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Chapter 8

Generating Scientifically Proven Knowledge about Ontology of Open Systems. Multidimensional Knowledge-Centric System Analytics

Tamara L. Kachanova, Boris F. Fomin and
Oleg B. Fomin

Additional information is available at the end of the chapter

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Abstract

Physics of open systems overcomes real complexity of open systems, perceives them in natural scale without resorting to expert knowledge, subjective analysis and interpretations. Its scientific methods and technologies produce scientifically proven ontological knowledge from the systems' empirical descriptions that in turn are gathered from a huge amount of semi-structured, multimodal, multidimensional, and heterogeneous data, provide scientific understanding and rational explanation of obtained knowledge, research its value (correctness, fullness, and completeness), and carry out a deep and detailed analytics of multidimensional open systems on the basis of knowledge about their ontology.

Keywords: open systems, Big Data, physics of open systems, ontological knowledge, knowledge mining from empirical data, value of ontological knowledge, multidimensional knowledge-centric system analytics

1. Introduction

Open systems are being exchanged with environment by substance, energy, and information. The fundamental laws still unknown to science define organization, existence, states, and evolution of such systems. For producing reliable knowledge about open systems, it is necessary to have a well-developed theory. Such theory has arisen within the frame of interdisciplinary branch "Physics of Open Systems" (POS) [1]. Its top purpose is a scientific understanding of the essence of complexity and rational explanation of deep relationship of complexity with laws of nature. POS perceives complexity of systems as complexity of movement.

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Big Data about open systems are created and continue to be incrementally created by empirical science. A new direction of POS came into being in the mid-1990s. Within it, the formation of cyber-physical paradigm of systemology, whose goal is to research open natural, social, anthropogenic, and complex technical systems, given by empirical descriptions, goes on [2–4]. *Further talk is only about this new paradigm of POS*. POS can be used for any self-sufficient totality of empirical data representing a certain slice of the system being researched in its natural scale and real complexity. Its main purpose is to overcome the fundamental complexity of open systems.

Scientific knowledge cannot be obtained from empirical data by purely logical means. Ontologies of scientific and empirical knowledge are significantly different. POS generates scientifically proven knowledge about the ontology of open systems from a huge amount of semi-structured, multimodal, and heterogeneous data. Scientific methods of POS are implemented: in technologies to automatically mine ontological knowledge about open systems directly from empirical data; in technologies of both scientific understanding and rational explanation of obtained knowledge; in technologies to analyze the value (correctness, fullness, and completeness) of knowledge; and in technologies for applying ontological knowledge about open systems in analytical, projective, and cognitive activity. On the basis of POS, the following activities are being performed: the mastering of a huge amount of data that are collected by empirical science; creating and exploiting the knowledge bases containing a scientifically proven ontological knowledge; and producing informational, intellectual, cognitive, and technological resources of knowledge as well as resources for solving complex system problems. POS assists in overcoming technological barriers of interdisciplinary interaction, helps to accelerate dynamics and improve flexibility of collaborative researches related to large-scale system problems in different branches of knowledge. Methods and technologies of POS has led to formation of multidimensional knowledge-centric computer analytics of open systems, that works with hundreds and thousands of variables, and operates automatically, without resorting to expert knowledge, subjective analysis and interpretations.

2. Conception of POS

Concept "System" is the initial and main concept of POS where a universal concentrated image of senses of the phenomena of the real world obtains its expression, and through which both scientific understanding and rational explanation of empirical facts are being achieved. At conceptualization of POS the following concepts play a key role together with the concept "System:"

- *relation*—is a condition of systemacity of the real world; an implementation of the principle of relationship universality; a manifestation of the unity of the whole; a carrier of regularity;
- *harmony*—is the fundamental basis of the unity of the whole comprehended through self-consistency, self-movement, inner conditionality, and orders;
- *symmetry*—is a particular physical equivalent of harmony; a harmonically conjugate unity based on the idea of form; the fundamental regularity; a tool to discover both hidden forms of system organization and higher synthetic system unity;

- *interaction*—is a fundamental understanding of the system's genesis; an interpretant of universal mechanisms of the system's self-movement and which discloses the system's senses encrypted in constructs that also are referents;
- *constructs*—are referents of deep system senses; polyadic system-forming relations endued with a characteristic symmetry and special system attributes;
- *structure*—is the base for existence of reality, the base that includes a multiplicity of steady relations; elements of at-oneness arising as a result of form-making processes.

2.1. Scientific approach

There are three ideas that shaped the scientific approach of POS:

- a scientifically proven knowledge about the ontology of open systems can be mined from big sets of semi-structured multimodal heterogeneous multivariate empirical data;
- a fundamental barrier of open systems' complexity can be overcome by identifying characteristic symmetries that disclose systems ontology;
- an open system obtains full, complete figuration in the state space whose organization is defined by the system's ontology.

Initially, the concept "System" arises without definition. A central problem of POS is to develop a scientific definition of this concept, to organize semantic sphere of system knowledge, and also its constructive figuration, and to reconstruct the system's essence as a one whole (**Figure 1**) [5, 6].

The triad "*Symbol – Word – State*" expresses an idea of cognition, understanding, and explanation of system's ontology. Semantic organization of the system ("Symbol") discloses organization of

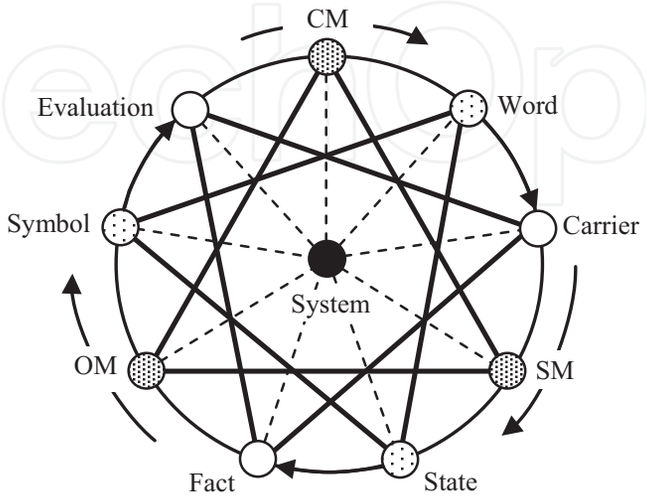


Figure 1. Definition of concept "system".

system's multiqualitative unity. Semantic activity of the system ("Word") is being manifested through qualities and properties of all elements and all parts of the system organization which are generating the system's language. Semantic forms of the system ("State") define formal synthetic image—reconstruction of the system unity able to be embodied in objects of reality. Ideal abstract forms of representing ontological knowledge have an absolute value. Through the concept "Symbol," the sense of concrete system went over into "expressive sphere," knowledge has obtained an adequate figuration, like a "*system in itself*." Through the concept "Word," the semantic significance of elements of ontological knowledge is disclosed to be understood like a "*system for itself*." Through the concept "State," both the states and regularities of generation of system's states became understandable ("*system for others*").

The triad "*Symbol – Word – State*" has its reflection in the triad "*Fact – Evaluation – Carrier*." This triad is engrained in observed reality ("Fact"), is in contact with reality through objects of reality ("Carrier") and establishes measures to express ability of the fact to perceive and undertake senses embodied in the carrier ("Evaluation"). The first concept of the triad ("Fact") expresses *hypothesis about the system* manifested in observed reality. The third concept of the triad ("Carrier") *connects hypothesis about the system with defining the system taken as "a whole" through system actual states*. The second concept of the triad ("Evaluation") evaluates *validity of this hypothesis*.

The triad "*OM – CM – SM*" is a modeling triad presenting methods of cognition of system's ontology (*ontological modeling—OM*), methods of understanding of system's senses (*communicative modeling—CM*), and methods of figuration of system's idea (*states modeling— SM*).

Both, the second concept "Evaluation" and relationship between concepts "Fact" and "Carrier" (triad "Fact – Evaluation – Carrier") demand that the definition should be extended [7] (**Figure 2**).

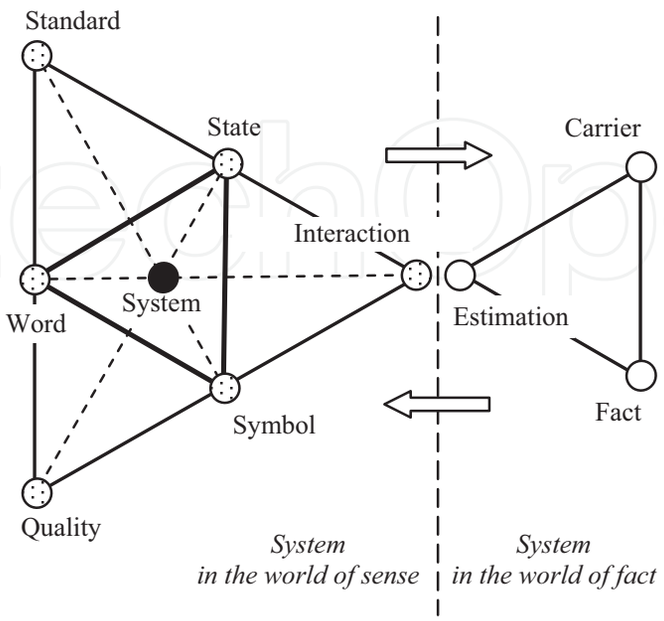


Figure 2. Extension of definition of the concept "system".

Such extension creates *axiological level of knowledge* [8]. At the axiological level of knowledge, the problem of value (correctness, fullness, and completeness) of ontological knowledge is solved. This level of knowledge is specified by the triad "Quality – Standard – Interaction." In measures of truth of sense and value of ontological knowledge it expresses a relationship between the worlds of system's sense and system's fact [9]. As a result of extending the system's definition, the triad "OM – CM – SM" includes (together with cognition, understanding, and explanation of ontological knowledge) also a value analysis of this knowledge. Application of the scientific method of POS to concrete system produces true knowledge to which certain value corresponds. The moment "Quality" define degree of the value of obtained forms in measures expressing the fullness of manifestation and depth of insight into the system's senses. The moment "Standard" states the measure of comprehension of disclosed and understood system senses by its real carriers. The moment "Interaction" measures degree of reconstructing the system's unity (as a whole), from the set of the system's states.

2.2. Methodological foundations

POS has proposed a logically complete system of concepts that are revealing sense of system's genesis. The following has become methodological foundation for this system [4, 5, 10]:

- a constructive definition of the concept "*System*;"
- a philosophical system of doctrines and fundamental concepts about senses and relationship between senses of the system in the chain of acts of cognizing the system's ontology (*doctrinal model*);
- basic concepts in their dialectical relationship that form a unified, holistic, and hierarchically arranged conceptual structure (*dialectical model*);
- stages of both cognition and creation of structural images of the system's senses on the basis of measure category and universal principle of symmetrization-dissymmetrization (constructive-methodological model);
- a set of sense relations that transfer all specific intrasystem regularities by way of generative and expressive moments (*symbolic model*);
- agreements about organization and use of the systems language (*language convention of POS*).

2.3. Principles to which POS conforms

POS is aimed at researching complex large-scale objects (phenomena and processes), they can be not only (and not necessarily) of physical nature. POS proceeds on the assumptions that if there is empirical description of object properties, its states, and conditions of its existence, that is enough to discover the essence of this object. POS considers the system as a tool for cognition of complexity and as special dimension of reality. POS, in its becoming and development, is based on the following principles:

- *principle of systemacity* (all objects that are carriers of the system states are ontologically united);
- *principle of holism* (system integrity is being stated);
- *principle of objectivity* (empirical fact is a unique source of objective data about system);
- *principle of compliance for system's observation channels* (uniform set of states variables; indicators sensitivity to various states; unified procedure for scaling measurements);
- *principle of counting quantities* (counting quantities are structural elements of every kind at each stage of cognition, understanding, explanation, and estimation of the system's ontology; the number of counting quantities is of special importance);
- *principle of complexity actualization* (initially, structures of binary relations of variables of the system's state are the carriers of heterogeneity intrinsic to the system);
- *principle of symmetry* (structures of binary relations in the system are being harmonized);
- *principle of subordination* (order parameters of the system define behavior of all system parts and elements);
- *principle of denotation* (referents of standards of states of the system's eigen qualities are the carriers of the system's state);
- *principle of desemantization* (ontological knowledge about the system is being transformed into understanding and rational explanation of the system's phenomenon);
- *principle of value* (relation of correctness, fullness, and completeness of ontological knowledge);
- *principle of assembling* (in each state, the system is a whole; reconstructing each system state is an assemblage of standards of states of the system's eigen qualities).

2.4. Axioms of the system

The base of POS is the system's axioms—are predicates of harmonization and systemacity, which explain the general idea to resolve heterogeneity inherent in the system, they assert statements of fundamental properties inherent in the system at various levels of cognition of its ontology [2–4].

- *pre-image axiom* (universal principle of harmony and the law of analogy);
- *axiom of relations harmonization* (in the system, all quantities are conjugate and proportionate, their variability is consistent);
- a*xiom of role contingency* (all quantities in the system have role definiteness; the system is able to change role definiteness of its quantities);
- *axiom of orientation* (fundamental carriers of the system's senses have spatial orientation; conditions when mechanism of inner orientation is being manifested in the system, are postulated);
- *axiom of determination* (the system in each of its qualitative definiteness knows unique dividing line between the big and the small at quantities variability).

2.5. Symmetries of forms of system organization

Symmetry displays harmony at the level of such categories as "the part" and "the whole," and manifests itself as unity of identity and distinction, conservation, and change. Cognition process of system ontology is being understood as disclosing more deep and general symmetries. Ascension from the symmetry of one level to another is related to discovering dissymmetry and to comprehension of facts of dissymmetry that are considered as variety sources, and which are subordinated to other deeper and general symmetries.

POS has discovered symmetries of forms of system organization [2–4]:

- *signed balance* (it states system attribute named "*Level of quantity values*");
- *symmetry of singlet* (main axial symmetry; it states system attribute named "*Role charge*;" it generates all kinds of system units);
- *symmetry of doublets* (it reveals senses of role charges: mirror symmetry (it states base interaction named "*Similarity*"); mirror-mirror symmetry (it states base interactions that named "*Switching*" and "*Absorption*"); axial symmetries 1 and 2; symmetry of rotation);
- *symmetry of triplets* (it states types of orientation: general axial symmetry (it states system attribute named "*Orientation*"); planes of symmetry 1 and 2);
- *symmetry of system units* [*point of symmetry* (*it introduces order center*); main axial symmetry (it reveals system organization in each *qualitative definiteness* of the system)].

3. Scientific foundations of POS

3.1. Reconstructive analysis

Solving of the general problem of reconstructive analysis of open systems on their empirical descriptions became the basis for creating POS. Method of reconstructive analysis has overcome the barrier of complexity of open systems and has provided the possibility to mine scientifically proven knowledge (about the ontology of open systems) from the big polymodal sets of heterogeneous empirical data with hundreds and thousands of variables [4, 11, 12]. Method of reconstructive analysis is not resorting to expert knowledge, subjective analysis and interpretations. Models of cognition of open systems, also systems axioms and principles of system's genesis act as a methodological base for reconstructive analysis. On their basis, *the semantic generatrices of the system, full reconstructive set of system models, and families of interaction models* are produced.

Semantic generatrices of the system are represented by *families of formal constructs with characteristic symmetries of forms of system organization*. Each model of reconstructive set of system models is:

- an underlying structural invariant of open system;
- a part of one whole (of the system) and also—all whole (of the system) in the context of this part;

- n-ary relation with fixed structure and morphology, axial symmetry and order center;
- a unique feature of the system, an abstract form of expressing certain quality inherent in the system.

The families of interaction models are 0-, 1-, 2-, 3-ary simplexes with s*pecific symmetries revealing the mechanisms of system's genesis*. Method of reconstructive analysis reveals multi-qualitativeness (complexity) of the system, presents the system in all its qualities, discloses the full families of models of intra-system interactions forming one whole from the set of all qualities inherent in the system.

3.2. Language of systems

A creation of systems language was of fundamental importance for POS, when it formed and developed as a "scientific method." The systems language has led to scientific understanding of ontological knowledge and to defining its value (correctness, fullness, and completeness).

Inner systems code manifested in ontological knowledge was revealed and understood. Language of systems overcame differences of methodological bases and eliminated technological barriers of scientific understanding of open system. Understood senses of systems became equally accessible to experts in different domains of knowledge. Through the language, the *postulates of reconstructive analysis have obtained the status of postulates of scientific theory*.

Language of systems is characterized through: lexical composition (*words, concepts, concepts qualities*); nominative units; paradigmatic and syntagmatic relations; assessment systems (*evaluation aspects, ideals, evaluative propositions, and assessment scales*); and computability of concepts qualities, concepts and words of the systems language (*axiological operators*). Language of systems has formalized and organized system thinking, has increased interdisciplinary interaction, has led to scientific understanding of the ontology of open systems and value of ontological knowledge obtained from empirical data. Both, reconstructive analysis and language of systems *became the scientific basis for creation of informational, intellectual, cognitive and technological resources of system knowledge* [5, 7, 13].

3.3. States, properties, and evolution of systems

Solving the general problem of rational explanation of ontological knowledge about open systems became the third essential result in formation of POS [7, 14]. The answer to the question—"… how system-wide, abstract, extra-subject, ontological knowledge about open systems (in force field and in relation to order parameters) is related to key concepts in the real world of systems (variables, states, properties of variables, properties of states, variability of quantities, variability of states, and variability of properties)?"—was obtained. The system regularities determine variability in "order parameters." Variability in "force field" is explained by the spectrum of system's possibilities. As a result of this decision, POS gives a rational explanation for relationships: between system's ontology and reality, system regularities and properties of system's carriers, system-wide regularities and predeterminacy of system's phenomenon.

3.4. Representation forms of system

POS works with systems' representations defined in feature space, space of qualities, linguistic space, state space, and space of system's behavior. In each space, the system has its own special forms of implementation [7, 14] (**Figure 3**).

System in Data is given in actual states by values for variables of state and environment (initial representation of the system). *System in Relations* is defined through attributed binary relations between variables (this initial abstract representation of the system is obtained directly from the System in Data). *System in Qualities* is given as a full set of its eigen qualities (this representation of the system arises as a result of overcoming the complexity of open systems). *System in Standards* is represented by images of ideal states of its eigen qualities able to transfer onto actual states of the system. *System in Linguistic Space* is represented by words, concepts, concepts qualities, and evaluations of concepts qualities of the systems language. *System in Forms of Standards Implementation* is shown by a full model set of the forms of standards implementation in the system's carriers. *System in States* is displayed by a full model set of system's actual states (states' reconstructions).

3.5. Ontological knowledge

Ontological knowledge represents system in three spaces: qualities space, linguistic space, and state space [5, 7].

Model of Qualities Space reveals complexity of the system taken as a multiqualitative essence, through a full set of formal system models and full sets of the models of intrasystem interactions.

Model of Linguistic Space gives a reasoned and scientifically understood space of eigen qualities of the system. The problem of reference of this space is solved by means of the systems language. Words and concepts of systems language as well as explications of semantic content of

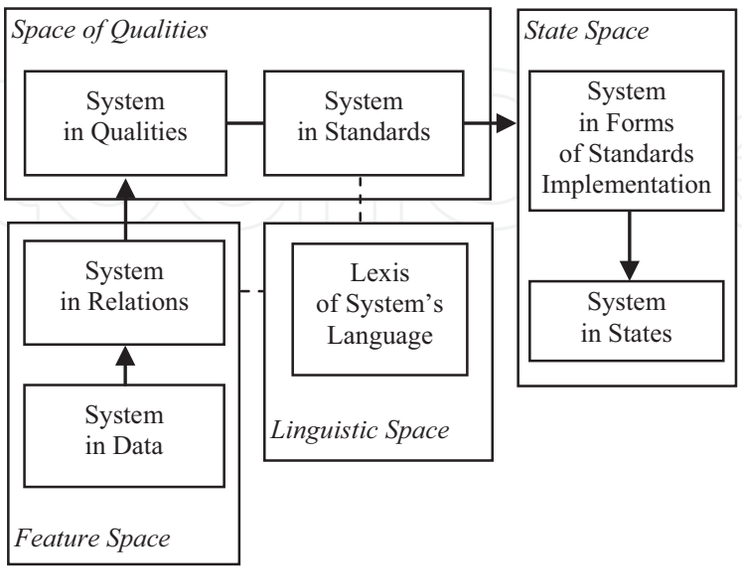


Figure 3. System in spaces of POS.

the system define Lexical Portrait of System. Evaluations of Concepts Qualities establish the relationship between linguistic space and qualities space.

Model of States Space constructively identifies system as "a whole" through system states and system-making interactions, and sets the conditions, rules, and limitations on forming and changing states of the system. States Reconstructions explicitly represent scientifically proven knowledge about actual states of the system. Models of Implementation Forms of standards map the space of eigen qualities of the system to its feature space. The feature space is structured. Obtaining reconstructions of all actual and potential states of the system is provided. Ontological knowledge has a two-level structure—knowledge elements and a base knowledge (**Figure 4**).

On the level of "Knowledge Elements" the sets of formal constructs—semantic generatrices of the system—are presented. The level "Base Knowledge" contains models of eigen qualities of the system, interaction models, and models of the system's states.

3.6. Axiological knowledge

Including axiological knowledge into explicative statements leads to objective description of open systems considering them as man-sized objects. Axiological knowledge represents evaluations of knowledge resources [5, 7] (**Figure 5**).

Information resource of knowledge sees the system as an empirical reality, defines the ability of system's empirical description to manifest, and express senses of the system in full and complete form. *Intellectual resource of knowledge* includes families of formal models of the system's qualities and models of interaction, provides qualimetric measures of the system models. *Cognitive resource of knowledge* contains collections of elements providing creation of constructively defined formats for cognitive schemas of intrasystem mechanisms. *Technological resource of knowledge* covers models of both states and properties of the system as a whole, and gives variety of evaluations to characterize completeness and adequacy of states models of the system as an integrated whole, in the context of relatedness of empirical fact and system sense. Axiological knowledge consists of the following:

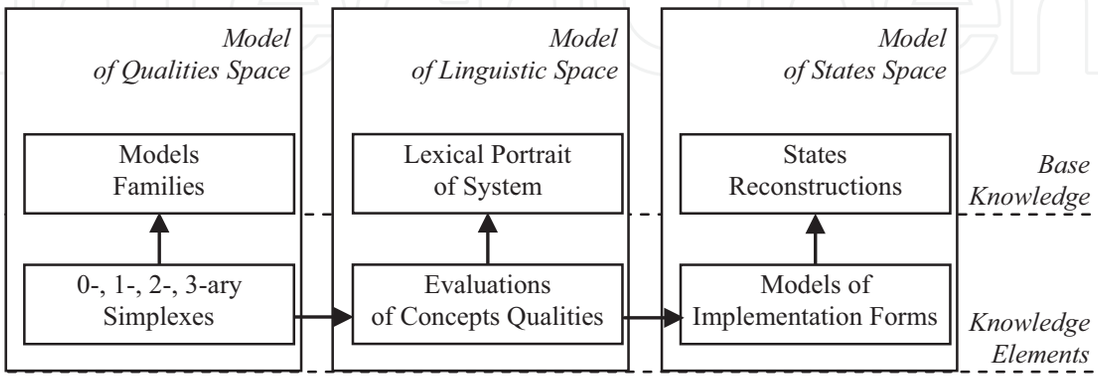


Figure 4. Organization of ontological knowledge.

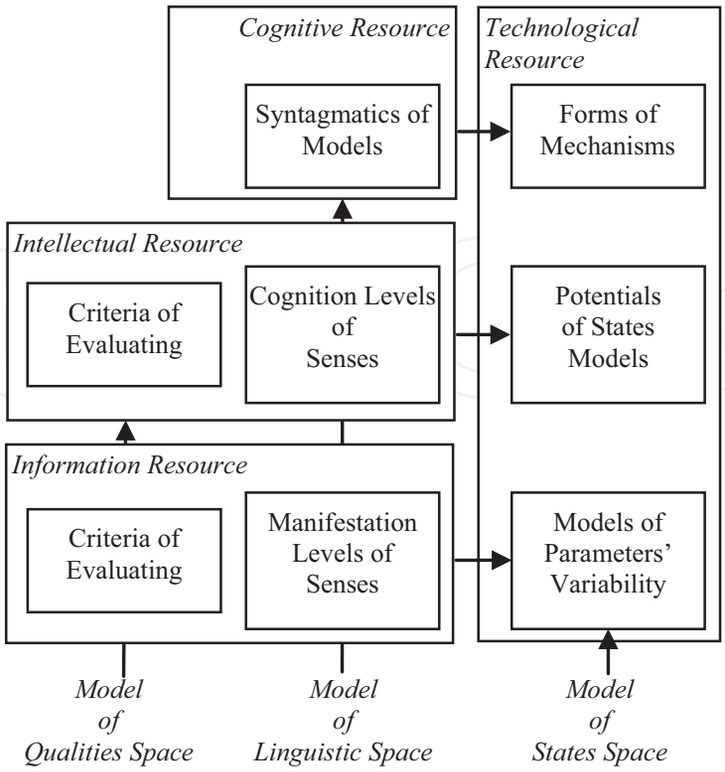


Figure 5. Evaluations of knowledge resources.

values of representation forms of the system; ideals and norms of these forms; measurement scales and procedures of estimating the value; and characteristics of correctness, fullness, and completeness of system knowledge. Value-based orientations discern the real and ideal; they discriminate correct knowledge from incorrect one; full knowledge from insufficient one; complete knowledge from incomplete one; as well as significant and essential knowledge from insignificant and inessential one.

4. Analytical core of POS

4.1. Possibilities of analytical core. Composition and structure

Analytical core of POS (AC POS) is an "intelligent machine" that is able [7, 11]:

- to automatically discover scientifically proven knowledge about the ontology of open systems from huge multidimensional sets of multimodal heterogeneous empirical data, without resorting to expert knowledge, subjective assessment, simplifications, and interpretations;
- to automatically provide a scientific understanding and rational explanation of obtained ontological knowledge;

- to automatically research the value (correctness, fullness, and completeness) of both revealed and scientifically understood ontological knowledge;
- to automatically generate informational, intellectual, cognitive, and technological resources of knowledge about the ontology of open systems.

AC POS includes three components (**Figure 6**):

- integrative component (it organizes interrelationship and uses elements of AC POS, and it will not be considered further);
- technological component;
- qualimetric component.

Ideas, approaches, and scientific methods of POS have been fully implemented in technologies of technological and qualimetric component. Technologies of *technological component* produce ontological knowledge, whose attributes are: truth, thingness, determinacy, concreteness, logical substantiation, verifiability, theoretical and empirical validity, and applicability. Technologies of *qualimetric component* create axiological knowledge, whose characteristics are the categories of value. Technologies of POS are universal and used in various areas of knowledge for large scale and deep research of natural, social, anthropogenic, and complex technical systems.

Empirical data systems (EDS), at input of AC POS, represent comprehensive empirical contexts of certain open systems and certain system problems related to these systems. For each open system, its data set complying with the requirements of POS is being formed. Its preparation consists of gathering empirical data, integrating, and systematizing collected data, and forming big data sets covering all basic aspects of systems' existence within a changing environment. POS don't consider solving these problems as its problems. Their solution is provided by Big Data technologies that have necessary functionality (for example, open

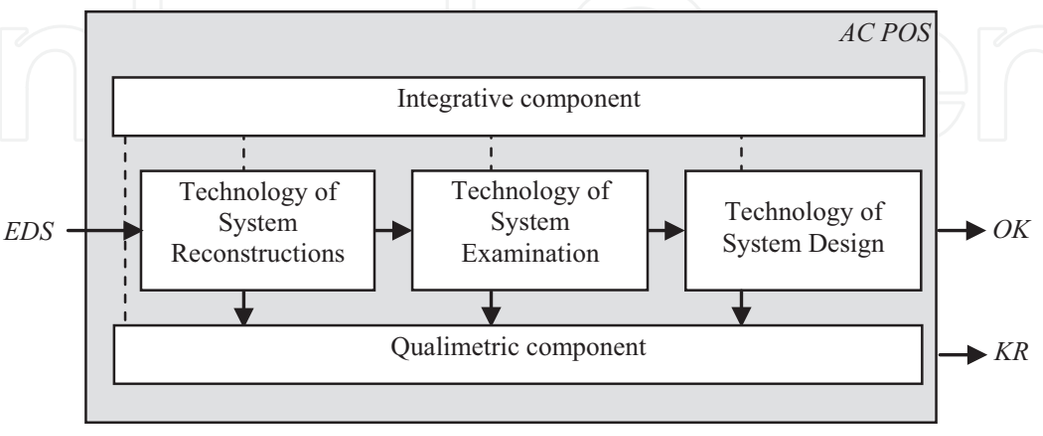


Figure 6. Layout of AC POS: *EDS*—empirical data system; *OK*—ontological knowledge; *KR*—knowledge resources.

platform Hadoop (IBM) or a product set of Oracle Corporation used to gather data and to systematize them). Interests of POS cover problems related to forming empirical contexts of open systems:

- vision development of systems and system problems, also their verbalization, isolation, and estimating scale and complexity;
- determining volume and nature of empirical data which, according to opinion of subject-matter experts, are appropriate for producing knowledge about the system and about system problems;
- discovery of possibilities, sources, conditions, rules, ways, and technologies for data supply that are used to form the empirical contexts of high quality.

Ontological knowledge and resources of knowledge at output of AC POS are results of the technological and qualimetric component. On their basis the scientific methods and computer technologies of multidimensional knowledge-centric system analytics of POS are being created.

4.2. Technologies of cognition, scientific understanding, and rational explanation of the ontology of open systems

Technology of System Reconstructions (*TSR*) on the basis of initial empirical context of the system produces the system's representation in eigen qualities and creates a complete set of models of intrasystem interactions [15]. *Technology of system examination* (*TSE*) transforms the system's representation given through eigen qualities, to representation of the system in standard states of its eigen qualities [14, 15]. *Technology of system design* (*TSD*) synthesizes adequate models of actual states of the system, researches emergent properties of the system, generates, shapes, and represents ontological knowledge about the system for further use [14, 15]. The organization of each of these technologies is disclosed according to unified scheme, beginning with the technology model and finishing by the patterns for automatically generated normative documented reports about obtained ontological knowledge [7, 12, 14]:

- *technology model*—sets the scheme of cognitive process [*process of ontology cognition* (for TSR), *process of understanding ontology* (for TSE), *and process of ontology explanation* (for TSD)] in its main concepts that are structured by categories of the system's representation and deployed according to stages of the process;
- *dual way* of cognitive process [*process of cognition* (for TCR), *process of understanding* (for TSE), *process of explanation* (for TCD)]—includes two stages (the *ascending* from fact to sense, and the *descending* from sense to fact). Each stage in a special way expresses inter-conditionality between the two worlds of the system—i.e., world of facts and world of senses;
- *key objects of technology*—represent (for TSR, TSE, and TSD accordingly) main concepts of the technology model in constructive and computable forms;

- *technology method*—sets computational procedures (for TSR, TSE, and TSD accordingly) that are needed to automatically generate the technology objects and their attributes, the procedures are based on own scientific apparatus of POS and on additional external methods of measurement theory, mathematical statistics, graph theory, set theory, mathematical logic, estimation theory, qualimetry, and computer visualization;
- *measurement scales*—represent values of attributes of technology objects: scale of values, and groupings scale—are tools for measuring the system's properties in TSR; scale of levels and scale of level's numerical forms—are used to evaluate concepts qualities in TSE; also a complete scale of level's numerical forms, weight scale, scale for measuring proximity to standard, also scale of level's predominance, scale of level's predetermination, and scale of significance and mobility of level—are instruments to measure the system's states in TSD;
- *patterns for normative documented reports of technology*—set the structure, sections content, and formats of knowledge representation.

In the case of TSR, normative reports represent *the system's portraits expressing ontological knowledge that has been revealed*: empirical portrait, statistical portrait, structural portrait, system portraits (ones of type, and ones of type forms), and realistic portrait. In the case of TSE, normative reports represent *scientifically understood ontological knowledge*: knowledge quality, knowledge volume, and each aspect of knowledge. In the case of TSD, normative reports represent *shaped ontological knowledge*: knowledge about the system as a whole, knowledge about the system's standards, and knowledge about the system's states.

4.3. Technology to analyze the value of ontological knowledge

Qualimetric component of AC POS performs multifaceted research on the value of obtained ontological knowledge and generates axiological knowledge about the system. In the ideal case, the system initially is represented by complete representative system of empirical data. After this, the technologies of cognitive processes of AC POS guarantee production of scientifically proven (formally correct), full, complete ontological knowledge about the system. In real situation, the technologies of AC POS generate correct knowledge that is not full and complete. Value-based and evaluative aspects of axiological analysis of the system's ontology discovered by cognitive processes are being researched in all such cases and in full.

Formal correctness is an important moment of ontological knowledge. Besides correctness, knowledge possesses value. These two moments oppose each other, complement one another, moreover none of them cannot be reduced to or replaced by another one. *Correctness relation* is being established between the object vision and the object itself, and is expressed through abstract descriptions. The object is the main thing here (an unchangeable element of correctness relation). The object vision is a variable element of correctness relation. *Value relation* is being established between the object and the statement about the object, and is given in evaluations. The evaluative statement about the object is the main thing here. If correspondence between elements of the relation is absent, then the object (but not the evaluation) should be changed.

Essence of value (value of element of system knowledge); *existing value* (subject-object relation between the system analyst and the object)—they serve as aspects of value. Essence of value reflects *potential value*, whereas existing value manifests *actual value*. Qualimetric component of AC POS computes estimates of potential value of knowledge. The question about actual value is related to choice of orientation at applying knowledge. Actual value is corresponds to the concepts of usefulness, degree of intensity, and tension measures. The system analyst addresses these concepts at certification of valued knowledge.

Technologies that form the technological component of POS disclose ontological knowledge about the system through the objects ("Models," "Attributes," "Words," "Concepts," "Concepts Qualities," "States," and "Properties"). They take a certain form for each system being researched [5, 7] (**Figure 7**).

Element "*Definiteness*" of the process of knowledge assessment forms value vision of elements of system knowledge that characterize the system as a whole. Element "*Order Existence*" describes value of knowledge about the system in whole and in parts of the whole. Element "*Explanation*" expresses the value of any element of disclosed scientifically understood and rationally explained knowledge about the ontology of open system. Organization of each element of value-based and evaluative process is being described according to unified scheme: element's model; knowledge value; process of evaluation; ideals (norms and samples); estimates; evaluation scales; and patterns for normative reports.

Element's model discloses a process of generating objects of each technology that is part of technological component of AC POS, evaluates these objects, and, where possible, improves objects being evaluated, thus improving the quality of generated knowledge.

The *value* is an essential property of ontological knowledge. Principles of value gradation are the following: knowledge *orientation* (disposition "well/badly"); *intensity* (expressiveness degree of value of knowledge elements); *preferability* (a value distinction and establishing an order for value); *includability* (consistency of given value with other values). Value is expressed in *evaluative proposition*. It includes: the object of evaluation (knowledge element); character

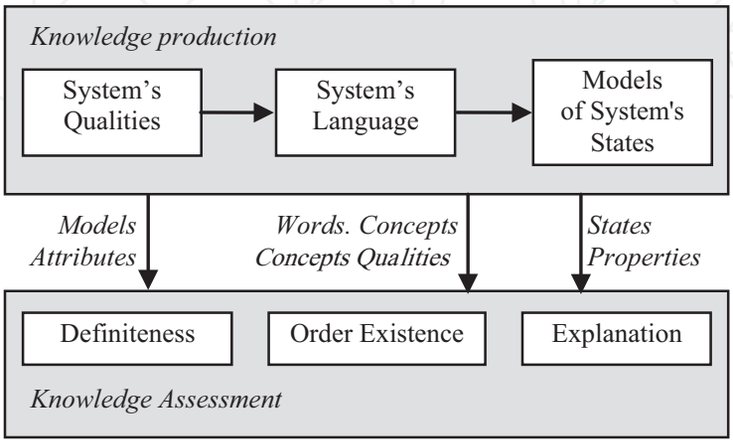


Figure 7. Relationship of cognitive process with value-based, evaluative process.

of evaluation (absolute or comparative); basis of evaluation (aspect of estimating); and the subject of evaluation. *Absolute evaluation* is being applied towards one evaluative object, is expressed in terms of "well/badly," and uses a concept of ideal. *Comparative evaluation* is being applied to at least two objects or two states of the same object, and is expressed in terms of "better/worse." Preference relation is being introduced through comparative evaluation. In general case, an absolute evaluative concept cannot be defined through comparative evaluative concept and vice versa.

Ideal is the starting point in forming absolute evaluations. Ideal is being perceived as a methodological construction which is constitutive for evaluation process and plays role of semantic invariant for different certain forms of the system's representation. Such invariant discloses value content and sets an absolute expression of value or the expression that should be. Ideal is a form of rational understanding, creating, and transforming techniques of the system's representation. Rationality and constructibility of ideal are being manifested through concepts of essentiality, allness, fullness, perfection, and integrity of knowledge. Ideals are always unconditional, absolute, and self-sufficient. A concept "*Sample*" is introduced for rational figuration of the sense of ideal. If the system's senses in ontological knowledge obtain certain figuration, but at the same time some semantic moments of the values have not obtained absolute and unconditional expression then ideal is being replaced by norm. *Norm* is a concept similar to ideal but it differs by its concreteness, attachment to forms of the system's representation. Norms is being determined on the basis of rules and implemented in samples.

Estimating a value is inextricably linked with estimate (a tool of value perception). Evaluation arises from comparison act and recommendations about how to choose what can be recognized as a value. Formed judgments about utility or harm, correctness or incorrectness, necessity or non-necessity of that which is being estimated are the result of such estimation. Axiological evaluations link theory and its application in practice. Emphasis is made on the practice.

The formalism of scientific method is provided by the action schemes with knowledge elements whereby the method applicability with evaluated level of quality of obtained knowledge is being achieved. The nature of evaluations can be qualitative and quantitative. Each value estimate conveys the intensity degree of value expression on the basis of *relevant graduated scale*. Scales that are used at absolute evaluations fix position of the ideal or norm. The ordinal scales are used at comparative evaluations. Both evaluations characterize the relation of evaluation object to the ideal (absolute evaluations) or to the beginning of order (comparative evaluations). *In POS, for each evaluation basis, the special scale is being created*. All objects being estimated in accordance to this basis are comparable on this scale.

Knowledge about the system is being represented in three formats: *data base and knowledge base*; *panels to display knowledge*; and *normative documented reports*. System knowledge in all its forms of representation creates following knowledge resources: information resource; intellectual resource; cognitive resource; and technological resource.

Information resource—represents empirical data about the system, ones being evaluated through fullness and representativeness using technology of forming system's context. A variable of the system's state is the central object of information resource. Technologies of AC POS form the system context of each quantity. This context includes variables' attributes and evaluative propositions about variables. Into this context, TSR introduces knowledge about system roles of variables and about their contributions into organization of system models. Into this resource, TSE adds evaluations of variables ability to manifest, discover, express, and perceive system senses. TSD completes creation of the system's context by obtaining knowledge that is explaining the mechanisms of quantities variability in the system's states.

Intellectual resource—contains reconstructive families of system models. A system model of the system's eigen quality is the main object of intellectual resource. TSR produces this model, namely creates contexts of models of the system's eigen qualities and computes their integral evaluations. TSE includes evaluations characterizing the system's ability to express its eigen qualities, into the models contexts. TSD finalizes construction of this resource by evaluation of synthesis of sense and fact.

Technological resource—is a family of models of implementation forms of standards and a family of models of actual states of the system, that are being produced by TSD. This resource represents system contexts of output objects (qualities and states of the system) of POS in complete form.

Qualimetric component of AC POS adds qualities evaluations of all its elements to informational, intellectual, and technological resources of knowledge. Contexts of all objects of TSR, TSE, and TSD are used to obtain the evaluations. Qualimetric component represents elements of axiological knowledge in the form of normative documented reports:

- *the report "Evaluations of information resource of knowledge"*—contains value estimations for elements of ontological knowledge on empirical and system level in accordance to categories "Indicators" and "Structures of relations," for representation forms named "Systems in data" and "Systems in relations;"
- *the report "Evaluations of intellectual resource of knowledge"*—includes value estimations of the representation "Systems in qualities" on system level and on verification level in according with representation forms named "System models" and "Clusters of objects;"
- *the report "Evaluations of technological resource of knowledge"*—contains value estimations for elements of ontological knowledge in relation to categories "Indicators", "System models," "Clusters of objects," and "Models of states" for representation forms named "Systems in data," "Systems in relations," "Systems in qualities," "Systems in standards," "Systems in implementation forms of standards", and "Systems in states."

Value-based and evaluative propositions complete the process of generating system knowledge. Knowledge elements are being endowed with attributes of correctness, fullness, and

completeness. The objectivity of ontological knowledge (about the system) is determined by degree of knowledge approximation to the truth. The objectivity is related to effectiveness of evaluative propositions that indicates to what extent evaluation engenders trust in the results of processes of cognition, scientific understanding, and rational explanation of the ontology of open systems.

4.4. The place of AC POS in the technological platform for creating and exploiting knowledge about open system

The technological platform (TP) of POS automatically solves the problems of producing, storing, circulating, and exploiting system knowledge [16]. TP POS includes four components: an analytical core, as well as descriptive, constructive, and projective components (**Figure 8**).

AC POS—is the main part of TP POS. Technologies of AC POS automatically mine scientifically proven ontological knowledge about the system and the system problems from huge amount of heterogeneous empirical data, and automatically research correctness, fullness, and completeness of the obtained ontological knowledge.

Descriptive component TP POS includes the following technologies: technology of problems' vision and technology of forming empirical context. *Technology of problems' vision*

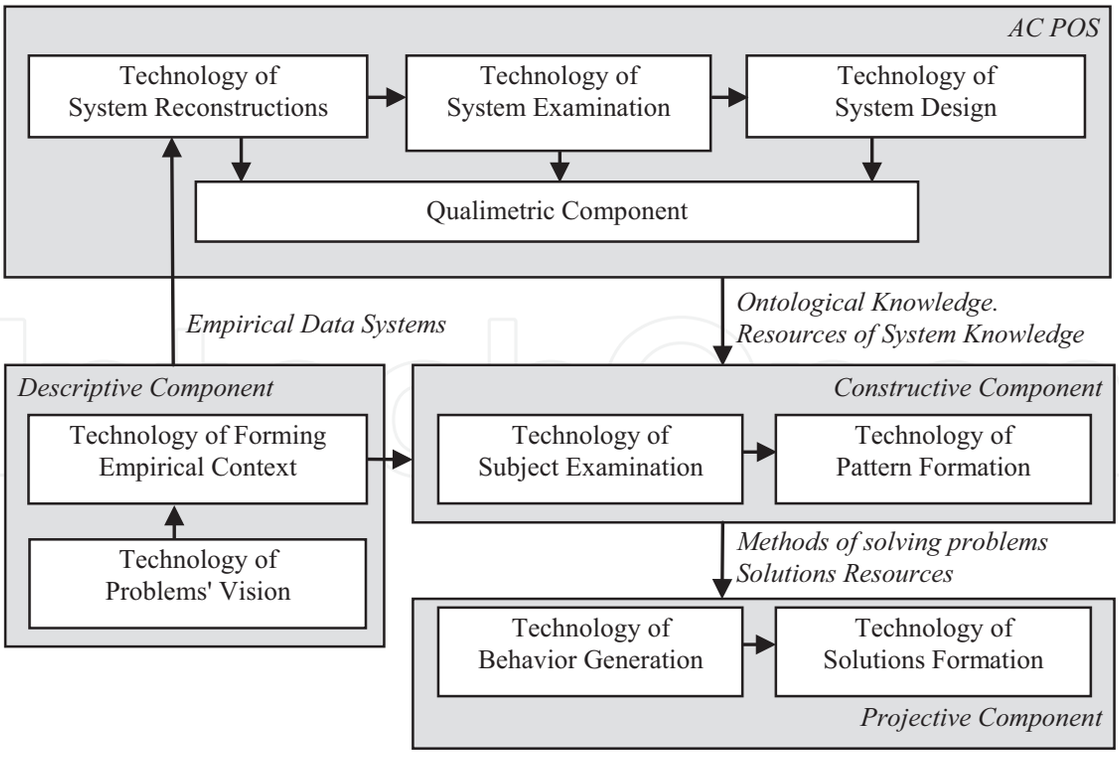


Figure 8. Layout of TP POS.

provides isolation and interdisciplinary verbal description of the system and the system problems. *Technology of forming empirical context* supports the creation of a huge amount of empirical data about certain open system and the applied system problems being researched. Its task is to transform multidimensional and multi-purpose vision of the system problems into their formed initial empirical context, whereby the "raw" initial data about the system and the system problems are being represented as normatively arranged EDS.

Constructive component of TP POS automatically transforms ontological knowledge about the system and knowledge resources obtained by AC POS into *solutions methods and solutions resources* for *general system problems*. Both, technology of subject examination and technology of pattern formation represent the constructive component of POS. *The technology of subject examination* converts ontological knowledge and resources of knowledge about the system into a description of the ontology of a particular subject area and the ontology of relevant applied problems being solved. *The technology of pattern formation* leads elements of system knowledge to formats taking into account a specificity of the subject area of the system problems provides automatic tasks solving and automatic filling the normative templates for documenting obtained results.

Projective component of TP POS applies the methods and solutions resources obtained by the constructive component for creating "pure-subject" interfaces to subject matter specialists, modeling environments, and data mining (DM) platforms. Both, technology of behavior generation and the technology of solutions formation are parts of the projective component. *The technology of behavior generation* is responsible for automatic generating:

- objective cognitive models of solutions of the problems on the basis of their subject ontologies and quantitative forms of system solutions;
- behavioral portraits of the solutions revealing the system's properties by modeling its variability in slices of space and time, events, states, situations, and changes.

The technology of solutions formation shapes the libraries of standard schemes for solving applied problems, develops and uses programs that are solvers for system problems.

A complete technological cycle of both automatic mining scientifically proven knowledge about open system from huge amount of empirical data and automatic generating the solutions of system problems by the methods of multidimensional knowledge-centric system analytics is objectified in TP POS in accordance to common scenario (**Figure 9**).

Clusters for research and technological development (RTD-clusters) are created within TP POS. They perform researches and developments in the following subject areas: "Safety (radiological, chemical, and social);" "System biology and Computational toxicology;" "Medicine and Extreme medicine;" "Planetary Physics and Solar-terrestrial physics;" and "System engineering."

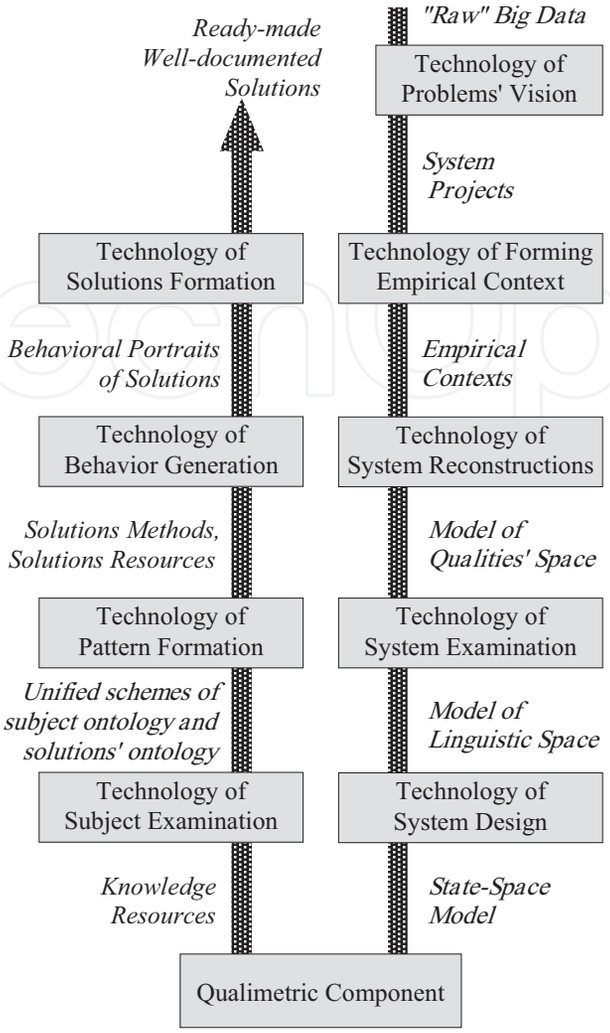


Figure 9. Scheme of technological process of TP POS.

5. Multidimensional knowledge-centric system analytics

5.1. Constructive component of TP POS

Scientifically proven ontological knowledge obtained from empirical descriptions of open systems by technologies of AC POS is expressed in the language of systems and does not have a subject format. Translating obtained knowledge into subject format requires creating expression tools able to link an understanding of revealed senses of the states as well as intra-system mechanisms of forming the system's states with their manifestations in subject areas of knowledge (**Figure 10**).

Constructive component of TP POS is intended for *developing methods of multidimensional knowledge-centric system analytics and creating resources of solutions* of general system problems in complex subject areas. Constructive component chooses elements of ontological knowledge that are needed to solve general system problems, transforms selected knowledge elements to

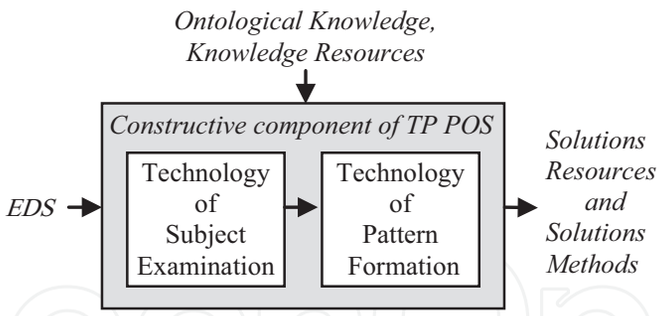


Figure 10. Composition and structure of constructive component.

General system problem	Readiness of solutions			
	2012	2014	2016	2018
Differential gene expression in accordance to microarray data	(5)	(5)	(5)	(5)
Natural system classification	(3)	(5)	(5)	(5)
Typology of system effects of multifactorial influences	—	(5)	(5)	(5)
Identification of states, events, situations	—	—	(4)	(5)
Forecast of states, events, situations, and changes	—	—	(3)	(5)
System comparativistics	(3)	(3)	(4)	(5)

Table 1. Becoming multidimensional knowledge-centric system analytics in TP POS: (3)—A laboratory layout; (4)—A prototype in real environment; (5)—A full readiness.

formats taking into account a specificity of the subject contexts of general system problems, solves applied problems, and creates templates for grapho-analytical processing of ready-made solutions. The work products of technologies of constructive component (solutions resources and methods for solving system problems) serve to develop the *programs-solvers and RTD-clusters of subject areas* in projective component of TP POS.

5.2. The general system problems

Constructive component of TP POS produces and uses scientific methods for solving general system problems of multidimensional knowledge-centric system analytics of open systems which work with hundreds and thousands of variables without resorting to simplifications, expert knowledge, subjective analysis, and interpretations (**Table 1**).

Methods to solve problems with using a general ontology of open systems are created in accordance to common scenario:

- forming an initial empirical context of general system problem;
- transforming the initial empirical context of the problem into representation "System in Data;"

- mining scientifically proven, scientifically understood, rationally explained, and estimated ontological knowledge from the "System in Data;"
- substantiating the idea of the method of solving general system problem on the basis of ontological knowledge;
- developing the model of the method of solving the problem;
- developing the formal objects, functionality, and mathematical base of the method of solving the problem;
- scaling values of this formal objects belonging to the method of solving the problem;
- creating normative template for processing automatically generated solution of the problem.

5.3. The problem about effects of the influence of chemical stressors on differential gene expression

Technologies of system biology are able to obtain EDS about gene expression of the whole genomes of different biosystems. The representations of gene ontology (GO) are used to isolate the system. The set of genes is structured in three representations (http://www.genetools.no), which map biological process, molecular functions, and cellular components, respectively. In each representation, the ontology has hierarchical structure. GO-categories correspond to structure levels. Each GO-category includes certain gene set (from hundreds to several thousands). In each GO-category, genes are endowed by some semantic homogeneity. Each GO-representation and any GO-category can be viewed as an open system, within which the gene expression (as a reaction to chemical influence) can be researched by methods of POS. An important domain of application of POS technologies is related to complex problems in system biology. These problems are connected with reconstructions of gene networks as well as reconstructions of metabolic, regulatory systems of cells, tissues, organs, and organisms. These reconstructions are being performed on the basis of the analysis of multidimensional heterogeneous experimental data being obtained by the microarray technology. Application of multidimensional knowledge-centric system analytics of POS open new opportunities for developing evidence-based system biology regarding actual problems of clinical genomics, transcriptomics, proteomics, metabolomics, and genetic toxicology.

Purposeful studies that use microarray technologies are conducted to reveal natural responses of biosystems to chemical actions. The parameters of experiments in such studies are the type and concentration of chemical, and time series. Each study provides the measured values of the expression levels of tens of thousands of genes. Different biological objects can react to same dose of a chemical by different levels of activity of the same gene. Repeated tests are conducted at the points of experiments for reproducibility of results. From the viewpoint of systems science, analysis of such huge amount of data is an important problem in bioinformatics.

Biosystems' reaction to chemicals arises as a result of coordination of multiple intrasystem processes influencing variation of gene activity. The multiplicity and variety of the effects of toxic stressors exhibit high heterogeneity of biosystems that is hidden in genomic data.

The general problem to discover regularities of the type: "(exposure dose × exposure time) → change of gene activity according to time series," has been solved within the partnership contract with US EPA[1] [17, 18]. The solution method reveals heterogeneous character of expected relationships between gene expression and chemical concentration (in accordance to the time parameter), obtains scientifically proven reconstructions of gene expression profiles, and leads to scientific understanding and rational explanation of revealed regularities. This method is constructed on the basis of *direct application* of general knowledge about the ontology of GO-categories considered as multidimensional biological systems.

The first stage of the method to solve the problem about differential gene expression on the basis of POS—is cognition of the system ontology of variations in the gene activity with respect to following genomic data: knowledge about the system mechanisms that determine levels of gene activity; reconstructions of the states of biological objects; and models of gene activity in the states. The second stage of this method is a filling the system ontology with following estimates: fullness and completeness of system knowledge; qualities of the formal models of standard states; adequacy of the reconstructed states; quality of modeling values of gene activity. The third stage of the method is using the system ontology to reveal natural variations in gene activity with respect to the parameters of the experiment. The method overcomes heterogeneity of genomic data, reveals, and explains gene activity conditioned by genome in the whole, and eliminates uncertainty of system.

5.4. The problem of natural classifying

In classification, two approaches dominate: formally rational (artificial classification) and cognitively substantial (natural classification) [19–23]. Building a natural classification requires a deep development of the ontology of subject area whose classification system is being created. An idea of natural classification directs the activity of classifiers during several centuries. However, until now, it has not led to the creation of scientific method that is a method of rational natural classifying and can be reproduced.

The general problem of natural systemic classifying in complex subject areas has been solved by method of multidimensional knowledge-centric system analytics of POS, and the method herewith can be reproduced [24]. *Conceptualization* of the method is based on three ideas (**Figure 11**). 1—The referents (objects) of classification field (CF) have a semantic unity at the ontological level; 2—POS discovers the *ontology of* "*CF System*;" 3—ontological knowledge about "CF System" *implicitly contains knowledge about the ontology of CP classes and CP in the whole*.

The ontology of "CF System" evolves into the ontology of CF classes through building the *intension and extension of CF* (*principle of classification duality*). The states of CF referents are determined by "CF System" that reveals the ontology of CF considered as a whole, and expresses the essential properties of CF referents (*principle of systemacity*). Semantic triangle of CF expresses *an idea of the ontology of classes*: classes names (a sign); classes referents (value of a sign); classes content (sense of a sign). Semantic triangle of "CF System" reveals *an idea of the system's ontology*: system

[1]The problem has been solved within ISTC Project No. 3476p "Unified Method of State Space Modeling of Biological Systems" (2006–2011).

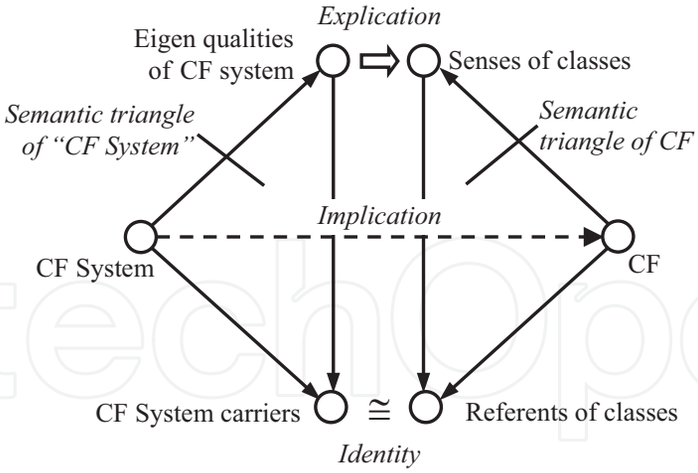


Figure 11. Conceptualization of a method for solving the problem on the basis of ontological knowledge.

name (a sign); system carriers (value of a sign); eigen qualities of the system (sense of a sign). The referents of classes are the real-world objects being observed. Each referent is the carrier of "CF System" (*relationship* "*Identity*"). The "CF System" is manifested in CF (*relationship* "*Implication*"). Eigen qualities of "CF System" are being implemented in the properties of classes, in the properties that are manifesting their sense (*relationship* "*Explication*"). Research of CF has three aspects: semantic (*intensions of classes*); denotative (*extensions of classes*); and estimative (*quality of classification*). Explication of general ontology of "CF System" onto the level of the ontology of the problem of natural classification develops *nominative function of language of systems until the ability to designate classes* (i.e., to disclose intension of CF, intension of CF classes, as well as extensions structures of CF classes and CF as a whole). Classes' archetypes and CF as a whole are explicated in ideal representatives of classes, on whose basis the morphology of each CF class and the morphology of CF, considered as a whole, are established.

The Model of solution method (hereinafter referred to as "model") (**Table 2**).

The classes' names, classes' referents, and the ontology of "CF System" serve as initial data for building the model. Classes' sense is represented by categories "Representation of classes" and "Ontology of classes." Classes' perception is being carried out in two directions: from gradation "Concrete" to gradation "Whole," and from gradation "CF System" to gradation "Extension

Gradation of category "Ontology of classes"	**Gradation of category "Representation of classes"**		
	Whole	**Part**	**Concrete**
Ontology of "CF System"	Ability to be a carrier of qualities	Nuclearity	System gradation of quantities
Intension of class	Archetype	Parton	Class
Extension of class	Taxon	Prototype	Indicator

Table 2. The model.

of class" accordingly. Gradations of category "Representation of classes" determine *forms of expressing a sense of classes*: the ontology of classes considered as a whole ("Whole"); indivisible semantic units of the ontology of classes ("Part"); and classes' denotata ("Concrete"). Gradations of category "Ontology of classes" indicate *the stages of semantic analysis of classes*: formation base of the ontology of classes (the ontology of "CF System"); semantic component of CF ("Intension of class"); and denotative component of CF ("Extension of class"). The model develops and specifies the conception of solution method, discovers the essence of explication of the ontology of "CF System," as well as generating the intensions and extensions of classes, and represents logically completed conceptual structure of the problem solution:

"*System gradation of quantities*"—a complete set of primitives to describe CF referents with using a common scale of measurement;

"*Nuclearity* (*Cores of standards*)"—standards of state of eigen qualities of "CF System;" the base to reveal invariants of intension of CF;

"Ability to be a carrier of qualities"—a corpus of the texts describing each CF referent through a unique assembly of nuclearities connected by the relations: "Universal/Particular," "Part/Whole," and "Genus/Species;"

"*Class*"—an element of CF, has a name, and is represented by a set of referents (for each class, the nuclearities dominant in the class are specified);

"*Parton*"—specific semantic moments of a class; an assembly of nuclearities of the first, second, third, etc., ranks (rank is the number of nuclearities within the parton);

"*Archetype*"—a hierarchical structure of partons; a reconstruction of class intension;

"*Indicator*"—a property objectively inherent in CF referents (a discretization of variables values of the referents is introduced through the concept "System gradation of quantities;" on this basis, the indicators-markers able to recognize a class in CF are discovered);

"*Prototype*"—a center of denotatum (extension) of a class; an idealized class referent where the idea of class archetype is expressed through a set of constituents (indicators);

"*Taxon*"—a structure of CF denotatum; it specifies six areas of referents for each CF class.

Method of natural system classification (hereinafter referred to as "method") asserts the reality of essential indicators, the reality of classes, the reality of taxons, and the reality of archetypes. The model serves as a basis for this method. The method defines the essential indicators of classes in a scientific and constructive manner. *Homologized eigen parts of class archetype* (*partons*) play the role of such indicators. Observed (measurable) indicators, as a part of parton, are specified by the name and level of value, are markers for classes, and have ability to distinguish classes. They are not in themselves natural indicators but rather express some properties objectively inherent in referents of classes.

Method produce scientifically proven system knowledge about the ontology of CF classes and on the basis of this knowledge creates and applies natural classification systems in accordance to the following statements:

- initial description of the system in data is considered as a whole without dividing into parts, related to testing and learning; the solution is being built on the basis of scientifically proven knowledge mined from all variety of CF referents;
- in generating knowledge about ontology of "CF System," the initial information about whether the referents belong or do not belong to certain classes is not used;
- explication of knowledge about the ontology of "CF System" *consists in developing nominative function of the language* of systems, this function should provide a designation of CF classes;
- invariant parts of the models of implementation forms of standards of "CF System" act in a role of system homologs of classes (*idea of homology*);
- variables and system homologs are able to distinguish classes (*idea of dominance*);
- pure manifestation of system homologs takes place in separate groups of classes' referents (*idea of compatibility*);
- variables and system homologs characterize a class (*idea of the frequency of occurrence*);
- each class is represented by carriers of its senses (*idea of referential conformity*);
- ideal sample of referent being the prototype of a class, represents this class (*idea of prototypicality*);
- relation between the prototype and referents of a class is homomorphic (*idea of likeness*).

Method uses four representations of CF: "CF in referents of classes;" "CF as a system;" "CF in problem space;" and "CF in solution space" (**Figure 12**).

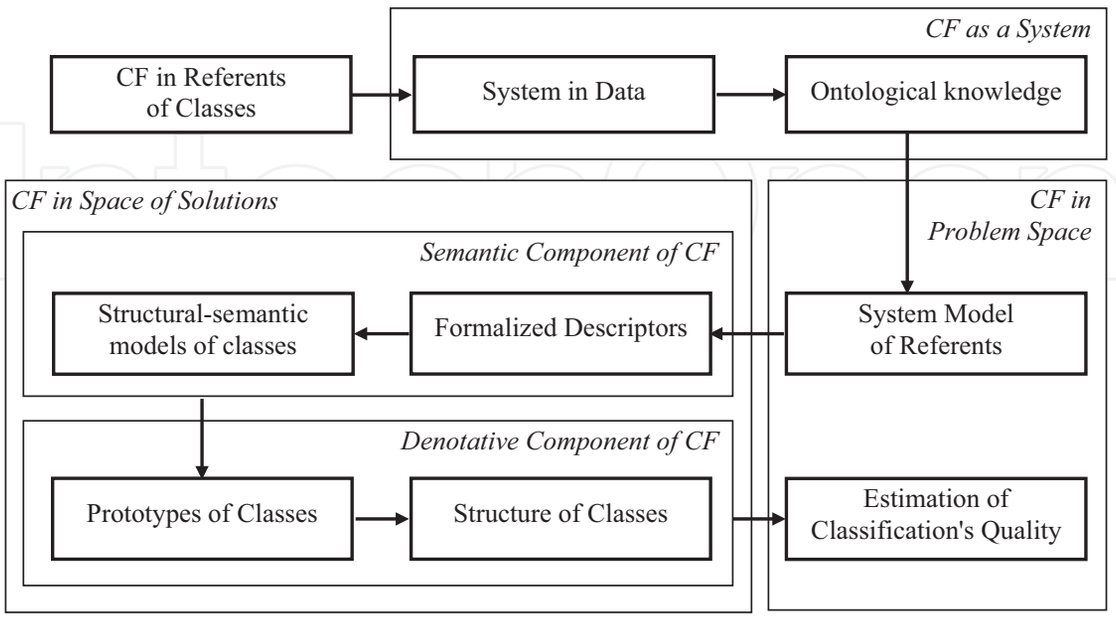


Figure 12. Structural scheme of the method.

Formal computable objects of the method are compatible with the model concepts. Intension of each CF class is represented in solution space by the multilevel hierarchical *structural-semantic model* of systemic natural indicators (formalized descriptors) of a class. Fullness and completeness of representing the intensions of classes through structural-semantic models guarantee a high solution quality of the classification problem *on its entire classification universe*. Structural-semantic models of classes are defined in the set of formalized descriptors (*partons*) of solution model by relations: "*Universal*/*Particular*," "*Part*/*Whole*," and "*Genus*/*Species*." *Core* of structural-semantic model contains formalized descriptors able to identify class as a whole. Model's periphery includes descriptors characterizing separate groups of class referents, but not a class as a whole. *Center* of structural-semantic model is defined on the basis of its core through *constituents of CF denotatum*.

CF in problem space answers to question about the possibility of solving the problem on the basis of the ontology of "CF System" and characterizes the quality of obtained solution. Fullness and representativity of the initial representation of CF in referents; knowledge value of the ontology of CF where CF is considered as a whole system; correct and full representation of intensions of CF classes as well as and intension of CF as a whole; and perfection of procedures for building classes extensions and extension of CF as a whole—all these define solutions quality of classification problems.

Functionality of the method is shown in **Figure 13**.

Syntagmatic analysis finds full sets of semantic indicators of classes, where the indicators are formalized descriptors. These sets arise as a result of right combinations (assemblies) of nuclearities. Such combinations generate descriptors of certain ranks in accordance to following restrictions: relationship to a class; relationship between quantities; domination in a class. Semantics of CF classes is defined by sets of formalized descriptors and particular paradigmatic relations between descriptors of classes. *Paradigmatic analysis* provides creation of constructive definition of structural-semantic models (intensions) of classes. *Prototyping* provides

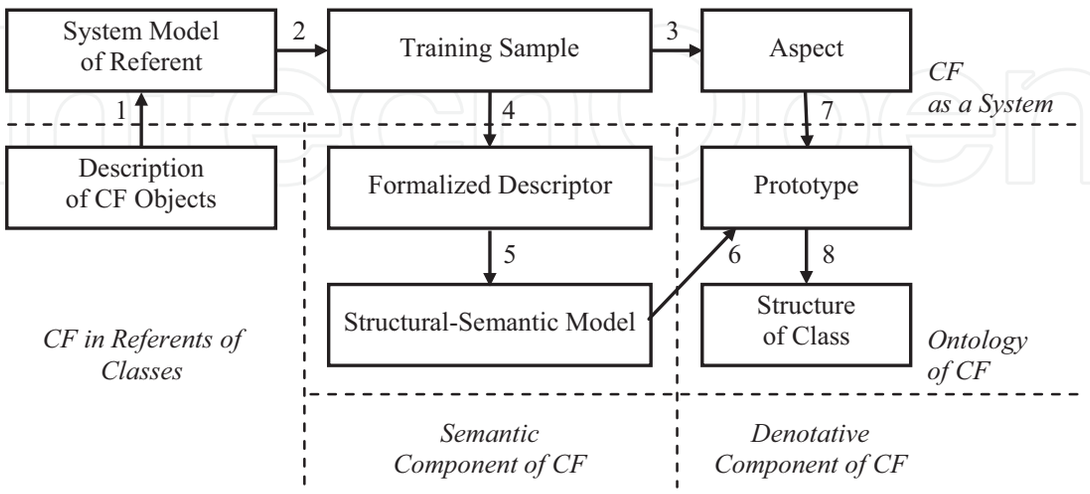


Figure 13. Functional scheme of the method: 1—Generation of ontological knowledge; 2 and 3—Distribution of nuclearities (indicators); 4—Syntagmatic analysis; 5—Paradigmatic analysis; 6 and 7—Prototyping; 8—Taxonomy.

construction of the representatives (in the model they are prototypes) of classes. Prototype of each class is specified by the set of natural indicators of a class. Each indicator as a part of representative is dominant. *Taxonomic approach* constructively defines denotatum (extension) of a class. Representative of each class sets in CF the area of denotatum of a class. In this area, the representative is the center (base point) of a class. Measure of proximity to the base point defines the organization of denotatum. Referents of all classes in CF obtain indicators of belonging to one of six areas of denotatum: center area (prototype of a class); core's area (objects are the prototype analogues); area around core (typical objects of a class); area of close (far) periphery (objects have sufficient (weakly expressed) proximity to the prototype); area of exclusion (the objects whose belonging to this class is doubtful—i.e., another's objects).

Composition of classes in CF is initially defined by experts. The method perceives it exclusively as a condition for detailed scientific research whose purpose is cognition, understanding, and a rational explanation of the given composition of classes. The problem's solution is of high value if all referents of CF classes belong to the area of centers attraction of the same classes; herewith the areas of exclusion of all CF classes are empty. Presence of referents in the area of exclusion of CF denotatum, together with the nature of distribution of the referents of each CF class by the areas of denotatum structure manifest degree of classes' homogeneity and validate correctness of initial statement of the classification problem. The solution reveals senses of CF classes, discovers the structure of CF denotatum, and gives to each class of CF a scientific validation or reasoned denial.

Solution of the problem of natural system classification of acute poisoning with organophosphorus substances can serve as an illustration of the method possibilities [25]. Organic phosphates, which have insect-killing effects (carbophos (malathion), dichlorvos, chlororvos (trichlorovon), methaphos (parathion methyl), thiophos (parathion)), have found broad use in agriculture and in house life. They are very toxic substances and pose a hazard to populations. The problem of acute poisoning with organophosphorus chemical warfare agents (Vx-gases, sarin, and soman) has taken on special significance in connection with destruction of chemical weapons. Clinical symptoms and signs of acute poisoning with organophosphorus warfare agents as well as with pesticides possessing insect-killing effects have much in common. The abnormalities arising in human organism in the event of poisoning with organophosphorus substances are extremely complex and insufficiently studied. In the event of acute poisoning with organophosphorus substances, the complexity of how the abnormalities develop is shown through multifactorial genesis of diseases, polymorphism of clinical semiology, and the reasons of a syndrome.

5.5. The problem of defining typology of system effects of multifactor influences

Method of solving the problem is published in [26]. High dimensionality of used data (hundreds and thousands of variables), data heterogeneity, a big number of acting factors and reacting variables, as well as measurement methods—all these define the problem complexity of system effects. Field of multifactor effects (FME) is represented as an empirical description of the system ("System in Data"). Each FME object sets one particular actual state of the system, the state that is represented by a vector of variables values which is the same for all objects. Concrete values of acting factors (tens and hundreds) correspond in this vector to concrete values of reacting variables (tens and hundreds).

The idea for solving the problem of regular relationship between acting factors and reacting variables implies cognition of the ontology of "FME System," and (on its basis) getting the ontology of system effects of multifactor influence (**Figure 14**).

The ontology of "FME System" implicitly contains knowledge about system effects in FME and is explicated on the ontology level of the problem. Language of systems together with nominative function also carries out a predicative function. "FME System" predetermines the topology of multifactor effects (relationship "Implication"). Relationship "Explication 1" signifies that eigen qualities of "FME System" is being transformed into propositional structures and predicates of significative scheme of FME, which, in turn, defines denotative scheme of FME. Relationship "Explication 2" expresses development, detailed elaboration, specification, and a concrete definition of the denotative schema of FME by its insight into system context. Knowledge about the ontology of FME is represented by significative and denotative schemes. For each reacting variable, the significative scheme sets general appearance of prototypical influence. On its basis, the set of predicates explaining any particular variant of the influence, as well as effect on this influence is defined. Denotative scheme sets models of all actual types of effects on the influences and defines the topology of the system's response to these influences.

The model of solution method (hereinafter referred to as "model") introduces key concepts of the method for solving the problem (**Table 3**).

The model defines and expresses the sense of concept "System effect of influence" in categories "FME Representation" and "FME Ontology." The system's ontology and the sets of both acting and reacting quantities are the initial data of the model. On the basis of the ontology of "FME System," the model discovers the structure of semantic, denotative, and estimative components of FME. The ontology of FME is implicitly contained in the ontology of "FME System." Perception of multifactor system effects is being carried out:

- by category "FME Representation"—in direction from gradation "Concrete" to gradation "Whole;"
- by category "FME Ontology"—in direction from gradation "Ontology of FME system" to gradation "Extension."

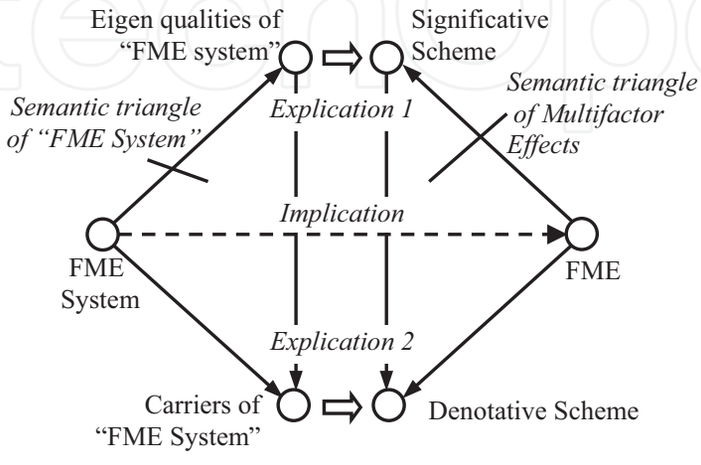


Figure 14. Method conceptualization.

Gradation of category "FME Ontology"	Gradation of category "FME Representation"		
	Whole	**Part**	**Concrete**
Ontology of "FME System"	System predication	Determination of quantities' levels	System gradation of quantities
Intension	Semantic relationship	Prototypical significant	Inputs–Output
Extension	Semantic dominant of the effect	Actual content of the effect	Object

Table 3. The model.

Gradations of category "FME Representation" specify various forms of expressing the senses of system effects of influence. Gradation "Concrete" specifies variables of state of the system and its environment in each actual state through disposition "Inputs - output." Gradation "Part" reveals indivisible semantic units of the ontology of FME. These units are: determined levels of quantities' values; sets of values' levels of acting factors; values of reacting variables specific to the levels of values; and actual variants of system effects. Gradation "Whole" defines the ontology of FME in the whole by means of following full sets:

- of states' standards of eigen qualities of the system;
- of semantic relationships between acting factors and reacting variables;
- of typical system effects of multifactor influences.

Gradations of category "FME Ontology" indicate the stages of semantic analysis of system effects. Gradation of "Ontology of FME System" sets the base for forming the ontology of system effects. Gradation "Intension" reveals organization of significative scheme of effects of influences. Gradation "Extension" defines the denotative scheme of the effects.

Key concepts of the model:

- "*System gradation of quantities*"—a full set of primitives designed for describing the values of state variables of the system and environment with using a common scale of measurement; by thus, an opposition of high and low levels of quantities' values determined by the system itself is being revealed.
- "*Determination of quantities' levels*"—full sets of system models statistically distinguishing levels of values of particular variables. They establish statistical relationships between variables and standards of eigen qualities of "FME System," relationships that explain actual states of the system.
- "*System predication*"—a full set of statistically derived relations "standard of states - level of quantity's value". Distinctive ability of standards can be weak (statistically determined) or strong (determined by the system and statistically).

- "*Inputs - output*"—a disposition of acting factors and reacting variables. A set of acting factors is specified in compliance with research objectives. Any reacting variable is being chosen from a target set of quantities whose variability types should be disclosed.
- "*Prototypical significant*"—a set of acting factors whose action is significant and which belong to the set of inputs determining levels variability of values of each reacting variable.
- "*Semantic relationship*"—a certain type of relations between acting factors and reacting variables. These relations disclose the types of implementation forms for prototypical significant, which determines an invariant relation between the values' levels of acting quantities and the value level of reacting quantity.
- "*Object*"—a certain object of the solution space.
- *"Actual content of the (multifactor) effect"*—a specific form of carrier of the regularity explaining variability of reacting variable.
- *"Semantic dominant of the (multifactorial) effect"*—a semantic filter based on oppositions of the indicators of actual contents that structures a denotative area of multifactorial effects.

Method for solving the problem (hereinafter referred to as "method") defines the topology of effects for each (and any) reacting variable in accordance to the stated set of acting factors. Specific sets of standards of the states of eigen system qualities rationally explain every *type of effect*. For each reacting variable *the typology of its system response is stated*. It is given by a set of significant acting factors which are gathered from *an ideal sample* of the relation "Multifactor influence – System effect." For any reacting variable, the method guarantees the following:

- obtaining the *prototypical significant*;
- constructing the *prototypical denotatum*;
- defining the *full set of types of system response to any possible options for multifactor influences*.

For each referent of FME, the method allows to obtain new format of representation. In this format, both a variation of influence and a set of types of the system's responses that are established by the corresponding model and macrostructure of the effect are fixed. *On full set of referents*, there is a general problem of the typology of global system. Its solution will answer about system reaction of all reacting variables to any multifactor influence. It is a key problem of the qualitative theory of open systems.

Computable objects of the method correspond to concepts of the model (**Table 4**):

Relations between formal objects of the method are derived from relations between concepts of the model. Constructive forms of the relations of generating and transforming objects define functionality of the method (**Figure 15**).

Concept of the model	Object of the method
System gradation of quantities	System in graduated data
Determination of quantities' levels	Parameter in the system whole
System predication	Actantial structure of standard
Inputs-Output	Target list of parameters
Prototypical significant	Ideal sample of the relation "Influence - effect"
Semantic relationship	Role semantics of predicate
Object	Carrier of the effect
Actual content of multifactor effect	Model of system effect
Semantic dominant of the effect	Macrostructure of the effect

Table 4. Relatedness of concepts of the model with computable objects of the method.

Production of system knowledge about the ontology of FME is provided by AC POS. *Selection of target variables*: acting factors are specified, reacting variable is selected. *The system's representation in graduated data*: scales for measuring levels of quantities' values are transformed into scales which are graduated by the system itself. *Effect's localization*: for all actual states of the system, in which all system effects of multifactor influences are defined, the models of reconstructions are created. *Quantities distribution*: on the basis of models of reconstructions, the frequencies of

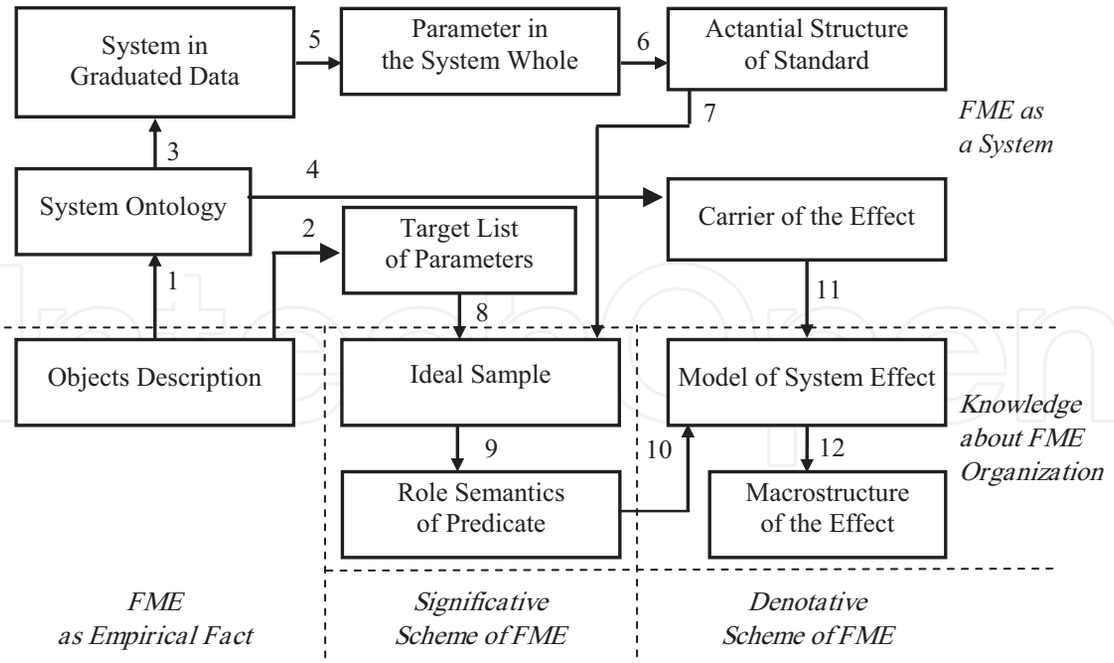


Figure 15. Functional scheme of the method: 1—Production of system knowledge; 2—Selection of target variables; 3—The system's representation in graduated data; 4—Effect's localization; 5—Quantities distribution; 6—Definition of valences; 7 and 8—Prototyping; 9—Role estimation; 10 and 11—Frame filling; 12—Revealing the typology of effects.

combinations of system variables and standards of the system's states are obtained, and statistical significance of these combinations is defined as well. *Definition of valences*: domination of states' standards is semantically determined; each standard of a state correlates with a certain set of actants, whereby its valence is being defined; the set of states' standards forms a complex structure of relations with actants. *Prototyping*: for each reacting variable, the set of standards is defined and the structures of actants of these standards contain this variable. The structures of actants include acting factors. The state's standard corresponding with such structure is the *standard-predicate* for these acting factors. Standard-predicate establishes relation between particular acting factor and reacting variable. This relation is statistically confirmed. The result is a list of significant acting factors that caused system response of reacting variable.

For each acting factor, the sign of statistical relationship with reacting variable is defined. *Prototypical denotatum*: each level of values of reacting variable is a prototype for a system response to an influence. *Prototypical significant*: is put into correspondence with prototypical denotatum, and is represented by typical set of levels of values of acting factors. *Role estimation*: classes of role semantics of standard-predicates are introduced for all referents of the relation "Influence - effect" (these classes are: "Action," "State," "Relation," "Indicator," and "Property"). *Frame filling*: for each particular result of role estimation, the localization of system effect is carried out; a set of attributes which characterize the effect of influence in categories of "Statal"/"Actional" is obtained. *Revealing the typology of effect* is made as a result of *multi-criteria discrimination* of system effects. Criteria of typological analysis of the effects are built on the basis of semantic oppositions. *Semantic oppositions*: are the combinations of criteria values, which characterize:

- certain simulated situation of multifactor influence, here the situation is considered in its full system context;
- system significance of attributes of variables and states' standards, the significance is being evaluated in the categories of "Statal"/"Actional."

Solving the problem of interventional cardiology serves as an illustration for the method possibilities [27]. Restenosis and in-stent thrombosis after percutaneous coronary intervention (PCI) is the essential clinical and socioeconomic problem in high technology medical care in ischemic heart disease (IHD). Special aspects of developing restenosis and in-stent stenosis, and of how individual sensitivity to antiplatelet drugs arises—all of these, in each particular case, are defined by combining a multitude of various pathogenetic factors (clinical, anatomic-morphological, molecular-genetic, biochemical, and technical) [28]. Advantages of the method is: broad coverage of the problem being researched in its natural scale and real complexity; taking into account the multiplicity of different factors influencing restenosis development; and a holistic view on pathophysiology of restenosis and thrombosis that occur after intracoronary stenting in patients with IHD. Multidimensional data array was obtained as a result of examination of the patients with IHD, and who have acute coronary syndrome after PCI with stenting. These data was obtained under inpatient treatment of these patients at FSBI "Federal Heart, Blood and Endocrinology Centre n.a. V.A. Almazov", Saint Petersburg.

Author details

Tamara L. Kachanova, Boris F. Fomin and Oleg B. Fomin*

*Address all correspondence to: bfomin@mail.ru

Faculty of Computer Science and Technology, Saint-Petersburg Electrotechnical University (SPbETU "LETI"), Saint-Petersburg, Russia

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