use of alphabet (libraries) of UFO-elements allows formulating the combining rules of these elements naturally following from the systemological approach, for constructing UFO-configurations. We offer to call these rules the **rules of system decomposition:**

1. The rule of association: elements should be linked together according to the qualitative and quantitative characteristics of links inherent in them;
2. The rule of balance: during the connection of elements to each other (according rule 1) the qualitative end quantitative balance of the inflow and outflow of input and output functional links must be observed at units of the system structure;
3. The rule of realisation: during the connection of elements to each other (according to the rules 1 and 2) the interfaces accordance and the accordance of the objective and functional characteristics must be observed;
4. The rule of closeness: internal (supporting) links (streams) of elements in system must be reserved.

Offered alphabet and named rules forms **a formal-semantic normative system** of systemological analysis and modelling, formalising by the pattern theory of Grenander funds.

Table 1

		Entries:					Exits:		
		Production	Providing			**Administrator**	**Product**	**Informational**	**Wastes**
			Substantial	**Energetic**	**Informational**				
Business system		V, E, D(G), C(Q)	V	E	D(G)	C(Q)	V, E, D(G), C(Q)	D(G)	V, E
Production	Substance	V_{in}	V_{pr}	E_{pr}	$D(G)_{pr}$	$C(Q)_{pr}$	V_{out}	$D(G)_{out}$	V_{wst}, E_{wst}
	Energy	V_{in}, E_{in}	–"–	–"–	–"–	–"–	E_{out}	–"–	–"–
	Information	$D(G)_{in}$	–"–	–"–	–"–	–"–	$D(G)_{out}$ $C(Q)_{out}$	–"–	V_{wst}
Transport	Substance	V	–"–	–"–	–"–	–"–	V	–"–	–"–
	Energy	E	–"–	–"–	–"–	–"–	E	–"–	V_{wst}, E_{wst}
	Information	D(G), C(Q)	–"–	–"–	–"–	–"–	D(G), C(Q)	–"–	V_{wst}
Allocation	Substance	V	–"–	–"–	–"–	–"–	V	–"–	–"–
	Information	D(G)	–"–	–"–	–"–	–"–	D(G)	–"–	–"–

Besides, OMSAD methodology is using a categorical principle during the construction of models. This principle postulates the necessity of prior assignment (definition) of the synthesised (designed) systems from categorical classification of such systems. Named principle, in fact, in the obvious form fixes the common sense used in the practical analytic work. The point is that decomposition (analysis) and aggregation (synthesis) procedures can be successfully realised only in that case, if they are directed by the final result. During the realisation of synthesis operation, it's necessary to know something at least about the kind of synthesised system, and during the realisation of analysis operation it's necessary to know something about the types of the parts, on which analysed system can be decomposed. Thus, mentioned above alphabet is a

realisation of the categorical principle from the point of view of system analysis procedure. For solving the modelling and designing problems of organisational systems OMSAD methodology is using the systems categories, represented in the table 1.
The experience of the practical using of systemological methodology showed, that context model of any organisation (business-systems), and also of any of it's subdivision, can be represented as unit from the table 1. For example, workshop, model and tool shops, naturally, are represented as the systems of the material production. Department of main constructor, office of the production technical training, economic planning department, accountancy, labour and salary department, marketing department, etc. is represented as the systems of information production. Department of technical control, department of main mechanic, department of main technologist, provision department, sales department, department of technical documentation, etc. is represented as distributive systems.
Formal-semantic normative analysis and modelling system and business-system categories can be considered, in particular, as the development and addition, for example, of the popular technology SADT. As is well known, this technology grants the formal universal possibilities on constructing of the functional business-processes structures. However it doesn't take into account the semantics of the domain and does not give to the analytic the information about the concrete interactions between the analysed systems and their possible filling. So, a context modelling and systems decomposition with the SADT funds are heuristic procedures and don't have any support with the proper CASE-tools (for example BPwin) on the substantial level.
Systemological approach «Unit – Function – Object» and OMSAD methodology allowed to work up a new method of business-systems analysis and modelling (**UFO-analysis**), which allows to adapt it's funds to the concrete data domain, i.e. to take into account it's semantics [6, 7]. Besides, the systems representation with this method as configurations of UFO-elements provides the concordance of the derivable models with the requirements of object-oriented design.
Briefly, the following main steps can represent UFO-analysis procedures:

- Revealing units links in the structure of the modelling (designing) system based on functional links of the system as a whole, defining by the customer or solving problem;
- Revealing of functionality supporting (providing, balancing) found units;
- Determining objects, corresponding to the revealed functionality, i.e. those realising it.

The specific peculiarity of this analysis method is providing automation possibility of these steps. Automation reaches due to using of formally semantic adaptive alphabet. At the same time it's necessary to take into account prepared beforehand classification of UFO-elements (UFO-library), which contains suitable elements for the given problem (data domain). In this case the first step may be identified with the system analysis stage, the second - with it's design, and the third - with it's implementation.
For automated application of UFO-analysis method we developed a program complex «UFO-toolkit», which is the CASE-tool, using knowledge base of the special configuration for providing a component approach to modelling, using semantics of domain and intellectualisation of interaction with user [7]. The tool is intended for object and simulation models construction of complex dynamic (organisational) systems. It has the following features:

- noticeably reduces the designing labour-output ratio owing to intensified automation of analytic activity;
- increases the objectivity of the analysis and the adequacy of modelling;
- automates a models creation process, through the use of ready (alphabetical, library) functional objects, presented in the knowledge base of the Tool in the form of UFO-elements;
- provides «intelligent» interaction with user, making familiar the ready component (UFO-elements).

At the same time if alphabetical elements appear to be program objects, realised as ready classes, then we can talk about UFO-analysis as a part of component technologies and business-objects technology CORBA (Business Object Facility – BOF). In the last situation the program CASE-tool, automating UFO-analysis procedures, can function within the frameworks of component business-objects architecture (Business Object Component Architecture – BOCA). At the same time, it will carry out an organiser (Framework) role, which, integrating business-objects into the functioning system, gives them the working places for realising their tasks. If we consider the alphabetical elements as the engineering elements, then UFO-analysis will be confirmed with the CALS-technology.
Thus, UFO-analysis method represents the development and concrete definition of the OMSAD methodology. It allows to use the formalised rules of revealing classes and objects of application domain during the OOA

process and to realise the system analysis of the events of different nature, considering them as functional flowing objects. Consequently, UFO-analysis can be considered as the method of system-objective analysis and modelling.

On the whole the considered method and Tool (UFO-technology) provide to user:

- objectivity of analysis and synthesis procedures of organisational systems;
- economy of the man-hours of analysis and modelling, because these procedures both comes to the construction of only one model;
- simplicity and availability of the business-processes analysis and modelling by specialists without special training;
- uniform presentation of external and internal models of the business-system, described by the same modelling language;
- facilitate of models adaptation to the concrete domain (taking into account the semantics domain);
- the possibility of creation and use the libraries (repository) of the model components for different application fields.

Besides, they have the following merits:

- provide the concordance of the system analysis results with requirements of object-oriented design, previously considering as orthogonal;
- provide a possibility of immediate use of the system analysis results during the creation of object-oriented software;
- raises the level of formality and automations of the modelling and analysis procedures;
- guarantee a concordance of all system characteristics due to unification of the different system consideration aspects in one model;
- provide facilitate of the construction of visual models of different abstraction level, representing at the same time a functional and objective structure of system;
- provide a possibility of the modelling of functional system characters, not having a mathematical interpretation or interpreted by any mathematical means, and also simulation of system functioning without any special modelling algorithm.

Represented analysis and modelling technology is used for correcting information-analytic business-systems accompaniment and provides an essential rise of the effectiveness of their activity. Developed method and program tool essentially facilitate the construction of organisational systems models and increase the quality of the organisational design and initial technological processes of developing object applications.

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