The Memory Model of Intelligent System Proactive Information Security Management*

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Abstract. The memory role in modeling of anticipatory behavior is noted. The article depicts the most studied human memory capabilities and features of the occurrence of cognitive and reflexive processes in it. Requirements to memory of the cybersystem capable of synthesizing scenarios of anticipatory behavior in the conflict during an anticipation are formulated.

Keywords: anticipation, cybersystem, modelling, human memory, anticipation behavior.

1 Introduction

At the initial stage of designing cyber systems to prevent computer attacks, endowed with the ability to anticipate, it seems necessary to analyze the most studied capabilities of human memory and the function of working with it. This is due to the fact that it is the person who is able to synthesize the scenarios of pre-emptive behavior at different levels, using for this various mechanisms based on the capabilities of his nervous system in general and the brain in particular. Perhaps that the implementation of similar mechanisms in the cyber system will be able to contribute to the generation of behavioral models aimed at preventing possible negative effects.

The main element of the early detection system of a possible attack and its preventive suppression is the module for synthesizing scenarios of anticipatory behavior in the information and technical conflict - Gyromat. And the system itself is a partially ordered hierarchy of gyromates with level-by-level coordination, which should allow solving the consistency problem in the conditions of model completeness of the theory underlying the projected system. Each individual gyromat must consist of four basic elements: the Interpreter, the Planner, the Generator and the Memory. Memory is one of the most important elements, because through it global and local interaction of the first three (basic) elements is realized. In view of this, it can be assumed that the more functionality aimed at generating strategies for pre-emptive behavior in the conflict will have Memory, all the more so the more effective the activity of the whole system can be.

2 Memory is the basis of intelligence of cybersystem

According to the results of the analysis of a number of works [1-7], it can be concluded that human memory can be divided into long-term (LM) and working (short-term) memory (SM), although short-term and working memory is most often shared. So the term short-term memory (SM) are used to characterize the execution of tasks that require a small amount of information to be held in memory. And the term working memory is used [8, 9] to designate a system that not only temporarily stores information, but also uses it, allowing to perform such complex actions as logical thinking, learning and understanding.

In the framework of the LM, attention should be paid to the differences between non-declarative (implicit) and declarative (explicit) long-term memory [1].

Non-declarative memory refers to situations in which forms of learning are manifested, which act more like actions than apparent memories (example: riding a person on a bicycle). A vivid example of the use of non-declarative memory are examples of the formation of conditioned reflexes [4, 5]. It can be argued that a person is able to control quite complex systems without an obvious conscious treatment of the rules underlying them. If we talk about explicit teaching, we cannot reject the fact that its results are affected by the depth of awareness of the observed phenomena and processes.

Declarative memory is the memory of events, facts, objects, etc. For the reproduction of information about the world around us, stored in declarative memory, and about the past experience, the participation of consciousness is necessary.

In 1972, Endel Tulwig singled out [2] within the framework of declarative memory the semantic (SM) and episodic memory (EM):

The SM is a system that keeps knowledge of the world; it goes beyond simple knowledge of the meaning of words and embraces sensory features; it can also include general knowledge about the course of observed processes, the functioning of certain objects, etc.;

The EM contains information on the basis of which it is possible to recall individual phenomena (events), «relive» them and, if necessary, use this information to plan further actions.

At present, the sensory-functional theory of the organization of the SM [10-13] acquires a fairly wide development, according to which it is suggested that information on objects in the joint venture is organized on the basis of differences between sensory or visual properties and functional properties. At the same time, according to the approach that takes into account many properties of memory [14], the brain is organized so that the memory of any property (for example, about color, about movement) is stored in its separate area [15]. This approach is very promising, since it is based on the recognition that most concepts have a number of properties, and that these properties determine the similarities and differences between categories.

Knowledge in the semantic memory is represented in the form of schemes [16]. Schemas include what are often called *scripts* and *frameworks*. Scenarios deal with knowledge about events and the sequence of events [17, 18]. Frameworks are structures of knowledge that are relevant to some aspect (object) of the world and contain fixed structured information. Schematic knowledge is very useful because they allow you to *form expectations*.

It is proved [19] that the deeper the processing of information when it arrives, the better it is stored in memory [20] and the better its subsequent reproduction. The processing of information can consist in repeated repetition of the material or in its binding to the material available in memory [20].

In 1969, the system model of the SM was proposed [21], which consists in the fact that the SM is a series of hierarchical networks. It also follows from the proposed models [21] that a person often successfully uses a SM, resorting to inferences. Herewith the time for making decisions about the more typical, or representative members of the category, is less than for the relatively atypical members [22, 23].

In 1975, the model was proposed [24], and further confirmed [25, 26] is the model of spreading activation, according to which, at the moment when a person perceives or thinks about a concept, a corresponding point is activated in the semantic memory. Then this activation with the greatest effect extends to other concepts closely related to it, and less noticeably - to concepts that are semantically remoted from it.

D. Hebb suggested [27] that long-term learning is based on neural networks that arise and change their parameters with simultaneous excitation of two or more nerve cells. It has already been proved [28-30] that various intellectual activities (learning) lead to various physical changes in the structure of the brain, and as a consequence to different effectiveness in solving the same problems.

Retrieving information from memory is moving from one or more stimuli to targeted memories (as a result of the spread of activation) with a view to make these target memories available and able to influence subsequent recognition. Activation level is a variable that determines the availability of a trace in memory and grows when something associated with it is perceived (or by direct access to it).

It has been confirmed that the practice of reproduction and additional study equally improve the memorization of "practiced" objects, but only the practice of reproduction worsens the memorization of "impractical" competitors [31, 32]. The connection between forgetting and time is described more as a logarithmic function [33]. An important element in the work of a person with memory is his ability to suppress memories [34]. It has been confirmed [35] that the basis for stopping unwanted motor actions and suppressing memories is the same process of inhibition.

The SM includes the following: the central processor (further referred to as the "central memory processor" - the CMP), the focus of attention (FA), and the episodic buffer

(EB). The main function of the CMP is the concentration of attention. CMP provides the ability of a person to focus on what he is currently engaged in. When automatic resolution of a conflict situation is impossible (or in the event of a new situation), a monitoring system of attention enters into force, which can intervene and decide in favor of one of the competing options or activate strategies for finding alternative solutions.

Episode Buffer (EB) is a storage system that can contain about four [37, 38] (seven [39]) portions of multidimensional information. Due to this ability, EB can play the role of a link between different subsystems of working memory, and also connect them with the input of information from the LM and from the perception. It is suggested [37] that information from EB is extracted through conscious understanding. This connects the SM model with such an influential point of view as the point of view on the function of consciousness. Thus, Baars [40] believes that the role of conscious understanding is to unify different information flows from different senses and to bind them to perceived objects and scenes.

The concept of the *focus of attention* in his works is widely used by Cowen [38] and believes that working memory depends on the activation that takes place in the LM and is controlled by the process of attention (actually through FA). The activated memory is multidimensional and, in this respect, it is similar to EB Baddley [37]; the main difference is that A. Buddle's objects are downloaded to the EB from the LM, and Cowen believes that "they are held in LM."

Based on the data on the principles of the functioning of human memory, set forth above, it is proposed to formulate a number of requirements (R) to the memory of the cyber system, given below.

R.1. Structurally, the memory should consist of:

R.1.1. Long-term memory [1] (knowledge base) consisting of [2, 4, 5]:

R.1.1.1. Associative-semantic (declarative / explicit) LM;

R.1.1.2. Associative-reflex (non-declarative / implicit) LM;

R.1.2. Working (operational) memory, consisting of:

R.1.2.1. The limited area of memory with operative access [37,40];

R.1.2.2. Controller, which sets the direction for moving the focus of attention in memory [38];

R.1.2.3. CMP [41], which determines the need for semantic intervention and carries out the logical (intellectual) processing of information placed in the operative memory;

R.2. Memory should contain data on the surrounding world (SP) [2] in the form of schemes [16]:

R.2.1. On objects and their properties [2, 3]

R.2.1.1. Information about the various properties of objects, should be stored separately [11-15] in the form of frames [16];

R.2.1.2. Information about the properties should be stored at the highest possible level of the hierarchy of data representation about objects (the principle of cognitive economy [21]);

R.2.2. On the flow of processes in the form of scenarios [16–18];

R.3. Memory should contain data on observed (experienced) phenomena and be able to recall specific individual phenomena / processes (episodic memory) [2];

R.4. The process of accumulating data in memory must be accompanied by its structural changes [28-30];

R.5. The quality of data storage in memory should be influenced by:

R.5.1. Multiple repetition of the data entering into the memory (the greater the number of repetitions, the better the memory) [42, 19, 43];

R.5.2. The number of links between incoming data and information stored in memory (the more connections, the better the memory) [19, 20, 43];

R.5.3. Presence of hierarchical structuring of stored data [44-47], for example, in the form of hierarchical networks [21];

R.6. The concepts presented in the memory, with their simultaneous "excitation," should be combined with an associative connection, the more such excitations, the "stronger" this connection should become [27];

R.7. The availability of specific data in memory should depend on the level of their activation:

R.7.1. The activation level must be a variable;

R.7.2. The higher the level of data activation, the higher their availability (if the activation level is high enough - above a certain value, then the data must be extracted from memory, otherwise - no);

R.7.3. The "brightness" of the concept in memory should increase with the activation of any associated concept or with its immediate activation;

R.8. The extraction of information from memory should be carried out by moving from stimulated concepts to targeted ones:

R.8.1. When accessing data stored in memory (when data is entered), the activation should propagate from them:

R.8.1.1. Activation should be the most widely spread towards concepts with which data are most closely associated, and in the least - in the direction of remote concepts [48-50];

R.8.1.2. The "stronger" the relationship between the stimulated and stimulating concepts, the greater the level of activation should a stimulated concept be obtained;

R.8.2. The organization of memory should allow to extract information from memory on the basis of the accumulated experience, logic and goals the system faces ("calculate" the necessary information);

R.8.3. A mechanism should be implemented that can suppress the "undesirable" retrieval of data from memory [34, 35];

R.8.4. The extracted target / intermediate concepts should be able to influence the results of the subsequent retrieval of information;

R.9. The quality of constructing "plausible" conclusions (in the course of inferences) based on information stored in memory should be influenced by:

R.9.1. The "distance" between concepts representing the object and its property (the greater the "distance", the longer the decision time for the presence / absence of the property of the object) [21];

R.9.2. The degree of popularity of the associative connection between concepts (the higher the value of the association, the faster the association is) [22, 23];

R.10. The relationship between forgetting data presented in memory and time should be described by a logarithmic function [33];

R.11. Multiple reproduction of certain concepts (as well as attempts to reproduce [51]) should worsen the reproduction of competing concepts [52];

R.12. Within the framework of associative-reflex memory, the possibility of elaborating conditioned reflexes should be realized taking into account the fact that [4,5]:

R.12.1. Multiple advance presentation of a conditioned stimulus without reinforcement by an unconditioned stimulus should lead to the difficulty of elaborating a conditioned reflex;

R.12.2. The presentation of a conditioned stimulus without reinforcement by its unconditional (after the elaboration of the conditioned reflex) should lead to a gradual fading of the conditioned reflex.

3 Levels of synthesis scenarios of the behavior of an intelligent system

Having considered typical scenarios of behavior in conflict [53-55], it can be argued that the division of memory into levels can also be performed on the basis associated with the depth of processing of data entering the input of the intellectual system. In this case, we can talk about the two main levels of behavior: the reflex and the intellectual (within the framework of which the semantic processing of information). Both these levels assume direct application of memory in the process of synthesizing scenarios of cyber system behavior.

Next, it is suggested that non-declarative memory be called associative-reflex memory (ARM), and declarative memory is called associative-semantic memory (ASM). It is natural to assume that both ARMs and ASMs can contribute to some extent to the construction of scenarios for anticipatory behavior.

Generalized schemes of reflex behavior are presented in Fig. 1, where "P" is the perception module, and "R" is the response module.

The main difference between the scheme of intellectual behavior and schemes of reflex behavior is the presence in it of the forecasting module - "F", whose functioning is based on the processing of semantic information (see Fig. 2).

Details of the scheme of intellectual behavior are shown in Fig. 3, which uses the following notation:

E_p – "Physical" perception through the sensor system (External),

E_{MB} – Perception of the model of behavior of the System (Internal),

E_{MDE} – Perception of the model of development of the "External World" (Internal),

$E_{\sum}$ – Evaluation ("Perception of Perception"),

F_S – Forecasting the behavior of the System,

F_{EW} – Forecasting the behavior of the "External World."

Explanation of the operations that are included in the typical scenarios of behavior in conflicts based on intellectual behavior (see Fig. 3) are given below:

01. Reflex response to stimulus;

02. Perception of the system by itself through a system of sensors;

1. "Physical" ("External") perception through a system of sensors, the construction of a primary model of the observed phenomenon;

2. Estimation of the model constructed according to the results of the "Physical" ("External") perception;

3. Construction of models describing the potential development of observed phenomena (Forecast of further "physical" perceptions of the External World);

4. Determination of the presence of the task (task identification);

5. Estimation of the degree of criticality of the problem;

6. Building models of potentially realizable behavior aimed at solving an identified problem;

7. Determination of the presence of the solution of the identified problem;

8. Evaluation of the suitability (optimality) of the solution;

9. Determination of the reaction order for solving the problem.

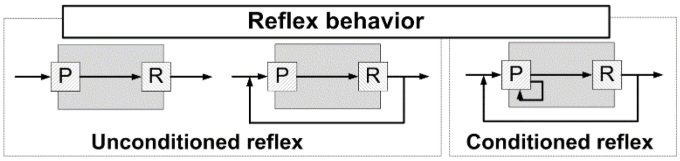

Fig. 1. Basic schemes of reflex behaviour

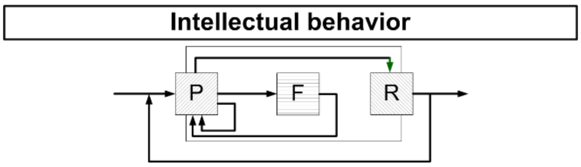

Fig. 2. Generalized scheme of intellectual behavior

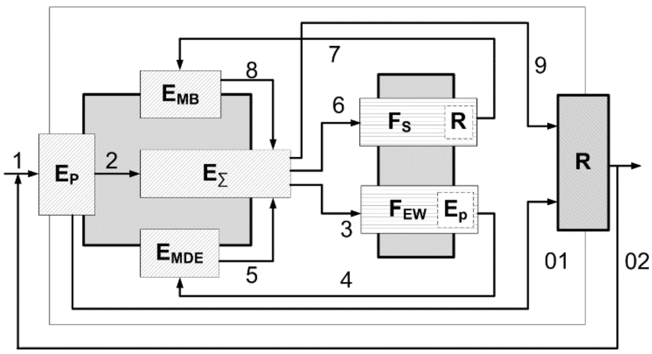

Fig. 3. Detailing the scheme of intellectual behavior

To the unconditioned reflexes that contribute to the anticipation in the conflict, it is necessary to include the mechanisms directly incorporated into the system when it is created. Such mechanisms should be able to uniquely respond to phenomena observed in cyberspace.

If we consider the mechanisms of behavior realized at the level of conditioned reflexes, it should be noted that at this level the system must be able to develop new and new mechanisms of its own behavior. However, in order for a new mechanism of behavior to be generated, the system must undergo the training stage (the formation of a conditioned reflex).

To systems capable of forming mechanisms of their own behavior at the level of conditioned reflexes, one can classify intrusion detection systems functioning on the basis of neural networks and designed to recognize anomalies in network traffic transmitted in the protected segment. One of the "weak" aspects of such systems is that they are often unable to explain to the operator the order of formation of the decision, as well as to argue it.

When considering conditioned reflexes through the prism of modeling scenarios for anticipatory behavior, it should be noted that the basis of conditioned reflexes is the ability to establish associative connections. As it seems, this ability is very important and should be implemented in the intellectual system of synthesizing scenarios of pre-emptive behavior in the conflict. The presence of associative links should allow the system to accumulate experience and take into account the contexts, and the ability to take into account contexts is one of the steps towards creating truly intelligent systems.

Of greatest interest is the level at which the system is capable of generating scenarios of anticipatory behavior, taking into account the semantics of the observed phenomena, processes and interacting (opposing) objects.

4 The memory model for the formation of pre-emption scenarios

To implement the memory functions discussed above, the developed intellectual system cannot do without language tools for describing, presenting and manipulating knowledge about the subject area of conflict. In this regard, it is proposed to construct an abstract system of knowledge in the form of a structured model of complementary formal semantics: denotational semantics of structures, axiomatic semantics of properties, and operational semantics of actions.

All the knowledge that the system will manipulate in the course of its functioning must be somehow represented in its memory (in the Knowledge Base of the system). For this it is suggested to use formalisms similar to semantic networks or frames, as their application seems to allow to describe arbitrary subject areas with the necessary degree of detail.

For the formalization of denotational semantics in the construction of arbitrarily complex ontological constructions, it is proposed to use the theory of data types and functional spaces of D. Scott, based on the use of partially ordered property of approximation sets.

To formalize the axiomatic semantics of the representation of knowledge, their logical interpretation and the derivation of unambiguous consequences from them, it seems possible to use a family of inference machines that operate on the basis of descriptive logics, supplemented by consistent axioms of the conceptual framework of the conflict domain.

During the formalization of operational semantics of behavior scenarios when choosing the concepts of atomic actions, it seems reasonable to use a weighting system to indicate in what contexts and how often various concepts were used. At the same time, it is proposed to model the dynamics of changes in the values of the proposed coefficients by the apparatus of an associative resource network.

To construct and present models of the behavioral patterns of the system itself [56], it is proposed to use the functional paradigm proposed by J. Backus [57] and allowing to form from the basic functions (actions, procedures, programs, etc.) and functional forms (which in turn are set based on from the semantics of the domain) more complex functional constructions.

At the input of a system capable of building pre-emptive behavior scenarios, data from the training system and data from the sensor system (in general, the "input" can be one) come in. Received data are proposed to be placed in the KB. At the same time, the data received at the input of the system must trigger the triggering of certain conditioned reflexes aimed at resolving the identified but semantically unconscious task. In this case, the realization of the conditioned reflex is the solution of the problem. If the corresponding conditioned reflex is not formed, then the system must perform task identification and search for a solution based on the knowledge available to the system.

Both the identification of potential tasks and the search for ways to solve them [58], the system should be implemented in at least two ways. The first way is search by analogy. Obviously, there can be a situation in which the system may lack knowledge, which allows the conclusion of new knowledge by analogy. In this case, the system should be able to construct new knowledge about possible processes, by combining the models of available permissible functions (actions) - the second method.

Independently of which of the following methods will be used by the system in generating new knowledge about potentially possible tasks and methods for solving them, it must be able to navigate through the data represented in its associative-semantic memory. The basis of this mechanism is proposed to lay the idea of a directed distribution of an associative signal over associative connections.

As it seems, the proposed model for the formation of pre-emption scenarios should be implemented in Gyromate [59], capable in its functioning to build in its memory the model of the surrounding cyber environment and synthesize the program of actions in accordance with its goals, which consist in maintaining the proper level of security of the critical information infrastructure from computer attacks, consistent with this model.

5 Conclusion

The analysis of the results of a large number of studies devoted to the study of human memory made it possible to identify the basic rules for its construction and functioning.

The allocated rules were put in the basis of the cognitive-functional memory specification of the projected cyber system, which, in the course of anticipation, was to synthesize scenarios of pre-emptive behavior in the conflict.

The conclusion is made that the ability of the system to preventive behavior can be realized at two levels: at the level of associative-reflex and associative semantic memory. In this case, an important place is given to the mechanisms:

development of a system of conditioned reflexes;

hierarchical representation of data in system memory (about objects, their properties and processes);

Changes in the availability of data stored in the system's memory (for implementing the possibility of accounting for contexts, as well as the procedure for "forgetting" false and obsolete data);

route of focus of attention (for allocation from memory of necessary knowledge, proceeding from problems solved by the system and incoming data);

implementation of "plausible" inferences based on information stored on the memory of the system (including, by drawing conclusions by analogy).

The implementation of these mechanisms in the system is necessary to ensure that it is capable of pre-emptive behavior in the conflict.

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