Features of the cognitive agent architecture on the basis of behavioral act modeling

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Abstract. Some specific features of using the bionic concept of functional systems for modelling the behaviour of a cognitive agent are outlined and treated herein. Main attention is paid to the implementation of the following stages of the behavioural act: perception, making decisions to achieve the goal and assessing the future results, implementing actions to attain the goal and assess the obtained results. The solution of the above tasks is directly related to the mechanisms for processing knowledge stored in the agent's memory.

1. Introduction

Agent-based technologies are one of the most promising areas in research, being both of theoretical and applied interest in such fields as military science, management, economics, robotics, e-commerce, Internet, education & training, etc. [1-4]. The relevance of studies of the cognitive architectures is determined by the possibility of creating an artificial agent, whose abilities are close to those in a human. Following the conventional way, solving this problem involves two stages. At the first stage, various aspects of human cognition are modeled. The second stage is directly related to developing an intelligent agent, based on certain axioms, postulates, prerequisites and limitations accepted at the first stage. However, we are facing some problems already when implementing the first stage, and it begins with answering the following questions: What is the knowledge of the agent? What mechanisms of cognition should be used? What are the limitations or restrictions imposed on these mechanisms? And so on and so forth… As a rule, a researcher has its own ready answers to these questions within the framework of the features of a given cognitive agent modeling conceptual design (configuration). Typically, these features include various types of memory, which contain the information about the agent's mental properties; the representation of structural memory elements (units); the functional mechanisms operating on these structures, for the purposes of decision making, training and predicting the actions. Thus, the classical BDI agent architecture [5, 6] is rested upon a social model taking into account the agent’s mental concepts, where the model of interaction with other agents does not fit well. In the context of the ACT-R architecture, the thinking is treated as a process of operating on symbolic information, represented in the form of declarative and procedural networks [7-15]. The hybrid ReCau architecture applies the emotions and abilities of the agent to learn, but their implementation is based on the simulation models and heuristic algorithms, that leave unresolved the issue of theoretical substantiation of their effectiveness and evaluation of their behavior, especially under the conditions of uncertainty [16-19]. In general, these architectures implement certain types of activities and do not pretend to be universal for any solutions that is actually required for cognitive environments. At the same time, cognitive architectures focus primarily on issues on integrating of the higher cognitive functions in the human brain. Due the absence of general theories of mind and due to a lack of the proper understanding of nature of these functions from the standpoint of cognitive architecture developers, implementations of these functions turn out to be widely arbitrary. This statement can be supported both by a great variety of approaches to defining and designing agents in an architecture and the multitude of the developer’s interpretations of an agent, its properties, relations with other agents, etc. In the circumstances, it seems to be appropriate to design a cognitive architecture based on the relevant theories and models used in neurophysiology. One of such models is the cybernetic model of a behavioral act proposed by Russian neurophysiologist P. Anokhin [20, 21]. An advantage of the mentioned model is that its propositions are very close to the concept of artificial intelligence and that it is very simple in an interpretation for cognitive architecture designers. The specific feature of the model is that a behavioral act is treated as an indivisible, integer reaction of the organism to an external influence or effect, including that informational one that allows modeling the cognitive functions from the unified standpoint. Therefore, the novelty of the present study is the system character of the representation of the cognitive agent architecture with the formalization of its basic cognitive functions during the behavioral act.

2. Theoretical part of the study

2.1. Formulation of the problem

According to the artificial intelligence terminology, the behavioral act consists of the following stages: perception of input messages and a definition or a formulation of the goal, making decisions on how to achieve the goal and assessing future results, implementing and execution of the actions to reach the goal and an assessment of the obtained results.

We associate the perception of external messages with the mechanisms of memory, where images of the external world are stored, as a reflection of the previous (or imposed from outside) experience of the agent and connected at a given time with the needs of the agent. At the same time, we do not pretend to provide a formalization of the continuous process of the external world perception. Messages from the external world are treated as stimuli in achieving the possible agent's goal (task), to which the agent gives its response or reaction, based on the available images and needs available in its memory. In case of recognition of input messages, a motivational excitation is formed, which makes it possible to construct the hierarchy of the agent's goals, in accordance with its current needs. In this hierarchy, the dominant need aimed at achieving a particular goal is selected.

Decision-making involves constructing of plans for plausible actions, in accordance with the agent's dominant need, and the formation of a model of expected result parameters. Among all plausible action plans, the most optimal one is chosen to be implemented.

An execution of each action aimed at the optimal plan implementation is accompanied by signals of the achievement of the result. The actions required to achieve the goal are executed as long as the parameters of the obtained result are found to be in full correspondence to the model of the expected result of the actions.

2.2. Perception

The stage of perception is the most important, because the appearance of the behavioral act, motivational excitation, goal setting and formulation of the agent's task depend exclusively on the result of this stage.

According to the P. Anokhin’s concept, the behavioral act begins with the afferent synthesis, which we will associate with the agent's perception. The afferent synthesis is realized through the following mechanisms: situational afferentation (S), motivation (M), initiating afferentation (IA) and memory (Mem) [20]. The situational afferentation is governed by the external environment stimuli (input messages which must show (or not)) that the existing situation corresponds to the realization of the behavioral act. The motivation is related to the satisfaction of the agent’s needs, which are interpreted to be a set of its goals. The dominating, at a given time, need is identified among the goals. The initiating afferentation is a stimulus for realization of the behavioral act subsequent stages, provided that such a situation and such stimuli of the external environment, which correspond to the dominant motivation, are available. In case of the afferent synthesis, an important role is played by the agent's memory, the content of which allows recognizing the stimuli of the external environment, comparing them with the agent's goals and launching the process of the behavioral act realization.

The functioning of the agent is oriented to practical activities, in connection with which we will associate it with the solution of a specific task, formed by stimuli of the agent's external and internal environment. This means that memory must store a knowledge sufficient to formulate the task in terms of the agent's world.

Assume that I_S, I_M, I_{IA}, I_{Mem} are knowledge of the mechanisms of perception. It can be argued that the realization of afferent synthesis is possible under the following memory state: $I_S \mathrm{I} I_M \mathrm{I} I_{IA} \mathrm{I} I_{Mem} \neq \varnothing$. 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 $I_S \mathrm{I} I_{Mem} = \varnothing$, then, either $I_M = \varnothing$ or $I_{IA} = \varnothing$, or both. Case $I_M = \varnothing$ 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 $I_S = \varnothing$, the outcome of the completion of the afferent synthesis process is the refusal to solve the given task.

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 imaginative representation. In this case, we can say that the messages are available to the agent for its perception. Hereinafter, a similar form of objectification of the input messages is called an information object. From the standpoint of semiotics, any information object, accessible to perception, may have three components as follows: syntactic, semantic and pragmatic components. While the syntactic component of the information object is associated with a sign system, which serves to describe it, the semantic and pragmatic components have a psychological aspect, determined by the specifics of the internal world (knowledge of the external world) of the agent, its needs and motivation.

The syntactic component of the information object is based on a set of interrelated signs from a certain alphabet. The interrelation of the 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, in the sign system, among the sets of signs, there are relations and connections available, which form an integral set. Such relations dictate 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 their relations replace the real object of perception by the mediated essence for consciousness. To understand this essence, it is necessary to define the meaning of the sign, i.e. its sense. The sign meaning represents the semantic component of the information object, which allows the agent to decode the content (sense) of an input message expressed by signs. If the syntactic component is associated with an identification of the object of perception, i.e. with the recognition of a sign or a set of signs as given, the semantic component allows recognizing an object through the formation of its perceptual image and its comparison with the reference images, which are stored in memory. In the agent's memory, such images are represented as signs with their meanings attached thereto. Detection of the information object semantic component means a certain comparability of the input message signs and the reference image signs as well as the transfer of meanings of the reference signs to the corresponding input message signs.

The understanding of an input message by the agent does not determine that any actions will follow by the agent. In order to react to a message by actions, by a certain behavior and even by a way of thinking, it is necessary to identify in the given information object a pragmatic component that governs the relationship between the message sense and the current motivation of the agent. The latter is generated based on an analysis of its needs.

As a consequence of considering the perceived object from the perspective of the three components and treating the object as information, the process of transferring messages from a source to a user can be viewed through the prism of the following three filters:

1) a syntactic filter, linked to the identification of an object, regardless of its content;
2) a semantic filter (selection of those data, which can be interpreted by the recipient, i.e. which correspond to the thesaurus of its knowledge);
3) a pragmatic filter (selection of those data among the understood data, which are useful for solving this task or satisfying the dominant motivation).

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

In simple cases, where input messages are one-dimensional or two-dimensional objects, the first stage of the situational afferentation can be realized based on 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, besides, $S_i = < C_i, R_i, A_i >$, where

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

$R_i = (R_{i,1}, R_{i,2}, R_{i,3})$ is the symbol for 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 symbol for 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 input message (task) for the agent is formed in the form of 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 based on the syntagmatic relations at the lexical level, we obtain a set of different formulations of the initial task *C*, which constitutes the superficial image of the current situation of the agent, i.e. $C, C_1, C_2, ...$.

The second stage of the situational afferentation can be also realized on the basis of the ontological model, where the role of the concepts is undertaken not by the lexemes, but by the syntagmas with the association relation: $G_p = < C_p, R_p, A_p >$, where $C_p = \{C_{p,1}, C_{p,2}, ...\}$ is the set of the *p*-th ontology concepts; R_p is an association relation on a set of concepts; $A_p: C_{p,j} R_p c_{p,k} \to (C_{p,j} \to C_{p,k})$.

If $C_w \in C_p$, $w = \overline{0,s}$, then the concepts from the associative row $C_w \to ... \to C_{p,k}$ are associated therewith. These concepts can further act as the dominant motivation, corresponding to a specific need of the agent.

It should be noted that the recognition of the input messages depends on the form of their presentation. Thus, the variant of the analysis based on the ontological model has been treated above. If an input message is metaphorical, then for its recognition required are other models, which are stored in memory, for example, on the basis of analogy.

The third stage is connected with the formation of a generalized image of the initial situation. Such a generalization is possible based on an analysis of the typical situations, precedents of solving the problems, and in case of their absence, the behavioral instructions stored in memory.

In the simplest case, the mechanism for identifying the dominant motivation may be as follows. We adopt in the agent memory stored is fuzzy matrix $C_{i,j} = P_i \times D_j$, where P_i is the symbol for the agent's needs; D_j indicates possible motivational stimuli. At the intersection of rows and columns in the matrix, given are coefficients $c_{i,j}$, which indicate the degree of correspondence between the need and the motivation. Then, if at the current moment the agent determines its preference for the realization of the needs $a_i, i = \overline{1,n}$, i.e. $P = \{\alpha_1 / p_1, ..., \alpha_n / p_n\}$, then to identify the dominant motivation at moment *t* it is sufficient to solve equation $P \circ C_{i,j} = D$, where «$\circ$» is the symbol for the max-min composition operation, and $D = \{\beta_1 / d_1, ..., \beta_m / d_m\}$. At the same time, we assume that the needs p_i raised to degree $max\{\alpha_i / p_i\}$, correspond to the dominant motivation d_j raised to degree $max\{\beta_j / p_j\}$. The considered mechanism is based on the application of a scheme of plausible reasoning of the form:

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

The given scheme works at fixed matrix $C_{i,j}$ and at the current changes in the agent's preferences regarding its needs. A change in coefficients $C_{i,j}$ is specified by factors that indirectly influence the correspondence between the motivation and the need.

In the considered approach to the definition of the dominant motivation, it is suggested that all reasoning is carried out by the agent based on its own model and its own analysis of the facts obtained in the process of the situational afferentation. In a real situation, the source of delivering facts may be another agent, who may have its own view of the preference regarding the facts as motivational stimuli and their relation to the agent's needs. If the agent in question has views of its preferences regarding the motivational stimuli of another agent, then it can compare them with its own preferences of the needs. In this case, the reasoning schemes based on fuzzy matrix and bi-matrix games can be applied [21].

The initiating afferentation involves an identification of the conditions necessary and sufficient for constructing plans for the realization of the dominant motivation. In [22] discussed is a procedural approach to the generation of a fuzzy situational network (FSN), which, with the availability of the initial set of known situations and various combinations of the set of the control actions, allows constructing and analyzing various 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: $S_i \Rightarrow S_j$,, where S_i, $S_j \Rightarrow S=\{S_1,\ldots, S_p\}$ are fuzzy formulas; «$\Rightarrow$» is a sequent sign, which, in the logical sense, is interpreted as a sign of implication S_j from true S_i.

In general terms, by a production is meant an expression as follows: (*I*); *Q*; *P*; $A \to B$; *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 core $A \to B$, and *N* describes the production post-conditions.

According to our interpretation, *P* stands for the conditions of the initiating afferentation. In a 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 [22], when constructing FSN, as a model of plausible plans, the initial typical situations, the set of the control actions and the target situations act as initial data. Such a collection results from the previous experience, but in order to use it, it is necessary to provide a comparability of the information, obtained at the stage of the situational afferentation, with the knowledge of the typical situations. Such comparability is provided by fulfilling the conditions $A \equiv A$ for the binary modus ponens, and $A^* \approx A$ for the fuzzy modus ponens.

In complex cases, P is supplemented by the dominant motivation and some unknown factors, which are sub-goals of the afferent synthesis phase and which can be realized on the basis of agreements or conventions with other agents.

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 Figure 1 herein).

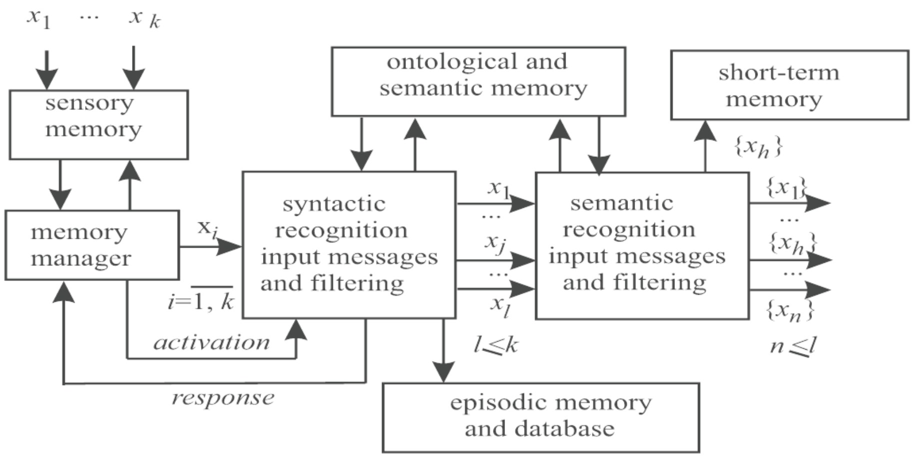

Figure 1. Features of syntactic and semantic recognition of input messages.

The input messages $x_1, \ldots, x_k$ are referred to the respective images in the ontological memory at the syntactic level. Those messages, the identification of which has been completed, are fed to the semantic recognition unit. The other messages, the identification of which has been found to be not successful, are included in the episodic memory database. After the syntactic recognition of the messages, the memory manager erases the sensor memory images. As a result of the syntactic recognition, the number of messages, delivered for further analysis, becomes equal to $x_1, \ldots, x_l$, and $l \leq k$. These messages enter the semantic recognition unit, where they are compared with the ontological models and descriptions in the semantic memory thesauri. As the result of the comparison, obtained are extended message sets $\{x_1\}, \ldots, \{x_n\}$, $n \leq l$.

The specific features of the realization of the motivational excitation with the formulation of goals and decision-making tasks are presented in Figure 2 herein.

Based on the mechanisms of analogy and association, the extended message sets are transformed into images of generalized messages $y_1, \ldots, y_n$, which are classified in relation to the needs of the agent, based on procedural memory models. This enables the agent to identify dominant motivation D and also formulate task Z peculiar thereto. According to the description of Z, its goal G and goal achieving criteria K, plausible plans for solving task Z are generated by means of the procedural models of the action planning models. In this case, it is assumed that G and K are defined at the stage of the semantic analysis. The produced plans enter the short-term and procedural memory parts to be further optimized at the next stages of the cognitive agent behavioral act.

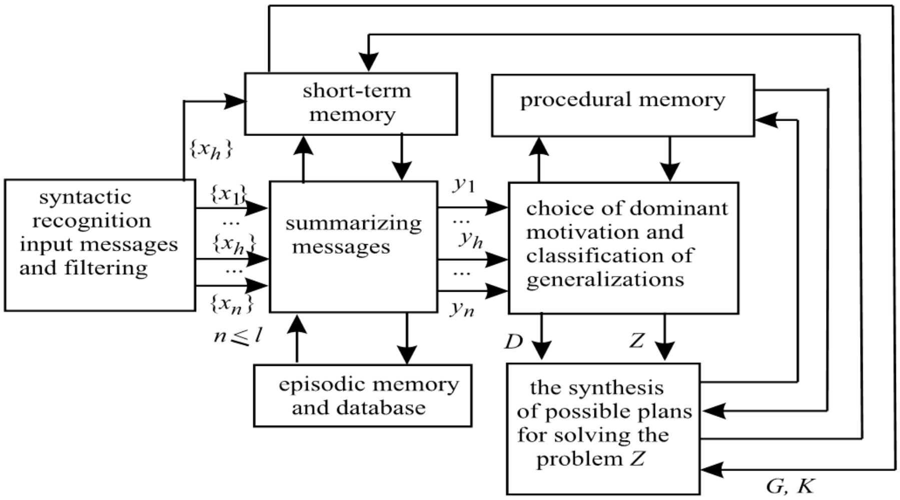

Figure 2. The specific features of the pragmatic component of recognition in input messages and motivational excitation.

Thus, the first stage of the cognitive agent's performance is to consistently solve the tasks of the interpretation (recognition) of the external environment input messages from the standpoints of the ontological model of the agent’s world, the analysis of the message data on the existing needs and the construction of a plan of plausible actions in the presence of the dominant motivation and sufficiency of the initial data. The solution of the above task is directly related to the mechanisms for processing the knowledge stored in the agent's memory.

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

The ontological memory serves for the syntactic and semantic recognition of the input messages.

The semantic memory stores general information about the agent’s world, for example, the meanings of words. The memory manager compares this information with those messages, which are already available in the short-term memory, in order to identify analogies, associations, generalizations and subsequent replacement of the primary messages by them in the short-term memory. Depending on the nature of the information, intelligible to the agent, a certain model of revealing the dominant motivational stimulus is extracted from the procedural memory. The dominant motivation actualizes the memory manager's attention to those short-term memory messages, which are found to be in correspondence to the mentioned memory.

In the episodic memory, on the one hand, stored are the images associated with the events of the agent’s past experience, and, on the other hand, received is a knowledge obtained as a result of solving the current task.

The considered peculiarities of the agent’s behavior at the stage of afferent synthesis do not limit the agent’s capabilities and possibilities at the subsequent stages of the behavioral act. The capabilities and possibilities are related to the learning and training of the agent, depending on the realization of its plan of actions and their results.

The final result from the afferent synthesis stage is a set of plans of the agent’s plausible actions.

2.3. Decision-making and action evaluation

Making a decision to achieve the goal with an assessment of future results and the realization of actions to attain the goal with an evaluation of the obtained results are separate stages of a behavioral act. However, it is advisable to consider them jointly due to the cyclical nature of their application in execution of the action plan chosen by the agent [23, 24].

Decision-making begins at the final stage of the afferent synthesis, connected with actions planning by the agent. A distinctive feature of the decision-making stage is a derivation of an optimal action plan from all possible, or plausible, plans available. Besides, both the possible plans and the derived optimal plan are treated as generalized plans, in accordance with the agent's previous experience. Proceeding to particular actions leads to the necessity of particularization of the optimal plan, considering the knowledge of the current status both of the agent and the environment, and it also involves estimations of uncertainties and risks of the realization of the scheduled actions. The particularized action plan is a model for attaining the goal that allows simulating and analyzing possible situations after realization of the actions, and, if necessary, correcting or improving the plan. Assume that X=<x_0, X_1, …, X_i, …, X_n> is a sequential discrete process of achieving goal X_n, and X_i={$X_{i,1}$, …, $X_{i,k}$}, $i=\overline{1,n}$ are possible results (states) of the i-th stage of the plan when realizing actions U_{i-1}, and x_0 - initial state (see Figure 3 herein).

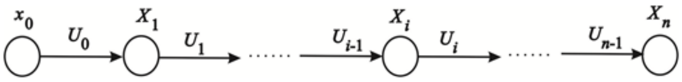

Figure 3. A multi-step process for solving a task.

Then, the model of the achievement of goal X_n constitutes a set of pathways from vertex x_0 to vertices X_n, subject to the following conditions:

- the result of the i-th step depends on the (i-1) -step;
- the perception, decision making and evaluation by the agent are subjective and approximate;
- due to an incomplete picture of the external environment, the results of the actions are ambiguous.

The model of attaining the goal particularizes the optimal plan by choosing both some specific actions and an evaluation of the results from the latter, as well as by assessing the risks, associated with the realization of the decisions, depending on the state of the agent's external and internal environments (see Figure 4 herein).

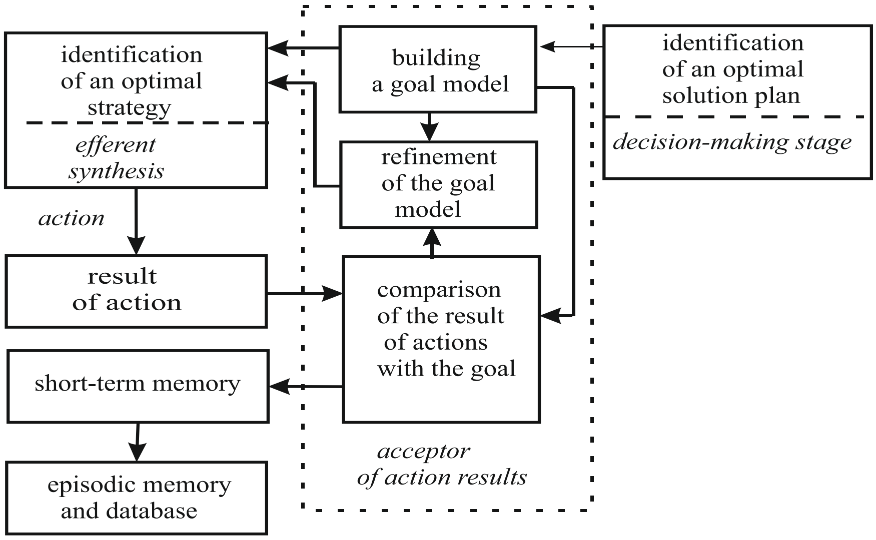

Figure 4. The stages of decision making, realization of actions and evaluation of results.

Based on the analysis of the goal model, identified is an optimal strategy for the agent’s behavior that presumes the selection of acceptable actions to reach the goal. The result of each action (decision) is compared with the expected outcome. If they agree, the next action, belonging to the optimal strategy, is undertaken. If the actual result of the action departs from the expected one, the goal model is corrected, and another optimal strategy is defined.

2.4. Application and discussion

The bionic concept of the cognitive agent’s behavior can be applied to intelligent systems oriented to the semantic analysis of messages delivered from the external environment.

Let us discuss the stage of perception by the agent searching for information on Internet as an example of applications of the cognitive architecture.

The existing algorithms of the information search are designed for those groups of the users, who demonstrate precisely defined information needs. In this case, the Internet search engines are effective enough, when using the syntactic models of recognition of user requests. However, the search engine does not employ a user-based model; it is the matter of fact that a real user may formulate his request in an improper manner, so that it may lead to finding of hundreds of thousands of documents, which possibly have no relevance to his information needs, but which would be presented upon searching to the user.

To effectively solve the task of the proper realization of the user's request, the search engine should employ some information about the user, for example, about his interests and preferences, schedules, personal contacts, as well as data on the information sources often addressed by him. Otherwise, the search engine will not be able to automatically filter out the relevant documents, which are really required by the user, since the user's world has not been taken into consideration. A search for information is a process of identifying the correspondence between the user's request and an electronic document that is provided in a certain sequence. Ideally, the search goal should be to satisfy the information needs of the user, expressed by his request. Hence, the search engine should possess knowledge of the information need of the user or properly reveal the need, or, in other words, understand what the user wants to receive as a result of his information search. Therefore, the information search systems should not be limited only to processing of keywords entered, but they should track interests of users, making the search more closely focused on the subject of concern. When implementing an intelligent search system, a system response to a query may be treated as a solution to a pattern recognition task.

Functioning of such 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. We assume that the search query is given as follows: "model of semantic search". If the search engine 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 as "information retrieval systems" or "intelligent search engines". To solve the problem of the subject area selection, the knowledge base should 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, should 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 based on 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 (see Figure 5 herein).

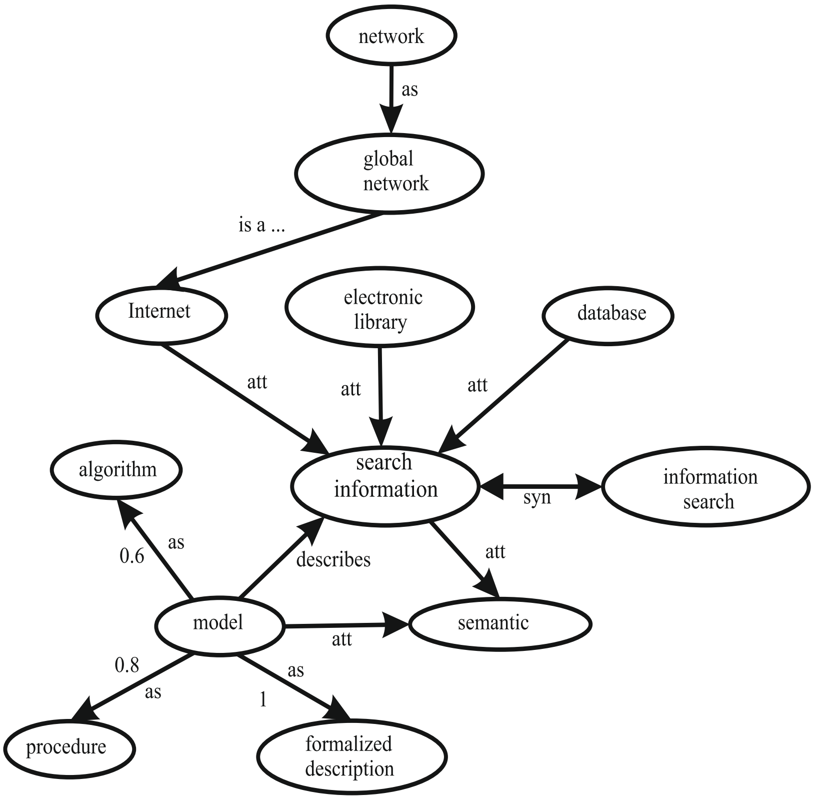

Figure 5. Semantic network of the user's extended query.

Let us derive subnetworks from the extended query semantic network, with 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 $\tilde{R}$ 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 $\tilde{R}$ several keywords have the same attribute, which is at the same time a keyword, then only one attributive relation is applied in a 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.

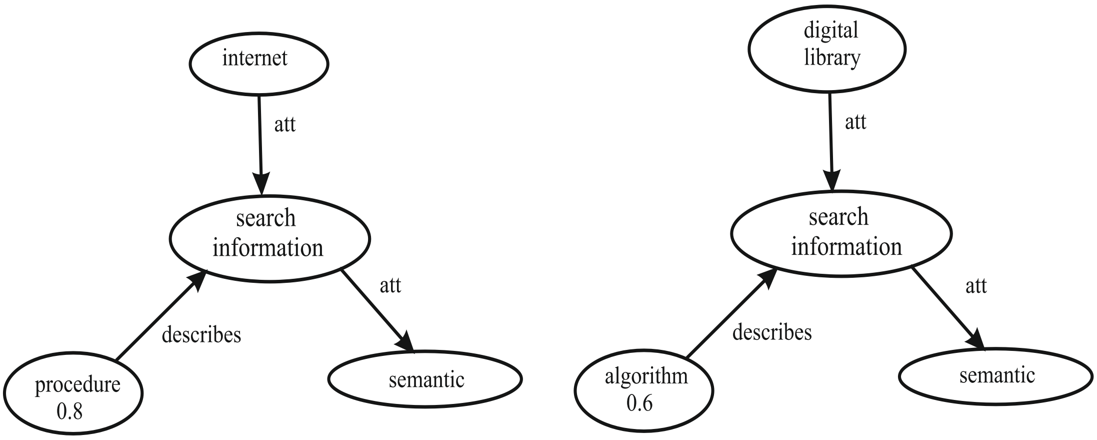

Figure 6. Examples of the extended query semantic subnetworks.

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 Figure 6 herein).

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.

3. 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 plausible actions with the availability of the dominant motivation and sufficiency of the initial data.

Decision-making is based on the optimization of strategies for the behavior in the context of the plausible action plans. At the same time, it is assumed that the agent operates under the conditions of incomplete and uncertain information that requires the applications of the appropriate models and mechanisms of reasoning.

The presented cognitive architecture, at the stage of the realization of the actions, implies that the agent possesses the ability to self-organization, which offers a possibility of correcting the initially constructed action plan, depending on the achieved results of the completed actions.

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