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Interpretation problems: general mechanism and fundamental limitations of classical methods

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Abstract

Purpose – The purpose of this paper is to investige the general computing mechanisms of solving the system information problems of interpretation and its fundamental limitations, due to physical basis Turing machine.

Design/methodology/approach – For creation of theoretical base of methodology, the authors make an attempt to demonstrate the possibility of a constructive building of Turing machine as meta-ontological basis of computing. In the course of this building the role of the operator of atomic implicative transition if-then as generic operator of recognition/decision-making is shown. In order to substantiate the thesis about the determinative role of implicative transition in the interpretation mechanisms, the authors will carry out the comparative analysis methods of interpretation in systems of pattern recognition and expert systems interpretation type.

Findings – The carried-out analysis allows to formulate a common mechanism underlying the classical methods of solving problems of interpretation and to concretize the fundamental limitations of these methods, caused computational basis of their actualization. The cybernetic interpretation of this mechanism is offered.

Originality/value – The fundamental limitations of classical methods of solving problems of interpretation sets the boundaries of the cybernetic approach and allows to outline a way out beyond it. In this context, the authors put forward knowledge-based mechanism of perceptual modeling of dynamics of system visual environment – autonomous agent.

Keywords Decision making, Cybernetics, Systems theory, Pattern recognition, Production rule, Turing machine

Paper type Conceptual paper

1. Introduction

In previous papers in the framework of physico-semantical information theory (Volchenkov, 2010) the fundamental concept of the information-supported nature of anthropogenic systems was developed. In the work (Volchenkov, 2011b) the general methods for solving system information problems of the information base of anthropogenic systems (the problems of building and maintenance) were considered and also cybernetic treatment of mechanism, lying in their basis, was offered. In the work (Volchenkov, 2012), which is its continuation, the ontological basis was considered for the second class of system information processes – goal-oriented transformations of objects external to the control system by means of using receptive information (peripheral or boundary information processes). The central problem here is the interpretation as an information source for the formation of the instructive (control) information.

The purpose of the present paper is establishment of the general computing mechanism of the solving of the interpretation problems in the context of classical methods. With object-semantic point of view of physico-semantical information theory accounting general-physical and general-system constraints underlying this mechanism has to play the determining role in the analysis of the boundaries of possibilities computerized solving interpretation problems.

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For the establishment of the general mechanism of the computer-base solving boundary information problems we will pass from the declarative formulation of the interpretation model offered in Volchenkov (2012) to the analysis of its computing aspects – processes actualization of model (Section 2). This transition will be the starting point of the analysis of the implicative nature of the mechanisms underlying the classical methods of solving interpretation problems.

For creation of a theoretical foundation of our analysis, we will turn to the consideration of the meta-ontological basis of macroscopic computing. With this purpose in framework of physico-semantical information theory we will demonstrate the possibility of a constructive building of Turing machine, coming from general-systemic principles. In the course of this building will be shown that operator implicative transition if-then is irremovable already at the atomic level as a generic operator recognition/decision making (Section 3).

In order to substantiate the thesis about the determinative role of implicative transition in the interpretation mechanisms, we will carry out the corresponding analysis methods of interpretation in systems of pattern recognition and expert systems interpretation type (Section 4).

Summing up the results of our analysis, we will formulate the description of general implicative mechanism of solving interpretation problems and will give its software-cybernetic treatment (Section 5).

In the end, we will focus on the fundamental limitations of classical methods, which follow from the presented concepts of the general mechanism of solving interpretation problems, and will discuss the questions of going beyond the modern cybernetic paradigm, putting forward hypothesis of cognitive control (Section 6).

2. Cybernetic model

In Volchenkov (2012), was proposed the generalized method of the solution of the boundary information problem based on so-called the interpretation model:

$$\omega(\mathrm{X}) = \left\{\omega_i \middle| L\left(\mathrm{X}, E^i\right) \rightarrow \varepsilon\right\}, \tag{1}$$

$$\mathrm{S}(\omega) = \left\{\mathrm{S} \middle| \mathrm{S}^c = F(S,\ \mathbf{I}^{\omega})\right\}. \tag{2}$$

The first part of the formulation Equation (1) describes interpretation of the current state of boundary object, external characteristics of which are presented by the set of features X. Here, ω is the result of interpretation, $\{E^i \in \mathbf{E}\}$, $\mathbf{E}$ is the set of interpretation data (declarative presentation of method of interpretation), L (X, E^i) is condition of adequacy of the set X to E^i, ε is indicator of adequacy (false/true, degree of confidence in fuzzy methods). Note that here we presented the more general formulation condition of adequacy than in Volchenkov (2012).

The second part of the formulation Equation (2) indicates that state of the system object, S(ω), corresponding to the interpretation of ω, is such that input action on the object in this state described by the instruction $\mathbf{I}^{\omega}$ can be transferred to the target state S^c (here F is the transition function).

The presented above the formulation of the interpretation model is declarative. We now turn to procedure representation this model:

$$\text{if (X) then } (\omega), \tag{3}$$

$$\text{if } \left((\mathrm{S}(\omega)\&\mathbf{S}^c\right) \text{ then } (\mathbf{I_c}^{\omega}). \tag{4}$$

The given representation describes consecutive implicative (causal) information transitions and is, in essence, the cybernetic reformulation of the interpretation model (control by feedback).

Control loop in general case includes direct "non-material" stream of notification information ω from boundary object (sensors) and power (material-energy) actions on the object (effectors) formed on base of the "inverse" control information $\mathbf{I}_c{}^{\omega}$, and $\mathbf{S}^c$ plays a role of goal-value of the system. The first implicative transition Equation (3) is realized in the block of interpretation transformation of information and the second transition Equation (4) – in the block of transformation interpretation results in relevant instructive information[1].

The realization of implicative macrotransition in the block of interpretation Equation (3) is performed on digital computers. Therefore, the configurator of basic structure of digital computers has to define limitations on possible mechanisms of computer actualization of the interpretation models. This determines the next point of our research – the object-semantic analysis of the fundamental structure (atomic basis) of the computing.

3. The computing basis

The starting position for our object-semantic consideration of the computing basis will be the conception of the automatic computing as the information working process, which includes the objects of work, the means of work (machinery and software), as well as software engineers and users (Bachmann, 1983). Universal computing machines and software in this process are means of work, providing processing objects of work – texts (the conversion of input data of a problem in an output result).

With a more abstract point of view the initial information resource for computing is a mathematical (declarative) description of solution of the certain problem (the conceptual level according to Bachmann (1983)). In declarative description the elements are abstract variables of the problem, between which with the use of the theory is established the system of interrelations or relationships. In the practical applications this symbolical description has to be used for the concrete numerical values and thus the means of transformation input-output corresponding to this description is necessary. The digital computer is the physical implementer of such transformations (realizes mechanization of calculations required for solving a problem).

In Volchenkov (2011b), computing was considered as a means solving system information problems. However, themselves the information-processing subsystems can also be treated as a special class of material systems, which can be subjected to general-system analysis. In this aspect computing (working process) can be interpreted as building (or rebuilding) of data carrier subsystem (object of work). Let us consider the atomic general-system prototypes of mentioned constituents of information working process.

According to physico-semantical information theory, material fixation of information is performed on neutral carriers (Volchenkov, 2010). The minimally necessary attributes of neutral carrier, which allows to represent it as an object of system transformation, are the working space and the elementary unit of a building. Therefore in theoretical limit a neutral carrier can be represented in extensive aspect (space of recording) as linear succession of identical cells (Volchenkov, 2009), and for specification of minimal element enough to postulate that information cells can have only the two distinguishable states (for instance, marked 0 and 1). We will identify this element of record/reading with the information bit (quantum of the minimal distinction).

Let us notice that carrier have the material nature. Any processing information requires corresponding reconstruction of such carrier, which can realize only external to carrier material agent – physical implementer (means of work – machinery). We will consider this minimal converter as the atomic operational element (means of work).

At last, every building in the constructive world according to physico-semantical information theory requires the corresponding plan construction (assembly) (Volchenkov, 2011b). It is not exception and the processing of information presented in form of neutral carrier. A special type of plan construction (reconstruction) for necessary transformation of neutral carrier (building an output configuration of the carrier from the initial) can be considered as general-system prototype of the program of computer information processing (means of work – software).

The operational element can be considered as the intermediary between the program and carrier of information (data). Let us consider atomic operations of operational element, which would have been minimally needed for an arbitrary reorganization of configuration of the neutral carrier and thus could correspond to elementary instructions of program of information processing.

First of all, the operational element must have access to the various elements of the neutral carrier (e.g. to move along carrier). This leads to the necessity of introducing atomic transport operations of one-dimensional shift. And, at last, it is necessary to provide possibility of transformation with an operational element of a configuration of the carrier. In atomic limit this transformation is reduced to the ability to produce single-element change. And as its minimum element is the bit, for representation of the corresponding element it is natural to enter atomic operation of the conversion bit/bit (i.e. $0 \rightarrow 1$ or $1 \rightarrow 0$).

The sequence of steps of solving a problem of construction depends as on a concrete initial configuration of the neutral carrier, and its changes in the course of transformations. These changes can influence on potentially possible subsequent actions (implementation of instructions of the program). In other words, is necessary backward information link between a state of the neutral carrier and the program. This link presupposes the ability to "recognize" the current configuration of the neutral carrier. It is natural to assume that the minimal ability of operational element to recognize, corresponding its atomicity, is the distinction the two states of cell: 0 or 1. The minimum reaction to result of recognition of a state of the current cell – a choice of the atomic action provided for this state, i.e. some instruction of the program (the address in the list of instructions), and its execution as the following step of actualization. Thus, we come to the necessity of introducing a third atomic operation – the implicative operator (if-then), describing atomic act of the recognition/decision-making. It is possible to find various names for this operator, which focus on different aspects of its use: logical (as distinct from arithmetic), condition-action, choice, branching, control, recognition, and decision-making.

In the aggregate this minimum closed design of transformation of neutral carriers constructed above is not that other, as known Turing machine – atomic basis of computer calculations. Without developing here this theme, we note that our constructive building the atomic basis of computing is in good agreement with general-physical principles of uniformity of space-time, short-range interaction (locality), and atomisticity of the material organization.

We especially emphasize implicitly implied dynamic character of computer processing information. Computing engine continuously and without external compulsion consistently automatic carry out the instruction behind the instruction of the program of transformation.

Thus, as any working process, the computer information processing extends in time. This fundamental characteristic of macroscopic computer processes can formulated as the principles of locality and sequence of process of transformation of information.

4. Analysis of the classical methods

The purpose of the carried-out building was establishment of meta-ontological basis of macroscopic computing. As we have seen, the operator recognition/decision-making (operator of implicative transition) fundamentally cannot be eliminated already at the lowest (atomic) physical level of computing. It allows us to assume that the implicative operator will play a leading role (can be generic) in the mechanisms of solving interpretation problems. We note in this regard that the use of systems of production rules, which can be viewed as a special kind of implicative operators, is the basis of knowledge representation in expert systems.

The "global" implicative transition of the interpretation bloc describes in procedure (causal) form information function of interpretation system as a whole. How interpretation process unfolds inside this block, continuing causal line of transformation from the input data to the result of a solution? Proceeding from the foregoing, in the investigation of this question, we will be interested, in the first place, "implicative structure" computer-aided systems of solving interpretational problems. For confirmation of the thesis about implicative transitions as universal elements of construction of interpretation system and the establishment of the general computing mechanism solving interpretation problems we will carry out the systematical comparative analysis of the classical interpretation methods used in the modern information system. It is natural to divide these methods on two the prevailing now applied: the systems of automatic pattern recognition and the interpretation expert systems.

Following classification (Novicov, 2010), we will divide the implicative operators into the two no overlapping classes: uniform and non-uniform. This partition is defined by object semantics of conditions and conclusion of implicative transition.

4.1 Systems of automatic pattern recognition

Metric methods. For metric (or discriminating) methods, in which the description of a pattern X can be represented as the feature vector, the formulation of the interpretation model takes the form:

$$\omega\,(\mathrm{X}) = \left\{\omega_i \middle| L\left(\mathrm{X},\ \mathrm{E}^i\right) \rightarrow \min\right\} i = 1, \ldots, m. \tag{5}$$

The model of the decision is based on the use of a similarity measure $L(\mathrm{X}, \mathrm{E}^i)$ where E^i is the standard of the ith class. The choice of function for evaluating similarity measure defines concrete method of recognition. Most often intuitive geometrical or statistical images of similarity are used. It should be noted that works on theory of pattern recognition are limited to the mathematical description of the corresponding methods (declarative representation) without the analysis (or considering its trivial) of the procedural mechanisms of computer realization this methods. The interesting us the implicative representation we find in the work (Nechansky, 2012), in which pattern recognition is treated as a decision-making procedure and is described by the formulation:

$$\text{if } (\mathrm{X_t} \sim \mathrm{E}_\omega) \text{ then } \omega, \tag{6}$$

where "~" is a certain system-specific rule of conformity.

In accordance with the purpose of our analysis, we will try to draw a production analogy of metric pattern recognition methods. At the implicative representation of problem of pattern recognition Equation (6) the standards of classes naturally are considered as the production rules of the following form:

$$(E_i) \Rightarrow \omega_i, \tag{7}$$

where E^i is the multifeature standard (premise) and ω_i the label identifier of the *i*th class (consequence). The recognition procedure in this aspect can be represented as an exhaustive search of such production in a set of productions of interpretation data, for which the description of an input pattern X is closest to premise of production (standard). The role of the operation of template matching plays for X the calculation $l_i(X) = L(X, E^i)$ where L is, for example, the potential function or the probability density and the value l_i can be considered as a fuzzy measure of belonging to the X to a class ω_i, which is analogous the factor uncertainty in production expert systems.

The production representation of metric recognition belong to the class of non-uniform implicative transitions (premise is feature description of class and consequence is its label identifier).

Methods of Boolean algebra. Subjects of interpretation in the logical methods of recognition are rather not objects of the outside world, but situations. Passage to logical representation means that identifiers are considered as Boolean variables, and the description of "feature space" is a set Boolean relations between classes Ω_i and features X_k in basis (AND, OR, NOT).

A priori information about classes and features in general case can be reduced to full disjunctive normal form (FDNF), E (Gorelik and Skripkin, 1989). Each summand in FDNF, being an basic product, explicitly specifies the values of verity elements $X_1,\ldots, X_n; \Omega_1,\ldots,\Omega_m$, for which the function E is true. Thus, the decisive system (the standards system problem) is reduced to the matrix of the representing basis, each column of which represents a binary vector of dimension of n + m. First n components of the vector (subvector X_l) describe the truth values for features $X1,\ldots,X_n$, and the remaining m (subvector Ω_1) – the corresponding values for classes $\Omega_1,\ldots, \Omega_m$.

The current situation is described by an observed relationship of features $G(X_1, X_2, \ldots) = I$ (I – universally true element). It is necessary to define the relationship of classes $F(\Omega_1, \Omega_2, \ldots) = I$ corresponding to the current situation.

The recognition procedure consists in search in the columns of representing basis a vector X_l, coinciding with the vector of the current situation G_k. The described algorithm of the decision allows implicative representation Boolean classification:

$$\text{if } (G_k = X_1) \text{ then } \Omega_l, \tag{8}$$

analogous to metric pattern recognition (implicative operator here can be considered as non-uniform).

Structural methods. The metric and logical methods are applicable when the objects are described by a simple feature set. In the general case, the objects may have some external structure (morphology). For recognition (classification) of such objects are used methods of syntactic analysis (it is supposed that primitives of structural representation and the relation between them were allocated at the level of preprocessing). In general terms, procedure of computer realization of these methods can be presented as follows.

Interpretation data are represented by the set of the productions, having (e.g. for context-free grammar) form of the rewrite rules:

$$N \rightarrow N'\alpha, \tag{9}$$

$$N \rightarrow \beta, \tag{10}$$

where *N*, *N'* are the auxiliary symbols and α, β the terminal symbols, representing graphical primitives.

The substitution production system describes the structural standards of class (grammar of structural class). The procedure of recognition is based on parsing (verification of conformance to grammar), which is carried out by consecutive application of the relevant products to the chain of primitives, representing the input pattern. The auxiliary symbols in the productions are intermediates, providing a variance of parsing, and at the completion of the correct (satisfying) parsing they are replaced by terminal symbols. Thus productions of syntactic pattern recognition can be considered as uniform (transformation string of symbols in a new string).

The operation of template matching consists in checking, whether contains the pattern obtained on the current step of parsing a substring coinciding with a condition one of rules of a set of productions. Since a choice of productions, in general speaking, is non-deterministic in nature, are being checked the different variants of sequences of application of rewrite rules. Sequences may break down, leading to the impasse (mode of returns). The search continues until conformance will not be found (or until all possible variants of sequences of parsing will not be tested without finding the conformance).

4.2 Interpretation expert systems

Productions systems. Interpretation data in the productions system are the unordered list of the production rules having the form of implicative transitions:

$$(e_1 \& e_2 \ldots \& e_n) \Rightarrow \omega, \tag{11}$$

where the left side (premise) is a set of facts e_i, determining the condition of applicability of the rule, and the right side is new fact – consequence. In the initial state the list of data contains the input facts of the problem. On each step of solving for the chosen input fact search in the list of productions (possibly with returns) actual production is run. Operation of template matching consists in check the condition of applicability of the production. The triggering the found actual production rule updates the list of the intermediate facts.

The production system can be optimized by structuring an order of the input facts of the problem. For transition to the structuring (hierarchical) form of representation we will separate in the production premise the facts describing the analyzed situation from consequence obtained in the previous step of solving (ω):

$$P: \ (E_i \& \omega) \Rightarrow \omega_i (i = 1, n_i), \tag{12}$$

where in the left side (in premise of the production) E_i is the reference values, n_i the number alternatives for current intermediate consequence ω, and in the right side – the new intermediate (or final) consequence ω_i, corresponded to the made choice. The pass to the hierarchical organization of productions system (in the form of tree OR (Pospelov, 1988)) leads to the economizing of a search component process of solving.

At the hierarchical formulation the analogy of the described production approach with the sequential pattern recognition is obviously traced. Each route in the tree OR corresponds to the so-called composite production. Composite production is called such a minimum length of chain of transitions $Q = P_f P_{f\text{-}1} \ldots P_1$, in which the fact, inferred any of its production should be used as the condition of one of the following production (Pospelov and Pospelova, 1987). Excluding intermediate facts, the result of composite products for the *k*th inference can be expressed in the form:

$$\text{if}\left(E_1{}^k \& E_2{}^k \& \ldots \& E_n{}^k\right) \text{ then } \omega^k, \tag{13}$$

where $\{E_1^k, E_2^k, \ldots, E_n^k\}$ is the set of facts entered on *k*th route and ω^k the final conclusion. This presentation corresponds to the obvious requirement that in the correctly constructed productions system the final fact is determined by only input data of the problem.

At the same time, metric (parallel) pattern recognition can be seen as one-step production solving, in which all the input data are equitable and their number is the same for all the classes of the interpretation problem.

Hierarchical representation of interpretation system agrees with the conception of problems solving in expert system – the so-called heuristic classification (Clancey, 1985). According to this concept solving begins with abstraction data leading to abstraction of the inoculating decision of a general type. This decision then is concretized by entering at each step of clarifying the facts. The transition *P* Equation (12) describes the step of such concretization. The described the productions belong to non-uniform class (facts/intermediate consequence). The object semantics of the intermediate conclusions is determined by selected categories of abstracting. According to Clancey (1985)) possible variants are: features – class, hierarchy properties, quantitative abstraction.

Predicate calculus. Elements of interpretation data in this case are predicates (the first order). The predicate symbol is used for representation of relations in some object domain. Function of the basic operator of if-then is performed in predicate calculus the so-called the implication:

$$H \supset C. \tag{14}$$

Here the formula *H* is the antecedent, and C the consequent. Both parts of the implications are, by definition, the correctly constructed formulas (uniform type of implicative transitions). At the use of the direct system of deduction of Nilsson (1980) implications of predicate system (with antecedents given to a one-literal form) are considered as generating rules. The mechanism of logical inference for predicate systems has production-similar character (the solution is found by searching a matching concordance graph of decisions).

Let us consider distinctive features of application of predicate calculus for solving interpretation problems.

Traditional application calculation of predicates – a possibility strictly to argue on the validity and falsehood of statements on the basis of the proof of the corresponding theorems, proceeding from the system of the axioms describing some limited object domain. In interpretation applications the system of axioms can be used to represent domain-specific knowledge (the description of boundary object) in a predicate form (facts and implicative expressions). For use in interpretation problems predicate system must have a variable character of input and output. The input data can be considered part of the facts (the variable facts (Pospelov, 1981)). Character of the answer (output data) is defined by a quite certain target predicate (predicate expression). Process of solving a problem, as a rule, consists in finding the special cases, satisfying to input data (from area of the variable facts). In this case, the answer is expressed by the value of variables target predicate expressions obtained in the result of the matching and unification. This circumstance determines the necessity for predicate systems of expanded treatment of template matching because is usually not allowed existence of variables in both participants of matching (Nilsson, 1980).

In calculation of predicates is possible the alternative to production-similar representation of logical conclusion – the so-called resolution technique. Not discussing here in detail the influence of superposition of a logical basis to implicative mechanism, let us note that in this case there is a specific way of formal expressing implication through other logical connectives, and this creates a possibility not production logical inference. In this case the role of implicative transitions in carrying out the proof plays the so-called resolution rule if $[(X \vee l) \wedge (Y \vee \neg l)]$ then $(X \vee Y)$ where $\wedge$ is conjunction, $\vee$ is disjunction, and $\neg$ is logical negation.

5. The mechanism of solving

5.1 The mechanism of solving

In all the classical methods is always possible presentation of interpretation data in the form of the set of production pairs (operators of implicative transitions) of one or another type. Within one method implicative operators have the same type. Imposition of logical basis on production mechanism creates, as indicated above for predicate calculus, additional features of the mechanism of interpretation.

Solving process is a multi-step sequential in nature and represents a chain of subsolutions. Expanding a chain of local decisions is carried out by search in a set of production pairs next suitable pair with the evaluation of variants by template matching. Thus template matching plays the role of the commutator that connects a links of trajectory of the interpretation process. Meaning this repeating in all the methods the scheme of actualization based on implicative transitions, we will speak about the general computing mechanism of solving interpretation problems.

Note, that with the complication of objects of problems the volume of interpretation data and, accordingly, the number of elementary implicative operators required to build interpretation system will grow that is consistent with the general thesis (Nechansky, 2012).

5.2 Cybernetic treatment

The described mechanism, as well as in case of system information problems of information base (Volchenkov, 2011b), can be interpreted in software-cybernetic terms (of achievement of "goal" by means of feedback). Input data (informing data from controlled system) can be regarded as a "disturbance" transferred to the interpretation system and the goal of decisive mechanism (formal or internal goal) can be considered finding the variant of interpretation data (and thus corresponding interpretation category) minimized the indicator of adequacy with input data. In the process of actualization on each step the decision is estimated, whether the condition of conformance with the current element of interpretation data is satisfied (whether the subgoal is reached). And by the results of estimation the decision is made: in case of positive answer a corresponding implicative transition is produced, otherwise – search (not excepting with returns) of other potential possible element of conformance continues.

6. Discussion

6.1 Fundamental limitations of classical methods

The research, which is carried out above allows us to concretize the fundamental limitations of the classical methods of interpretation which, in the end, due to the computational basis underlying mechanism of their actualization. Carrying out the analysis of these limitations, we implicitly sent from the broader context of the future development of artificial intelligence systems. We will formulate results of our analysis in the form of the following key points:

(1) Any computer information-decision system works in its constant context and is accommodated to decision one narrow domain-specific problem.

(2) Interpretability of situation assumes stability (in an ideal – invariability) features (and relation) and strict (regular, repeatable) correspondence between them and thematic classes.

(3) In addition to interpretability, there has to be a complete consistency between observability and controllability, which may not be achieved in each particular case (Volchenkov, 2012).

(4) The decision system does not operate with "raw" input data. For regularizing problem usually preprocessing sensory data and extraction formalizable features and relations are required.

(5) Measures of similarity with the standard applied in metric methods of pattern recognition have artificial character. They use geometrical or statistical analogies of similarity/distinguishing, which can inadequately describe the morphology of the real patterns.

(6) In essence, all the classical interpretation methods are methods of classification: the result of interpretation has purely symbolic type (is label identifier). It only is the determinant of the class of control decisions. At forming these decisions is not reflected more detailed information about the state of the object, which could be used for specification of control algorithm.

(7) The locality and the sequence of process predetermined by atomic basis (see Section 3). As indicated in (Storozh, 2002), this limitation is due to the use as an instrument of classical mathematics as such, based on the use of the principle of consecutive calculations. The locality of process of interpretation does not allow to interpret a picture of the controlled object as a whole (synergetic) pattern. It means that in system there is no internal interpretability of the current interpretation problem: in each time point the system "remembers" only the current (actual) state of solving. The semantics of features and classes remains completely a prerogative of developers and users. It is possible to assume that any compensation of discrepancy between the locality of computing basis and integrity of the controlled object just and is use of mechanism of search engine.

(8) The interpretation system does not manifest any own activity (there is no generation of a new information). Essentially, it is simply a system of switches that are activated by external signals and its functioning is fully determined by the text (program code), given by the designer. Response of the system only actualizes explicit or implicitly predetermined the way of solving.

6.2 The hypothesis of cognitive control

The analysis of computing mechanism and limitations of classical methods of solving interpretation problems opens up the possibility to discuss the probable ways of progress in this area.

The investigated set of classical methods of interpretation united by a common computation mechanism and computer basis, can be considered as a cybernetic approximation to solving boundary information problems. This approximation allows us to solve first of all the simplest technical problems of this class. At the other pole of boundary information problems is the problem of information support of processes of functioning autonomous agents in variable environment in real-time. The complete solution of these problems is possible, apparently, only beyond the paradigm cybernetic approximation.

Perspective of transition to a new paradigm is consistent with that anthropogenic systems as systems of the information-supported nature in its development follow path, comparable to the evolution of biological systems.

Continuing biological analogy (Volchenkov, 2012), note that if the processes of the cybernetic type correspond to homeostasis and self-reproduction processes within a body, then the processes of the boundary type analogous to the active behavior of an organism in the environment, which ensures its survival. The simplest device for solving boundary value problems in biosystems is classical conditioning (conditioned-reflex system) and reverse afferentation. Progressive evolution of the biological mechanisms controlling external activity led at a certain stage to the emergence of highly developed visual system and mental functions (rudiments of intelligence) as means of providing an external activity of the organism at a higher level. It is assumed to be that this new system is functioning to a basis of cognitive knowledge ("commonsense knowledge").

At present possible to make only hypothetical assumptions about the perspectives of creating an artificial analogue of such a post-cybernetic mentality. At a general conceptual level natural to supposed that, by analogy with biological systems, that overrunning the cybernetic approach is expressed primarily in the transition from implicative system to the control system based on the use of cognitive knowledge.

Thesis about knowledge as the basis of cognitive control well agrees with the meta-ontological principle, according to which, along with constructive, or variant relations in Universe there are additional constant or invariant relations accumulated information carrier in the apparatus of cognitive knowledge (Volchenkov, 2009, 2011a).

In cybernetics solver the palliative of invariance are such features as narrow specialization of thematic domain, stationary of controlled system, and immutability of interpretation data (and uniqueness of actualization implicative operator). The problem complicating objects of interpretation or expansion of thematic area is decided here, as indicated above, extensive way – the increase in interpretation of data that come into collision with limits of speed and machine memory (Nechansky, 2012).

Transition from cybernetic to cognitive control by analogy with system information problems of a kernel (Volchenkov, 2011b) is thought as replacement of the implicative mechanism with the mechanism of hypothetical perceptual modeling of dynamics of system visual environment – agent. It is supposed that this modeling will be based on system of cognitive knowledge of the agent as the meta-ontological invariants expressing nature regularities. The use of multi-variant model situations-solutions allows to make predictions on the basis of which the selection of the optimal (from the point of view of goals) correction of agent's behavior is continuously performed. Here it is also appropriate to quote (Katrechko, 1999): "The core of the fantasy is the mechanism of 'anticipatory reflection'. The essence of this mechanism is that the mind rather than to reflect available […] how would run ahead and 'builds' (with the help of imagination) a possible model, obviously exceeding the requirement of solving the local problems facing it."

At last, we note that, as has been shown, the existing paradigm of computer science is closely connected with modern macroscopic computing (Turing machine). However, it remains an open question whether it is possible going beyond the cybernetic approximation – creating cognitive control tools – on ways to develop non-classical interpretation methods, or need a change of system-physical basis of computing.

7. Conclusion

In this work, the next step was made in the development of physico-semantical information theory. According to the physico-semantical concept the use of digital computer as the physical solver determines the object-semantic or meta-ontological basis and possible a priori the mechanisms of solving system information problems (Turing machine).

This conception has stimulated the consideration from unified theoretical positions the classical methods of interpretation used in application systems of pattern recognition and interpretation expert systems. Was demonstrated the universality of application of the implicative operators, which enabled us to formulate general mechanism of a computer actualization of interpretation methods.

The analysis of this mechanism allowed to concretize the fundamental limitations of the classical methods of interpretation and to consider them in more general aspect of artificial intelligence as the cybernetic approaching. As a natural going beyond the boundaries of this approaching in the framework of physico-semantical information theory, we have put forward the hypothesis of the cognitive control based on knowledge as meta-ontological invariants.

Note

1. Note, that the formulation Equations (3) and (4) can also be seen as a variant of representation of uniformed cybernetic functional element of decision-making on Nechansky (2011, 2012).

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