Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 3 Issue 3, March - 2019

Semiotic Model of the Cognitive Agent Perception

Astanin S.V.
Russian New University, Taganrog branch, Taganrog, Russia
Email:astser@mail.ru

Zhukovskaya N.K.
Russian New University, Taganrog branch, Taganrog, Russia
Email: nasha-0207@yandex.ru

***Abstract*—The article considers the features of the bionic concept of functional systems for modeling the behavior of the intelligent agent. The main attention is paid to the implementation stage afferent synthesis, connected with solving problems of recognition of incoming messages, the external environment, analysis of data messages to meet the needs of the agent and to build a plan of action possible with the existence of the prevailing motivation and sufficiency of the initial data. The decision of the listed problems directly connected with the mechanisms of processing of knowledge stored in the memory of the agent.**

***Keywords*—adaptive behavior, the intelligent agent, afferent synthesis, the ontological model, dominating motivation, memory of the agent.**

I. Introduction

Agent-oriented technologies are one of the most promising areas in research, being both of theoretical and applied interest to such fields as management, economics, e-commerce, Internet, training, etc. Designing multi-agent systems is a new line of research, within the context of which many issues remain unexplored. This fact is witnessed both by a variety of approaches to creating agents with respect to their architecture and implementation and various authors' definitions and interpretations of an agent, its properties, relations with other agents, etc. [1] But it should be noted that some concepts, which allow us to consider basic notions from a unified standpoint, are capable of excluding or avoiding such inconsistencies and contradictions. So, we can stress that the theory of functional systems developed by A.P. Anokhin, which finds currently a wide application in studies of natural and artificial self-organizing systems [2-4], may be offered as an adequate conceptual basis for the design of agents

According to the concept by A.P. Anokhin, a behavioral act consists of the following stages: afferent synthesis, decision-making, acceptor of the action results, efferent synthesis, formation of the action itself and an evaluation of the achieved result [5]. Herein we consider some peculiarities of the methods applied to implement the first stage of the cognitive agent behavioral act as a complex process of perception and processing of messages coming from the external world. We associate the perception of external messages with the mechanisms of memory, where images of the external world as a reflection of the previous (or imposed from outside) experience of the agent, associated at a given time with the needs of the agent, are stored. At the same time, we do not pretend to formalize the continuous process of the external world perception. Messages from the external world are treated as stimuli for a possible agent's task, to which he responds based on the available images and needs available in its memory

II. THEORETICAL PART OF THE STUDYE

A. *Peculiarities of the perception associated with the memory of the cognitive age*

According to the theory of functional systems by P.K. Anokhin, an afferent synthesis is the initial stage of a behavioral act and consists of the following mutually interacting mechanisms: situational afferentation (SA), dominating motivation (M), launching afferentation (LA) and memory (Mem). In order to apply these mechanisms to real activity, some conditions shall be met as listed below:

1) The memory should not be empty.

2) The memory stores knowledge, the volume and content of which is sufficient to solve, for the purpose of this consideration, tasks of a recognition and an analysis of input messages, as well as selection of actions that follows.

The first condition states that the perception of the external world (as well as the agent's perception by itself) is impossible under erased memory. According to the second condition, knowledge (in the form of images) of the external and internal environment and the perception mechanisms listed above (in the form of their descriptions and rules of applications) should be stored in memory.

Assume that I_S, I_M, I_{IA}, I_{Mem} are knowledge of the mechanisms of the perception. Thus, in accordance with condition 1) it can be argued that the realization of the afferent synthesis (AS) is possible with the following memory state: $I_{SA} \cap I_M \cap I_{LA} \cap I_{Mem} \neq \varnothing$.

Thus, in the absence of input messages (IM), when $I_{IM} = \varnothing$, there is no precedent for the afferent synthesis realization. If $I_{IM} \neq \varnothing$, but $I_{SA} \cap I_{Mem} = \varnothing$, then, either $I_M = \varnothing$ or $I_{IA} = \varnothing$, or both. Case $I_{Mem} = \varnothing$ is typical for input situations, where there are no messages corresponding to the agent's needs. Case $I_{IA} = \varnothing$ is associated with the presentation of a task, when and where the agent has no experience of solving thereof.

The stimuli of the initiating afferentation can be explicitly contained in the situational afferentation (an order, an instruction, duty regulation or job description). Besides, they may arise, in the presence of a dominant motivation, in the process of particularization of some indefinite, incomplete or inaccurate initiating afferentation parameters (concrete values of resources allocated to the solution of the problem; the agent's own state that allows solving the problem). In any case, if $I_{SA} = \varnothing$, the outcome of the completion of the afferent synthesis process is the refusal to solve the given task.

Memory being the carrier of the experienced knowledge, based on which the behavior on the perception of input messages is organized, occupies a special position in the AS realization. Thus, in the absence of memory ($I_{Mem} = \varnothing$), information about the external environment cannot be recognized, and motivation and stimuli do not appear. Assume the existence of different memory levels $I_S = I_1, I_2, ..., I_i, ...I_j, ..., I_n$, and in this case, the higher is the index, the higher is the memory level it corresponds to. In psychology, different classifications of memory exist. It is generally accepted to consider the dependence of the memory properties on the characteristics of the activity of memorization and reproduction as the most generalized basis for distinguishing various types of memory. In particular, according to the nature of the mental performance, prevailing in activity, memory is divided into motor, emotional, image and verbal-logical memory classes. Adhering this way, it should be noted that in case when some memory levels are absent, different motivational excitations might be generated based on the remaining levels, as well as responses to certain stimuli, not necessarily associated with the solution of the production problem. Thus, for example, if only a motor level in the memory is available, an external painful exposure applied to the hand skin triggers the conditioned hand withdrawal reflex. At the same time, the existing classifications of the memory levels are not capable of giving an answer, for example, to the following question: what is the difference between the memory levels responsible for solving a typical task and a problematic one at the AS stage? Obviously, the answer to this question can be given only when the memory and the mechanisms of thinking are treated collectively. Within this section it is sufficient to introduce n memory levels, which can include both the classical types of them and the memory levels associated with specifics of the formulation of the tasks and their recognition at the stage of the situational afferentation. At the same time, if the memory of some levels is absent, the mechanism of thinking has to address the other, possibly lower, levels of the memory. In this case, it is expected that the response to the stimulus will be other than a response to the same stimulus, but with the use of the information at the higher memory levels.

B. Mechanisms of the situational afferentation from the point of view of semiotics

We assume that the agent's input messages are always fixed. This means that they are objectified by means of a certain sign system or a material carrier in the form of a text, a formula, a scheme, an image, and another imaging representation. In this case, we can say that the messages are available to the agent for its perception. Hereinafter, this sort form of the objectification of the input messages is referred to as an information object. From the standpoint of semiotics, any information object, accessible to perception, can have three constituents as follows: a syntactic constituent, a semantic constituent and a pragmatic one. While the syntactic constituent of the information object is associated with the sign system that serves to describe it, the semantic and pragmatic constituents have a psychological aspect, connected with the specifics of the internal world (knowledge of the external world) of the agent, its needs and motivation.

The syntactic constituent of the information object is rested upon a set of interrelated signs from a certain alphabet. The interrelation of signs is established by the rules of a particular sign system and allows, for example, forming a word (a lexeme) for a text. In addition, within the sign system, certain relations and connections between the sets of signs exist to form an integral complete set. This sort of relations and connections dictates the rules for constructing sentences. Examples of the sign systems are as follows: a text, a table, a drawing, an aircraft, a man, an animal, etc.

From the standpoint of semiotics, the signs and their sets with the relations is an equivalent of the real object being perceived due to the mediated essence by the consciousness. To understand this essence, it is necessary to identify the meaning of a sign, i.e. its significance. The significance of a sign represents the semantic constituent of an information object that allows the agent to decode the content (the meaning) of an input message expressed by the signs. While the syntactic constituent is associated with an identification of a perceived object, i.e. with recognizing a sign or a set of signs as given, the semantic constituent provides recognizing an object through the formation of its perceptual image and the comparison of the latter with reference images already stored in the memory. In the agent's memory, such images are represented as signs with their assigned meanings. An identification of the semantic constituent of an information object means certain comparability of the input message signs with the reference image signs and the transfer of the meanings of the reference signs to the corresponding input message signs under processing.

An interpretation of an input message does not imply that any action by the agent follows. In order to respond to a message by undertaking actions, by generating a certain behavior and even thoughts, it is necessary to find in the information object its pragmatic constituent that determines the relationship between the message significance and the current motivation of the agent. The latter is produced on the basis of an analysis of the needs.

Thus, the same information object can be treated from the point of view of the availability of the three constituents to an agent. If the object is specified at the level of the syntactic constituent only, then we may assume that the description of the perceived object is comparable to the concept of "data", which treated as signs require their identification only. At the level of the interpretation of the message, the agent shall derive both the syntactic and the semantic constituents. The presence of these two constituents in the perception by the agent is associated with the description of the object at the level of knowledge. And only if all three constituents of the object are successfully extracted, we can say that the agent obtains the information, because it is precisely the pragmatic constituent that allows answering the following question: what I need it for, when, where and how I can use it.

As a consequence of the treatment of the perceived object based on the concept of the three constituents and perceiving it as information, the process of transferring messages from a source to a consumer can be viewed through the prism of the following three filters:

1) a syntactic filter, associated with the identification of an object, regardless of its content;

2) a semantic filter (a selection of the data that can be interpreted by the recipient, i.e. which correspond to the thesaurus of its knowledge);

3) a pragmatic filter (a selection, among the interpreted data, of data useful for solving this task or satisfying the dominating motivation).

According to the concept by P.K. Anokhin, the situational afferentation is a generalization of the current situation (the state of affairs) in the circumstances of the agent: an analysis of the task (the objective), the required resources, an assessment of its own capabilities, an evaluation of possible strategies of other agents, an assessment of the previous behavior types of other agents, etc. In this connection, the following functions of the situational afferentation (SA) can be distinguished: a generalization, a recognition, an analysis, and filtering. We believe that these functions are realized not simultaneously, but in stages. At the first stage, a superficial image of the current situation is created on the basis of the recognition of the latter and the comparison with the models available in the memory. The main task of this stage is to identify the semantics (sense) of the input messages. The second stage is associated with an in-depth analysis (detailing) of the interpreted messages, and it is realized after the semantically interpreted messages become necessary for realization of the agent's needs. And, finally, the third stage is designed to generalize the analyzed messages.

The introduction of the stages into the realization of the SA functions is consistent both with the semiotics and the concepts offering sequences of solving problems in other research areas.

For example, in pedagogical psychology, three levels of education are introduced. The first level is associated with the recognition of the studied objects or processes in case of repeated perception on the basis of previously established descriptions or actions on them [6]. The second level allows both reproducing the previously acquired knowledge and applying it to typical situations (reproduction of information from the memory; solution of typical problems according to the previously acquired pattern). The third level is a level of the acquisition of information that allows the learner to independently reproduce and transform the knowledge (generate subjectively new information about studied objects and actions on them) and apply it to a variety of non-typical situations.

Recently, the following mechanism of human cognitive activity has found its applications in psychology and pedagogy [7]: synthesis - analysis - synthesis. The essence of this mechanism of cognition is as described further herein. Initially, a subject perceives an object as a whole entity, however a superficial manner (the synthesis). A more detailed familiarization therewith leads to an identification of the properties and characteristics of the object (its analysis). Expanding its knowledge of the object to a certain level, the subject can again perceive the object as a whole entity, but on the basis of the entire detailed totality or integrity of its properties (the synthesis).

D. Poya, analyzing the subject's reasoning, identifies the following steps in learning objects: generalization, specialization and analogy [8]. By generalization we mean the transition from the consideration of a certain set of objects to the consideration of a larger set thereof, including the given object. The specialization is the transition from the consideration of the given set of objects to the consideration of a smaller set that is contained in the initial set of objects. The analogy provides transferring of some mechanisms or certain properties of the object, which are known to the subject, to an unknown object under examination.

In all the considered approaches one and the same thought can be traced: learning an object begins with a superficial familiarization therewith, connected with the knowledge of the object's form. Then the transition to a deeper examination and cognition of the object's peculiarities and characteristics is carried out. At the third stage, an analogy is used as a method of cognition that allows transferring knowledge of the object to another object, probably of a different nature. The peculiarity of these stages is the involvement by the subject (agent) of different mental activities.

Thus, the first stage of SA is governed by the syntactic and semantic analysis of information. The second stage, according to our interpretation, is the pragmatic analysis of information. At the third stage, an image of the agent's responding behavior to the input and the agent's own state is generated, and a decision is made on how to respond thereto.

C. C. Realization of situational afferentation on the basis of ontologies

In simple cases, where input messages are one- or two-dimensional objects, the first stage of the situational afferentation can be realized on the basis of an ontological model of the agent stored at a certain level in its memory.

Assume that $S_1, ..., S_i, ..., S_n$, $i = \overline{1, n}$ is a set of terminological ontologies, and in doing so,

$S_i = <C_i, R_i, A_i>$, where

$C_i = \{c_{i,1}, c_{i,2}, ...\}$ is a set of concepts of the i -th ontology;

$R_i = (R_{i,1}, R_{i,2}, R_{i,3})$ is the designation of the relations on the set of concepts;

$R_{i,1}$ is the synonymy relation;

$R_{i,2}$ is the hierarchy relation;

$R_{i,3}$ is the association relation;

$A_i = (A_{i,1}, A_{i,2}, A_{i,3})$ is the designation of the axioms;

- $A_{i,1}: c_{i,j} R_{i,1} c_{i,k} \to c_{i,j} = c_{i,k}$;

- $A_{i,2}: c_{i,j} R_{i,2} c_{i,k} \to c_{i,j} \in c_{i,k}$;

- $A_{i,3}: c_{i,j} R_{i,3} c_{i,k} \to c_{i,j} \approx c_{i,k}$.

Let us assume the task for the agent is formed in the form of a sentence $C = (c_1, ..., c_m)$, where c_l , $l = \overline{1, m}$ are lexemes. If $c_l \in S_i$, then, basing on the axioms, lexeme c_l can be replaced by the concept(s) $c_{i,v}$. By combining the obtained concepts from different ontologies on the basis of syntagmatic relations at the lexical level, we obtain a set of different formulations of the initial task *C*, which, together with *C*, constitute a superficial image of the current situation of the agent, i.e. $C, C_1, C_2, \ldots$.

The second stage of the situational afferentation can also be realized on the basis of the ontological model, where not lexemes but syntagmas with the association relation undertake the role of the concepts:

$G_p = < C_p, R_p, A_p >$, where

$C_p = \{C_{p,1}, C_{p,2}, \ldots\}$ is a set of concepts of the *p*-th ontology;

R_p is the designation of the relations on the set of concepts;

$A_p : C_{p,j} R_p c_{\ p,k} \rightarrow (C_{p,j} \rightarrow C_{p,k})$.

If $C_w \in C_p$, $w = \overline{0, s}$, then the concepts from the associative series $C_w \rightarrow \ldots \rightarrow C_p$ are associated with it. Further these concepts may act as the dominating motivation, corresponding to a specific need of the agent.

The third stage is connected with the formation of a generalized image of the initial situation. Such a generalization is possible on the basis of an analysis of the typical situations and precedents of solving the problems, and if they are not available, based on some behavioral instructions stored in memory in the form of embedded metagraphs.

An embedded metagraph is a construction of the following form [9]: $G=(X, E)$, where $X=\{x_i\}$, $i = \overline{1, n}$ is a finite non-empty set of vertices, and there exist functions $f_1^l : g_1^l(x_1^l, e_1^l) \rightarrow x_2^p$, $f_2^p : g_2^p(x_2^p, e_2^p) \rightarrow x_3^r$, …, $f_{n-1}^t : g_{n-1}^t(x_{n-1}^t, e_{n-1}^t) \rightarrow x_n$; $E=\{e_k\}$, $k = \overline{1, m}$ is a set of edges of a graph where $e_k=(V_i, W_i)$, $V_i\ W_i \subseteq X, V_i \bigcup W_i \neq \varnothing$, i.e. each edge of an *n*-dimensional graph joins two subsets of the set of vertices. Here *i* determines the level of nesting, and indices *l*, *p*, *r*, ..., *t* are the number of vertices and edges at the corresponding level.

If the edge of an *n*-dimensional graph is directed, then the graph is called an oriented *n*-dimensional graph. Nested metagraphs are a generalization of the ordinary graphs, hypergraphs, and metagraphs. In the general case, vertices x_2^p are the hyperedges of graphs $g_1^l(x_1^l, e_1^l)$, vertices x_2^r are the hyperedges of graphs $g_2^p(x_2^p, e_2^p)$ and so on. The edges can connect vertices of any level of the representation, i.e. both individual vertices and hyperedges that is typical for metagraphs. Such a description allows representing the nested structure, each vertex of which can be arranged as a "nesting doll".

The concept of a nested metagraph contains and matches two important properties of the system: its unity (a set of interrelated elements) and its divisibility (each element of the system is considered to be a system, too). Thereby, it is possible to indentify subsystems in a system. This also allows, in each specific case, focusing on the system or its subsystem, which is of value for an analyst at a given moment.

D. The use of analogy for recognition of input situations

The problems of the semantic analysis are related to the comparison of the initial object descriptions to the reference images stored in the agent's memory. These problems include classification, recognition and reasoning by analogy. When solving each of these problems, there is a set of objects, which are characterized by a known set of attributes with specified significances. As to the problem of images classification, decision making consists in applying a previously formulated rule that makes it possible to find that an object belongs to one of the classes. In other words, a classification is ordering of the objects by their similarity. Considering the problem of images recognition, an applicable classification rule is formulated on the basis of examination of the set of objects with their already known attribution to different classes. Herein the similarity of an arbitrary object and the reference representatives from different classes is to be found. When solving the problems by analogy, established shall be a correspondence between initial object A and object B perceived earlier, at the level of various constituents, and by means of establishing this correspondence the identification and the interpretation of object A is provided. What all the problems have in common is that the objects are compared according to their similarities or differences between them. A characteristic feature of the problems of the classification and pattern recognition is that the comparison of objects is carried out with the same set of attributes, and as a rule the attributes are independent. To establish an analogy, not the attributes of objects and their significances, but the relationships existing between the significances of the attributes play a decisive role. Accordingly, an analogy is treated as a similarity of the relations between the considered objects.

For those cases, when the attributes describing the objects are independent, and the proper objects are characterized by large dimensionality of the attributes for their identification, one can use well-known methods of classification and cluster analysis.

Reasoning by analogy plays a crucial role for a human individual and is widely applied in semi-formal explanation of the methods of decision-making under the conditions of alternative choice. At present, the relevant literature offers descriptions of several formalized approaches to an implementation of supplying output by analogy:

An evaluation of analogies by pre-specified criteria;

An analysis of structural and substantive analogies between concepts;

An analysis of analogies in plans for solving the problems;

An identification of analogy based on an analysis of the context of objects.

As a rule, the analysis of analogy between objects in the approaches listed above is based on finding a similarity between the attributes that describe the compared objects. Thus, when solving the problems of classification and recognition, there is a typical case, when the object is compared by its attributions to the other objects, the classification of which have been already completed, and, based on the similarity of the attributes, a decision on assigning the object to a particular class is made. In situational management systems, the current situation is compared with the reference ones stored in the knowledge base, and subsequent decisions are made on the basis of the similarity of the situation descriptions. Decision-making in the above treated cases has two common points. Firstly, there are many alternatives that require ordering the priorities as applied to a specific situation. Secondly, such ordering is based on the concept of similarity and analogy between the objects or processes under study.

For a number of applications it is important to properly describe objects, taking into account the structure of their constituents. In this subsection we discuss an approach to constructing a formalism of plausible reasoning by analogy, according to the relevant structural and substantive description of objects. The basis for such formalization was the original analysis of the concept of analogy by D.Poya [8]. At present, there are several approaches to the analysis of analogy between objects and the formalization of reasoning rested thereupon [10, 11]. The groundwork for the above mentioned approaches is formed by the apparatus of the theory of fuzzy sets and fuzzy logic.

In [8] the following stages of the analysis of objects are noted, which are necessary for establishing an analogy: a generalization, a specialization and an analogy. By the generalization we mean the transition from the consideration of a certain set of objects to the consideration of a larger set including the given object. In other words, the generalization provides for the transition from the consideration of an object to a certain class of objects. The specialization is the transition from the consideration of a given set of objects to the consideration of a smaller set, included therein, or the transition from the consideration of a class of objects to a certain object included in the given class. In [8] it is stressed that the essential difference between the analogy and other similarities is specified by the intentions of a thinker or by the goal that a human individual sets for himself by comparing the objects. Similar objects are in agreement with each other in a certain relation, however if a human individual intends to reduce this relation to some specified concepts, the similar objects may be regarded as analogous ones. Thus, objects are analogous if they are in agreement in explicitly defined relationships of their corresponding parts. In [8] several types of analogies are introduced, based on practical examples, and the formalization of the logical conclusion is reduced to an inductive-deductive scheme. Assume *A* and *B* are two sentences (theorems). Assume that there exists theorem *H*, the consequences of which are theorems *A* and *B*. If a consequence is proved, then according to the inductive-deductive scheme one can make a plausible conclusion with respect to the second consequence as well. To believe in the existence of *H*, it is necessary to prove that *A* and *B*, in a certain sense, are analogous. Thus, for example, if there are two knowledge bases *A* and *B*, parts of which are in agreement, it is possible to construct knowledge base *H*, from which *A* and *B* follow. It is also possible to argue as follows: Assume that we have two physical objects P_1 and P_2, and let us suppose that M_1 and M_2 are the models of these objects. Then, if M_1 is analogous to M_2 and there exists a conversion Ψ of model M_1 into model M_1^1, then on the basis of the analogy between the models and function Ψ the model M_2 can be converted into model M_2^1.

The use of analogy in the process of the perception of input images at the semantic level is associated with a possibility of automatic construction of knowledge bases of problems similar to the descriptions of the problems that are already stored in the agent's memory.

The majority of the approaches to formalizing the types of reasoning by analogy can be reduced to two schemes as follows:

1. We consider objects *x* and *y* with their descriptions G_1 and G_2 , respectively. If G_1 and G_2, in a certain sense, are similar, then there is an analogy between *x* and *y*, expressed by description *A*, besides, $A \subseteq G_1$ and $A \subseteq G_2$.

2. For object *x* with its description G_1, property W^* is typical. We consider object *y* with its description G_2, which remains unexplored with respect to property W^*. If descriptions G_1 and G_2 are analogous, then object *y* has property W^* with a degree not greater than that of the analogy of G_1 and G_2.

The first scheme deals with searching for an analogy between the descriptions of objects, and the second one takes into account the conclusion made according to the analogy.

When considering the mechanism of reasoning by analogy, we introduce the following definition of an object. An object referred to as object *Q* is denoted in the categories of the form and content (significance). The attributes, features or properties of an object to characterize its single (particular) manifestation will be called the internal content of the object. The internal content is structurally organized, i.e. there is a way of interrelation between its attributes, which is an internal form of the object and which determines the general manifestation of the object. In addition to the internal content and form, object *Q* may have its external content, i.e. a set of properties (either structurally organized or not) to characterize the internal form of the object. Thus, object *Q* is determined by its internal content (the particular manifestation of the object), its internal form (the general manifestation of the particular) and its external content as characteristics of the internal form.

The introduced definition of an object makes it possible to provide a clearer description of schemes 1 and 2. Thus, in the second case, the internal forms (generality) of objects *x* and *y* are compared, and the external content is known for well explored object *x*, too. If the forms of objects *x* and *y* are analogous in a certain sense, then the external content of object *y* is the same as it is the case with the external content of object *x*. In the first case, objects *x* and *y* are represented only by their internal forms. Based on the similarity of the internal forms G_1 and G_2, found is the analogy, which exists between the descriptions of objects *x* and *y*.

E. *Mechanisms of dominating motivation*

Let us consider a simple mechanism for identifying the dominating motivation. Let the agent memory store fuzzy matrix $C_{i,j} = P_i \times D_j$, where P_i represents the agent's needs, and D_j denotes possible motivational stimuli. At the intersection of the rows and columns of the matrix given are coefficients $c_{i,j}$ to define the degree of the correspondence between the need and the motivation. Then, if at the current moment the agent determines its preferences for the needs to be realized $\alpha_i, i = \overline{1,n}$, i.e. $P = \{\alpha_1 / p_1, ..., \alpha_n / p_n\}$, then to determine the dominating motivation at moment *t* it is sufficient to solve equation $P \circ C_{i,j} = D$, where "$\circ$" is a sign of the maximin composition operation, and $D = \{\beta_1 / d_1, ..., \beta_m / d_m\}$. At the same time we assume that the needs p_i, with a power equal to $max\{\alpha_i / p_i\}$, correspond to the dominating motivation d_j with a power equal to $max\{\beta_j / p_j\}$.

The considered mechanism is based on the application of a scheme of plausible reasoning of the form:

$$\frac{\begin{array}{l} p_i \rightarrow d_j \\ p_i * \end{array}}{d_j *}.$$

The given scheme works in case of fixed matrix $C_{i,j}$ and the current changes in the agent's preferences regarding its needs. The change in the coefficients $C_{i,j}$ is determined by factors, which indirectly affect the correspondence between the motivation and the need. To explicitly take into account such factors, one can use a scheme of nonmonotonic reasoning with exclusions of the form: **if** <premise> **then** <solution> **if not** <exclusion>, or if *P* then *D* if not *E*, where *E* is an exclusion [12]. This sort of the scheme assumes that once a premise is established, a decision can be made if at the same time an exception is not established. Since exceptions are very rare, in most cases a solution follows a premise. In this case only decision *D* or exception *E* may be true, that is, we see the exclusive-OR relationship between the decision and the exception. Thus, the ratio defined with the "**if not**" operator between *D* and *E* has the following form:

$$(D \cap \neg E) \cup (E \cap \neg D),$$

where $\neg, \cup, \cap$ are fuzzy complement operators, *S*-conorms and *T*-norms, respectively. In [12], coefficient γ is introduced into the ratio to show the weight (the importance) of the exception. In this case, the modified ratio takes the following form:

$$(D \cap \gamma \neg E) \cup (\gamma E \cap \neg D),$$

besides, when γ =0, the exception is not taken into account.

Thus, the use of exceptions allows storing fixed matrix $C_{i,j}$, in memory, and changing the set of exceptions and their importance factors during the learning process.

The above considered approach to defining the dominating motivation implies that all reasoning is undertaken by the agent on the basis of its own model and analysis of the facts obtained in the process of the situational afferentation. In an organizational system, the source of facts may be another agent, for example, a chief, who may have his own opinion on the preference of facts as motivational stimuli and their relevance considering the needs of the agent. If the agent has its own views of the preferences relevant to the motivational stimuli of the chief, then it can compare them with its own preferences of the needs. In this case, two schemes of reasoning are used as given below:

at the known agent’s preferences, the preferences of motivational stimuli are determined on the basis of matrix $C_{i,j}$ and direct composite output;

at the chief's known preferences, based on the $C_{i,j}$ and reverse composite output, determined are the agent's preferences regarding its needs.

Based on the comparison of the agent’s and chief’s preferences, the strategies with the highest preference values are separated.

In order to take into account the chief's preferences, matrix $C_{i,j}$ can be considered as a payment matrix as well, and the needs and motivations can be treated as the agent’s and chief’s strategies, respectively. In this case, a solution concerning the optimal strategies is sought in the class of fuzzy matrix and bimatrix games.

First let us consider a fuzzy matrix game of two persons, defined by payment matrix $C_{i,j}$. In the classical matrix game the payment matrix coefficients determine the wins / losses of the players, when they use certain strategies. In our case, the wins / losses are fuzzy terms of linguistic variables “Wins level" / "Loss level", when the agent realizes a certain need, and the chief uses a certain motivation. Each fuzzy term is a fuzzy number, defined on the universal set of wins / losses. As it is the case with the classical formulation, matrix element $c_{i,j}$ is interpreted as the value of the win, for one player, and as the value of the loss, for the other player, and these values have opposite signs (see Fig. 1 herein).

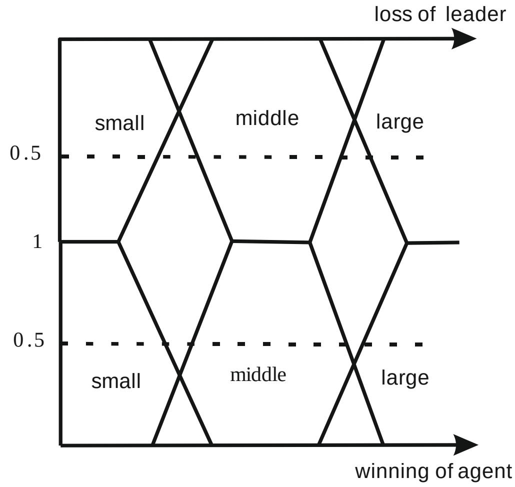

Fig. 1. Assignment of the payment matrix linguistic values

In the context of the classical formulation, it is implicitly assumed that the strategy preferences are indistinguishable and equal to 1.

In this case, to determine the price of the game in pure strategies, the maximin composition is used with respect to the decisions of the 2nd player and the minimin composition with respect to the decisions of the 1st player. In other words, the players preferences are specified as p_i and d_j, and the upper price and lower price are defined as follows:

$$v = min(P \circ C_{i,j}) = min(max\, \min_j(p_i, c_{i,j}));$$

$$\varpi = max(D \bullet C_{i,j}) = max(min\, \min_j(d_j, c_{i,j})).$$

When searching for a solution of the game in mixed strategies, $c_{i,j}$ is interpreted as an evaluation of the possibility of the corresponding win/loss which is specified linguistically. A solution of the game, when formalizing the linguistic terms by fuzzy numbers of triangular and *L-R* types, can be found, for example, in [13-15].

A bimatrix game allows taking into account the agent's heuristic knowledge of the behavior of another agent. Thus, in [16] discussed is an approach to constructing fuzzy matrices of the agents' wins with the known linguistic preferences of strategies, specified preference functions and rules for estimating any pair of strategies. Besides, each player determines linguistic payments in the form of fuzzy matrices of the preferences for any pair of strategies. The process of solving the game is divided into three stages: fuzzification, fuzzy inference and dephasing, which are defined for each of the players by a fuzzy matrix of the preferences. These stages support in automating the choice of fuzzy strategies by the players and their respective fuzzy preferences needed to solve the fuzzy game. The result of these stages is the superposition of the matrices of the player preferences in the form of a fuzzy bimatrix game, shown in Fig. 2 herein.

	d_1	…	d_m
p_1	$\alpha_{1,1}$ $\beta_{1,1}$	…	$\alpha_{1,2}$ $\beta_{m,1}$
…	… …	… ….	… …
p_n	$\alpha_{2,1}$ $\beta_{1,n}$	…	$\alpha_{2,2}$ $\beta_{m,n}$

Fig. 2. Bimatrix fuzzy game in the form of preferences matrix of players' strategies pairs

Then the Nash equilibria are found:

$$\beta_{j,i}(d_j{*},\, p_i{*}) \ge \beta_{j,i}(d_j{*},\, p_i),$$

$$\forall p_i \in P,\, \alpha_{i,j}(p_i{*},\, d_j{*}) \ge \alpha_{i,j}(p_i{*},\, d_j),\, \forall d_j \in D$$

F. Mechanisms of dominating motivation

The launching afferentation is connected with the identification of the conditions necessary and sufficient for constructing plans for the realization of the dominating motivation realization. In [17] considered is a procedural approach to the generation of a fuzzy situational network (FSN) which allows, when the initial set of the known situations and various combinations of a set of control actions, constructing and analyzing different transitions from some initial situation to the target situation. At the same time, shown is a possibility of describing FSN by production system $W=\{W_1,\ldots,W_k,\ldots,W_m\}$, where the *k*-th production is an expression of the form W_k: $S_i \Rightarrow S_j$, and in this case S_i, $S_j \in S=\{S_1, \ldots, S_p\}$ are fuzzy formulas; "$\Rightarrow$" is a sequent sign, which, in a logical sense, is interpreted as a sign of logical sequence S_j from true S_i.

In general terms, the production is considered as the following expression:

$$(I);\, Q;\, A \to B;\, N\,,$$

where *I* is the name of the production, *Q* characterizes the scope of application of the production, *P* is the condition for the applicability of the production kernel $A \to B$, and *N* describes the production postconditions.

According to our interpretation, *P* is the launching afferentation conditions. In simple case, the P conditions are determined at the stage of the situational afferentation for the realization of the modus ponens rules of the form $A,\, A \to B;\, A{*},\, A \to B$. According to [17], when constructing FSN as a model of possible plans, the initial typical situations, the set of control actions and the target situations represent the initial data. Such a collection results from the previous experience, however in order to use the latter, it is necessary to compare the information, obtained at the stage of the situational afferentation, to that about the typical situations. This sort of comparability is provided by fulfilling conditions $A \equiv A$ for a binary modus ponens, and $A{*} \approx A$ for a fuzzy modus ponens.

In complex cases, *P* is supplemented by the dominating motivation and some unknown factors, which are sub-goals of the afferent synthesis phase. In accordance with the concept by A. Anokhin, the realization of the sub-goals is delegated to functional systems of a lower level.

The methods of afferent synthesis discussed above are directly related to the mechanisms of processing information stored in memory. Based on advanced concepts, we can distinguish the following types of memory: the sensory memory, the short-term memory and the long-term memory (please, refer to Fig.3 herein). Taking into account the peculiarities hereof, let us consider the objects that are stored in the last-mentioned two types of memory.

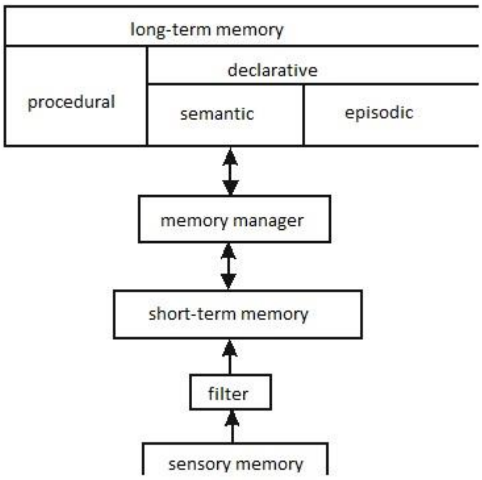

Fig. 3. Types of the agent memory

The short-term memory is designed to reflect events, which have taken place at the present time, as well as to interpret or comprehend them. Therefore, there, for a certain time, stored are the messages, filtered from the sensor memory according to certain criteria. Thus, the motivational stimuli, meeting the needs of the agent, may operate as a filter.

The semantic memory is responsible for storage of general knowledge of the agent's world, for example, for significances of words. The memory manager compares this information to messages from the short-term memory in order to identify analogies, associations, generalizations followed by the substitution by them of the primary messages in the short-term memory. Depending on the nature of the information intelligible to the agent, a certain model of revealing the dominating motivational stimulus is extracted from the procedural memory. The dominating motivation actualizes the memory manager's attention to the short-term memory messages, which correspond thereto. In connection with the fact that we are dealing with the agent of an organizational system, we assume that the dominating motivation is related to the production problem, the solution of which is determined by a certain model. The implementation of the model requires that some specified initial data are to be available. If all the initial data are specified, then possible solutions of the problem in the form of FSN are constructed. If the initial data are insufficient, then the functional systems of a lower level are synthesized. Thus, in [18] a model of the coordinated behavior of the agents is considered in case of an allocation of a common resource allocated by the chief for a solution of the particular problems. In dynamics, each agent, when allocating resources, can use the information about the behavior of the other agents in previous cases and the previously accepted agreements. This sort of the information is stored in the episodic memory [19, 20].

The above peculiarities of the syntactic and semantic recognition of the input messages by the cognitive agent can be displayed by the following diagram (see Fig. 4 herein).

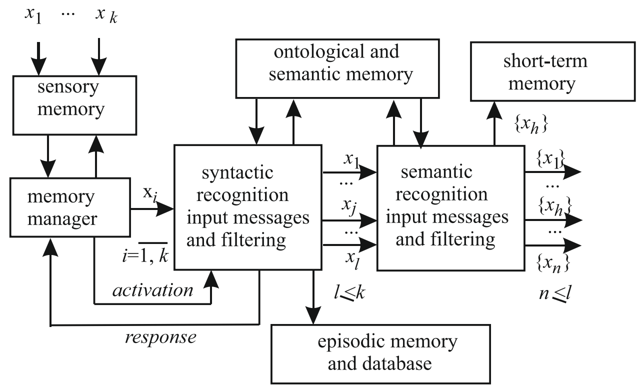

Fig. 4. Features of syntactic and semantic recognition of input messages

Herein x_1, …, x_k are the input messages, which are correlated with the images in the semantic memory at the syntactic level. The messages, which have been successfully identified, are fed into the semantic recognition unit. The other messages, the identification of which fails, are included in the episodic memory database. After the syntactic recognition of the messages, the memory manager erases the images in the sensor memory. As a result of the syntactic recognition, the number of messages for further analysis becomes equal to x_1, …, x_l, and in this case $l \le k$. These messages are delivered to the semantic recognition unit, where they are compared to the ontological models and descriptions of the semantic memory thesauri. The comparison results in extended message sets $\{x_1\}$, …, $\{x_n\}$, $n \le l$.

The specific features of the realization of the motivational excitation with the formulation of goals and decision-making tasks are presented in Fig. 5 herein.

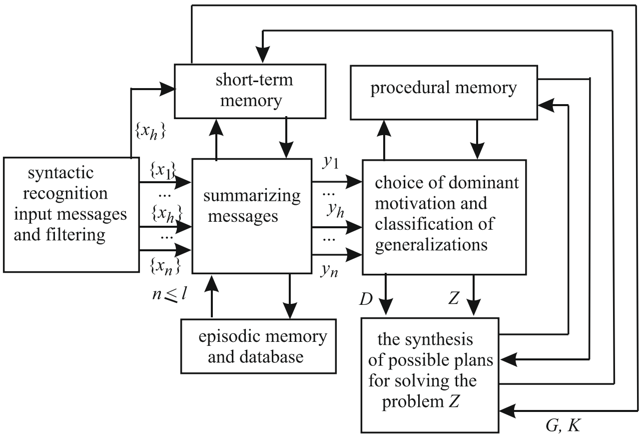

Fig. 5. The specific features of the pragmatic component of recognition in input messages and motivational excitation

Based on the mechanisms of analogy and association, the extended message sets are transformed into images of generalized messages y_1, …, y_n, which are classified in relation to the needs of the agent, according to the procedural memory models. This allows the agent to identify its dominating motivation *D*, and also formulate problem *Z*, which is in the correspondence thereto. On the basis on the description of *Z*, its goal *G* and goal achieving criteria *K*, possible plans for solving problem *Z* are generated by means of the procedural action planning models. In this case, it is assumed that *G* and *K* are formulated at the stage of the semantic analysis. The produced plans are delivered to the short-term and procedural memory for further optimization at the subsequent stages of the cognitive agent behavioral act.

III. Supplements and Discussion

The semiotic model of perception in accordance with the bionic concept of the behavior can be used in intelligent systems that are oriented to the semantic analysis of messages coming from the external environment. The peculiarity of such systems is the solution of the following tasks:

- recognition of situations. An intelligent agent should be able to recognize situations or events of the external environment as exemplary cases of the models which are already known by the agent or familiar to him. Recognition is closely related to reasonings by analogy and categorization. The cognitive architecture must include such a recognition process that allows identifying, when a particular situation corresponds to a stored pattern or category, and, possibly, measuring the degree of this correspondence;

- decision-making and choice. To work in some environment, an intelligent system also needs the capability of making decisions and choosing between potential alternatives. The decisions are often associated with the recognition of a situation or a pattern;

- perception and assessment of input situations. The intellectual agent should also be capable to go beyond the perception frameworks of isolated objects and events in order to understand and interpret the surrounding situation more widely. An evaluation of the external situation requires that the intelligent agent combines the perceptual information about many entities and events, obtained from as many sources as possible, to compose a large-scale model of the current environment;

- reasoning and persuasions. Recognition of input messages or situations in the external environment is closely related to reasonings. The cognitive architecture should have mechanisms, which allow drawing conclusions with the use of the knowledge structures in memory. As an example of using the model, let us consider the peculiarities of the functioning of an intellectual information retrieval system in an electronic library or on the Internet.

The existing information retrieval systems (IRS) are focused on searching for data, which is sufficient for groups of users, showing their exact information needs or suggesting that IRS is aware of them [21,22]. In reality, IRS does not possess any user model, and the proper user can formulate his/her request in an improper way. As a result, at the IRS output there are hundreds of thousands of found documents, and, at best, the user have to manually process (flip through) them to check them for their relevance with respect to his/her information needs.

To effectively solve the tasks given by the user to IRS, a search engine must have some information about the user, for example, about his/her interests and preferences, time schedule, personal contacts, as well as data about the information sources usually employed by him. Otherwise, IRS will not be capable to automatically filter out materials of interest to the user, to understand which area of knowledge the word entered by the user into the search line refers to, if such a word has several meanings, or to find spare time for some events in his/her schedule. If the user wishes to make sure that the found solution is correct, the system will supply him/her with a chain of his «reasonings», built in order to get the result, present the data sources used and indicate the degree of their reliability, based on their digital certificates. All of the above is applicable to the intellectual functions of IRS, which are today poorly represented. An information search is a process by means of which, in a certain sequence, the user's request is correlated with an electronic document. Ideally, the search goal is meeting of the information needs of the user, expressed via his/her request. In accordance with this definition, IRS must know or reveal the information need of the user or, in other words, understand what the user wants to receive as a result of his/her information search. In fact, we are speaking about the realization of the IRS information service. To properly explain this statement, let us apply the following analogy: You decide to buy fashionable shoes, and for that, you go to a shoe store. At the same time, the concept "modern fashionable shoes" is only hazily understood by you. To clarify your ideas, you require a support provided by a shop assistant who will clarify your preferences like season, size, color, shape, etc., describe the current trends in fashion, and on the basis of these data offer you versions of the shoes available. If the shop assistant is properly trained, he will always find out what you mean by fashionable shoes and what is the difference between your ideas and the actual stock available. On the basis of the above, he will identify your personal needs and give recommendations how to meet them. Then, you will accept (or not) the recommendations, make the final choice in favor of a certain offered version and pay for the goods. The described process represents an exemplary case of the realization of the service by meeting the need, which is known to the shop assistant. In fact, the information service should not differ from the above analogy. Realization of such search requires certain tools both at the stage of analyzing user groups with their information needs and the stages of formulating the need and analyzing the content of full-text documents. Design and construction of such tools is impossible without using the methodology of artificial intelligence that enables us to create intelligent search systems on the principles of interactive query generation, semantic models of search images and their comparison as structures of knowledge rather than data.

The information search systems should not be limited only to processing of the entered keywords, but they should track interests of users, making the search more closely focused on the subject of concern. When implementing an intelligent search system, the system response to a query may be treated as a solution to a pattern recognition task. In the information search it seems to be reasonable to use the semiotic approach to determining the information needs of a user in the form of identified goal G and the basic concepts of content-related interpretations of documents. According to the semiotic approach, data are interpreted as facts represented in a sign (syntactic) form; knowledge is understood as a meaning attributed to facts, and information is treated as facts, not only understood, but also of relevance for use.

Functioning of an intelligent search system involves two opposite processes: the first process deals with an acquisition of new knowledge and data. In doing so, the semantic descriptions are transformed into data. The realization of the second process implies extracting from the data that sort of information and knowledge that is actually required by the user to meet his information needs. Besides, the formalized query by user T must necessarily contain the semantic and pragmatic components, and the description of documents should be limited to the semantic images. In this case, the knowledge base may contain both ontologies of subject areas, thematic vocabularies and rules, which allow expanding the search query, narrowing the search space and correlate the descriptions of the query with a document from the relevant subject area.

Let us consider an illustrative example. Let us assume that a search query is given as follows: "model of semantic search". If the search driver were a person, broad-minded, but being not aware of information search issues, he would highlight the keyword "search" and specify "search of what subject?". If it were a person, competent in information search technologies, then, from the query context, he would immediately define the subject area "information retrieval systems" or "intelligent search engines". To solve the problem of the subject area selection, the knowledge base must have its own rules, which, in the first case, should initialize a dialogue with the user to properly specify the desired subject area; and, in the second case, allow identifying the subject area on the basis of the query analysis. For an in-depth analysis of the subject area, it is necessary to determine the user's information need, i.e. to find out the necessity of using the information about the models of semantic search. The pragmatic component of the query can also be identified in the dialogue. For example, the user can report that the desired information is required to prepare a report, a scientific article, a course of lectures, etc. The proper identification of the information need will make it possible to narrow the search area, already within the specific subject area, with focusing on the analysis of those documents, which are sufficient to meet the user's goal.

The next issue is to compare the query and a document, which belongs to a confined search space. For this purpose, it is necessary to have their descriptions expressed in the same language of representation. In particular, semantic networks may be such a representation. The procedure for converting a query and a document into a general form of the representation is carried out on the basis of the subject area ontologies, various vocabularies, supported by the morphological, the syntactic and the lexical analysis.

Thus, in our exemplary case, in the query it is necessary to identify the keywords (phrases) and establish relations between them. Let us assume that, as a result from the dialogue, or with the use of the base of the search system knowledge, the "model of semantic information search" query has been properly defined, and the user, or the system, has separated the following keywords and phrases in the query text: "model", "information search", "semantic". Based thereon, let us formulate an extended query in the form of a semantic network $\tilde{R}$ (see Fig. 6 herein).

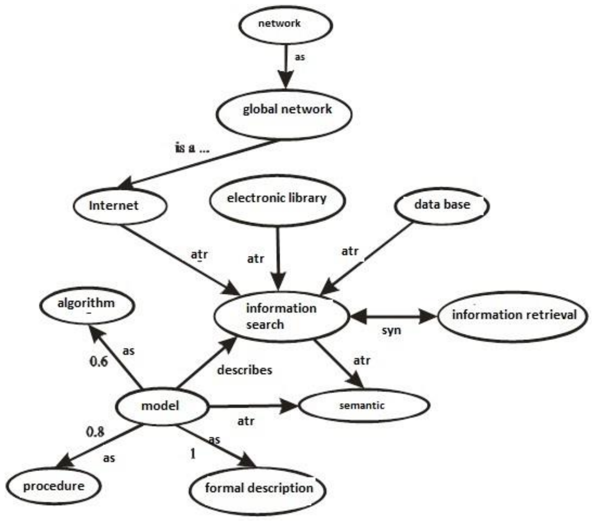

Fig. 6. Semantic network of the user's extended query

Let us derive subnetworks from the extended query semantic network, adhering to the following principles:

in the query semantic network, it is possible to replace the keywords, at the expense of associative relations, synonymous and attributive relations, by the corresponding semantic network concepts;

if a keyword in the query semantic network is an immediate attribute of certain concept x, then the keyword will be an attribute of the concept y, which is an association or a synonym of concept x;

if a keyword in the query semantic network has associations, it can be replaced by them, under substituting its weight by another weight, which corresponds to the associative relation between them;

if a keyword in the query semantic network has synonyms, then it can be replaced by the corresponding synonym;

if in a number several keywords have the same attribute, which is at the same time a keyword, then only one attributive relation is applied in the given subnetwork;

if a keyword in the query semantic network is an attribute of concept x, which is an example of concept y, then this keyword is an attribute of concept y, as well as an attribute of other concepts associated with the y associative relations.

Actually, the discussed principles are the rules, which make possible to derive the subnetworks, which are semantically associated with the user's initial query, from the extended query semantic network.

To illustrate the discussed approach, let us separate the semantic subnetworks associated with the user's initial query "model of semantic search" from the extended query semantic network shown in Figure 6 herein.

The following types of relations are applied herein:

- as (an association);

- is a … (is, an example);

- atr (attributive);

- syn (a synonym);

- describes (linguistics).

For simplification, only the meaningful concepts and relations are shown with respect to the network.

In accordance with the principles of deriving the semantic subnetworks from the extended query, we can separate some relevant subnetworks as given below (see Fig. 7 herein).

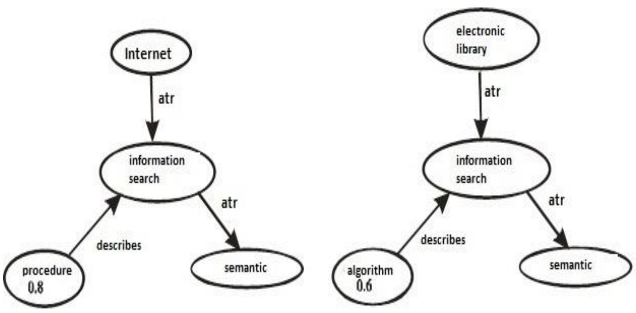

Fig. 7. Examples of semantic subnets advanced query

The presented approach outlines some possibilities and capabilities of the semiotic model of the cognitive agent to expanding the scope of perception at the expense of its own knowledge and constructing a user model in the process of a dialogue.

IV. Conclusion

The application of the symbolic approach for the realization of the bionic concept of the cognitive architecture offers possibilities to use well-studied methods of artificial intelligence aimed at designing agents able to be adaptive to the external environment.

According to the philosophy described herein, the first stage of the agent's behavioral act represents a sequential solution of the tasks of the proper understanding and interpretation (recognition) of the input messages, delivered from the external environment, from the standpoints of the ontological model of the agent's world, an analysis of the given messages for the existing needs and construction of a plan of possible actions, provided that the dominating motivation is available and the initial data are sufficient. Solving of the above problems is directly related to the mechanisms responsible for processing knowledge stored in the agent's memory.

The considered peculiarities of the agent's behavior at the stage of afferent synthesis do not limit its capabilities and possibilities at the next stages of the behavioral act. These capabilities, possibilities and options are related to the training of the agent, depending on the realization of actions plan and the achieved results thereof.

References

[1] Gorodetsky V.I., Grushinsky M.S., Khabalov A.V. Multi-agent systems (survey)//News of Artificial Intelligence, №2, 1998: 64-117.

[2] Red'ko V.G. Models of adaptive behavior and the problem of the origin of intelligence // Mathematical Biology and Bioinformatics, 2007, V.2, No1, p.160-180, http://www.matbio.org/downloads/Redko2007(2_160).pdf.

[3] Zhdanov A.A. The method of autonomous adaptive control //Izv.RAS. Theory and systems of control. 1999, 5: 127-134.

[4] Vityaev E.E. Principles of the brain, contained in the theory of functional systems by P.K. Anokhin and the theory of emotions by P.V. Simonov //Neuroinformatics, 2008, 3(1): 25-78.

[5] Anokhin P.K. Functional system as the basis of the physiological architecture of the behavioral act / PK Anokhin. Selected works. Systemic mechanisms of higher nervous activity. - M.: Nauka, 1979: 13-99.

[6] Solovov A.V. Designing computer systems for educational purposes: Textbook. Samara: SSAU, 1995:138.

[7] Vasilieva I.G, Kulikov D.V, Kuzeev I.R. The crisis of the scientific worldview and the role of human consciousness / In Sat. scientific articles «The World Community: Problems and Solutions». - Ufa: UGNTU, 1999, 2: 41-53.

[8] Poya D. Mathematics and plausible reasoning. Moscow: Izd-vo Inostr. lit., 1957 – 535p.

[9] Astanin S.V, Dragnysh N.V, Zhukovskaya N.K. Nested metagraphs as models of complex objects // Engineering Bulletin of Don. Rostov-on-Don: SKNTS VS SFU, 2012, 4 (2): http://www.ivdon.ru/uploads/article/doc/IVD__92_Astan.doc_1434.doc.

[10] Prade H A fuzzy set-based approach to analogical, default and other kind of plausible reasoning//6-eme CongTes International de Cybernetique et Systems.Paris 1984:187-192.

[11] Boureily L, Chouraqui E , Ricard M. Formalization of an approximate reasoning- the analogical reasoning// Proc. of the IFAC Int Symp on Fuzzy Information Knowledge Representation and Decision Analysis. Marsille July 1983:135-141.

[12] Shahsi, K. Raju, and P.S. Avadhani. Reasoning with Fuzzy Censors// IEEE Trans. Syst., Man, Cybern., 1994, 24(7):1061-1064.

[13] Cevikel A., Ahlatcioglu M. A New Solution Concept in Fuzzy Matrix Games//World Applied Sciences Journal, 2009, 7(7):866-871.

[14] Alcalde C., Burusco A. and Ram´on Fuentes-Gonzalez L-Fuzzy Concepts and linguistic variables in knowledge acquisition processes//CLA, of CEUR Workshop Proceedings, CEUR-WS.org, 2010), Sevilla, Spain3. 672: 38-49.

[15] Cun-lin Li: Characterization of the Equilibrium Strategy of Fuzzy Bimatrix Games Based on L-R Fuzzy Variables. J. Applied Mathematics 2012, 15p.

[16] Garagic D. and J. B. Cruz. An Approach to FuzzyNoncooperative Nash Games/Journal of optimization theory and applications: September 2003. 118(3):475–491.

[17] Astanin S.V, Zhukovskaya N.K. Management of business processes on the basis of their modeling by fuzzy situation networks / Management of large systems. Moscow: IPP RAS, 2012. 37:145-163.

[18] Astanin S.V., Zhukovskaya N.K. Intrafirm mechanisms of distribution of limited resources on the basis of the negotiation process // Applied Informatics, 2012, 2(38):118-124.

[19] Coward L.A., Gedeon, T.D. Using the change manager model for the hippocampal system to predict connectivity and neurophysiological parameters in the perirhinal cortex. Computational Intelligence and Neuroscience. 2016, 2.

[20] RudnerM., Rönnberg, J. The role of the episodic buffer in working memory for language processing. Cognitive Processing. 2008, 9(1): 19-28.

[21] Borlund P. Experimental components for the evaluation of interactive information retrieval systems. Journal of Documentation. 2000, 56(1): 71-90.

[22] Harter S.P., Hert C.A. Evaluation of Information Retrieval Systems: Approaches, Issues, and Methods. Annual Review of Information Science and Technology. 1997, 32: 3-94.