
CONCEPTUAL IDEA OF IDENTIFICATION OF PATTERNS AND PROBLEM SOLVING IN THE HUMAN'S MEMORY AND THE POSSIBILITIES TO USE IT IN ARTIFICIAL INTELLIGENT

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Abstract: *Given cybernetic idea is formed on the basis of neurophysiologic, neuropsychological, neurocybernetic data and verisimilar hypotheses, which fill gaps of formers, of the author as well. First of all attention is focused on general principles of a Memory organization in the brain and processes which take part in it that realize such psychical functions as perception and identification of input information about patterns and a problem solving, which is specified by the input and output conditions, as well. Realization of the second function, essentially cogitative, is discussed in the aspects of figurative and lingual thinking on the levels of intuition and understanding. The reasons of advisability and principles of bionic approach to creation of appropriate tools of artificial intelligent are proposed.*

Keywords: *pattern, perception, identification, solving, problem generator, understanding, intuition.*

ACM Classification Keywords: *I.2.0. Artificial intelligence: general – cognitive simulation; I.2.4. Artificial intelligence: knowledge representation formalisms and methods – semantic networks; I.2.6. Artificial intelligence: learning; I.5.1. Pattern recognition: models – neural nets; J.3. Life and medical sciences – biology and genetics.*

Introduction

The conceptual level of Modeling natural mechanisms of psyche means penetrating into it from the top to the bottom – from certain psychical functions to information principles of its physical realization, i.e. from the psychical result to the information mechanism of its obtaining [1-4].

Thus, the Conceptual Model determines (using top-theme) "the understanding of the relationships between structure and function in biology".

Information processes taking place in the physical substance of nervous system consist of two main classes: purely combinational processes (as unrelated to memorizing) which occur in sensory organs, organs moving control etc., and combinational- accumulating processes which occur in the Memory.

One should consider that thinking processes as a starting postulate belong to these processes (including processing of both the input and output information coming into and out of the Memory, respectively); i.e. the Memory is also a thinking medium encircled into the total neural net of the whole nervous system.

Where is the limit of the Memory and how is it organized?

We shall consider below the Conceptual Model of the Memory and processes which occur in it, and direct our attention both to the recognition function relating to the Memory concept as itself and the function of solving problems already relating to purposeful thinking as the most important one for metabolism. These functions are dominating for artificial intelligence problems and the Conceptual Model (CM) will, therefore, be of interest within the subject "From Nature to Artificial".

Memory and Recognition of Patterns

The Memory functions include such concepts as "recognizing", "remembering", "imagining" etc. Unlike perceiving the information from environment, it is suitable to represent all these actions as demonstrating the so-called "mental sight", i.e. a look which is initialized within the Memory and acted as exciting the certain sensory memorized structures in the Memory network, their combination etc. So, what is this structure?

To answer this question and understand the global defining principle of the Memory organization (that is required for the Conceptual Model), it is necessary to start with the basic hypothetical prerequisite which ensues,

as it were, from "common sense" (but doesn't coordinate with experimental data which it doesn't follow since it is impossible to observe sufficiently in general and in details).

And such a prerequisite as the main basic hypothesis is the following one:

"The pattern reconstruction in the Memory (imagination, mental sight) is determined by exciting all its elementary components which took part in the pattern perception".

It would be considered as a law of nature, as an immutable but inexplicable fact. Really, how does it happen that fluctuations of the potential of the neural net components are transformed to, visible inside (also audible, tangible, palpable) patterns? But it happens, isn't it? So, this fact should be the basis for the further constructions.

These constructions should already result in capability to form the signals inside the Memory. These signals are able to excite the components of the pattern perceived and fixed in the Memory, and there is already no information about this pattern at the Memory input. Concerning this initial information, the internal exciting signals are the information flow, which is reverse with regard to the information formed in the Memory.

Fig. 1 illustrates the aforementioned fact: Memory is represented with its main fields (see below) and the arrows denote delimitation between the direct and inverse information. So, we conclude that the "Memory" begins, in fact, where the reverse bonds finish. They finish just at the level of "c" conceptors, which repeat "r" receptors. Reverse bonds shouldn't extend over "r" receptors since the illusions occur during the mental sight, i.e. one sees, hears and touches that it isn't sensed at present time. So, the Memory limit is just positioned between "r" receptors and "c" conceptors; therefore, duplicating the first ones by the last ones is necessary for it.

The latter ones, "c" conceptors, are actually the smallest sensory components of the perceived patterns and the most elementary sub-patterns regarding to the Pattern. These sub-patterns hierarchically and naturally group together into larger sub-patterns, then the latter ones group in even larger sub-patterns, etc., up to the sensory concentration of the whole Pattern in the single structure unit which denotes only its symbol.

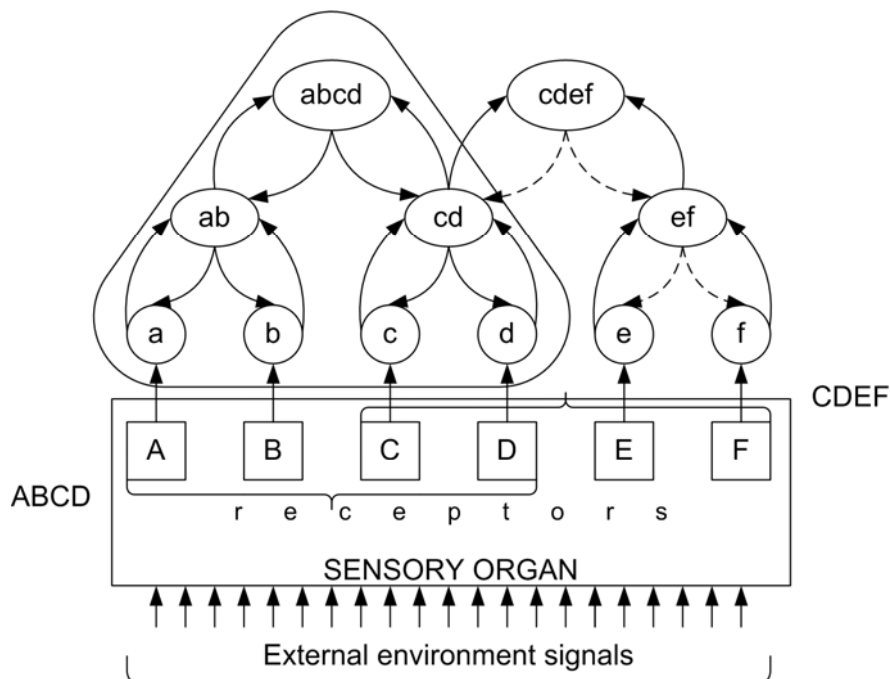


Fig. 1. Elementary structures of pattern perception, memorizing and recognition

Thus, when constructed information signals enter the Memory from outside, the nonlinear pyramidal Model of the pattern expressed by this information will be constructed in the Memory. The down-going reverse bonds from the top of the pattern pyramid up to its base (consisting of conceptors which repeat input receptors) are necessary for memorizing the pattern, i.e. for making possible the pattern reconstruction by "mental sight" according to the aforementioned main hypothesis. So, the Model of the concrete pattern, both as an object and as a structure

in the Memory, is the pyramid hierarchical construction with up-going convergent inductive (from partial to general) bonds and down-going divergent deductive (from general to partial) bonds.

The Memory as a whole consists of the set of such Models as the Memory loops associatively bound by the general components. The Memory is a structural realization of the semantic network as a system with knowledge fixed in it.

The aforementioned fact can be illustrated with the network, which is enough simple for visualization (Fig. 1). The network consists of fully constructed (i.e. fixed in the Memory) ABCD pattern and CDEF pattern entered into the Memory but not fixed in it.

It is caused by the fact that the pyramid (i.e. the Model) of the ABCD pattern already has reverse bonds and pyramid of the CDEF pattern isn't still constructed in full.

These patterns have one general CD sub-pattern which is the associative element of both pyramids. Such using of the general parts of the pattern provides: first, economy of constructing the semantic structures in the Memory; second, spontaneous (i.e. self-originated) parallelism during processing the pattern information in it that is essentially favorable for effectiveness of this processing (see below). Finishing the construction of the CDEF pattern means creating the reverse bonds in it (shown via dotted line).

Finishing the construction, i.e. changing the Model of demonstrated pattern into the memorized one, can be performed by several successive demonstrations of the same pattern that results in beating the genetically innate reverse bonds or even in their appearance.

The creation of the pattern structures in the Memory (Models) is scientifically valid. The aforementioned conception on constructing these structures, nevertheless, requires the following plausible hypothesis: constructing the direct up-going bonds for perceiving the concrete patterns by the Memory precedes an appearance of the reverse down-going bonds which ensure their memorization (see the main hypothesis) by learning.

Thus, a brain Memory medium of a new-born child (or other individuals with enough developed nervous system) is already saturated by bonds needed to obtain the information from organs of sense. The Memory itself is originated in full by constructing the already reverse bonds in metabolic process begun from the birthday (and while preparing the relevant capabilities even before it). Therefore, the brain as the thinking mechanism creates itself but under the environment impact. Let rather look aside and notice that so-called innate abilities are apparently caused by peculiarities of the genetically innate direct bonds. The demonstration of these abilities (as the construction of the relevant full pattern structures in the Memory) already occurs as a result of learning; i.e. phenomenal talents appear as a result of coincidence of two factors: the genetically constructed relevant structures in the Memory Medium and its subsequent learning as an impact of external factors.

As a consequence, the brain's Memory in its conceptual representation is a hierarchical semantic network restricted from above with ending of ascending connections (straight lines coming from sensory organs) and from bottom - with ending of backward connections to structure units, which directly perceive information entering the Memory (formed with specific sensory organs from specific signals). And whole thinking from simple recognition of pattern information to its analysis and synthesis and subsequent actions on sets of patterns, connected with creation and transformation of different situations, are performed in the closed restricted space, connected with dual-side informational links with external (toward it) environment. The first link is intended for information perceiving from the environment, the second – for information (directing, informative and other, created directly in Memory) production into the environment.

Now we consider recognition as the simplest psychological function, which determines the presence of the Model of the recognized pattern in the Memory as its definite structure.

If such structure exists (e.g. abcd Model described in Fig. 1) then the secondary spike of exciting this structure already passed by the reverse bonds will take place after presenting the prototype of the structure and its switching-off. It means implementing the "mental sight", i.e. recognizing the presented pattern in accordance with the main hypothesis. If the fully reverse bonds are absent, i.e. the pattern isn't filled in (such as cdef in Fig. 1) the secondary spike will not take place.

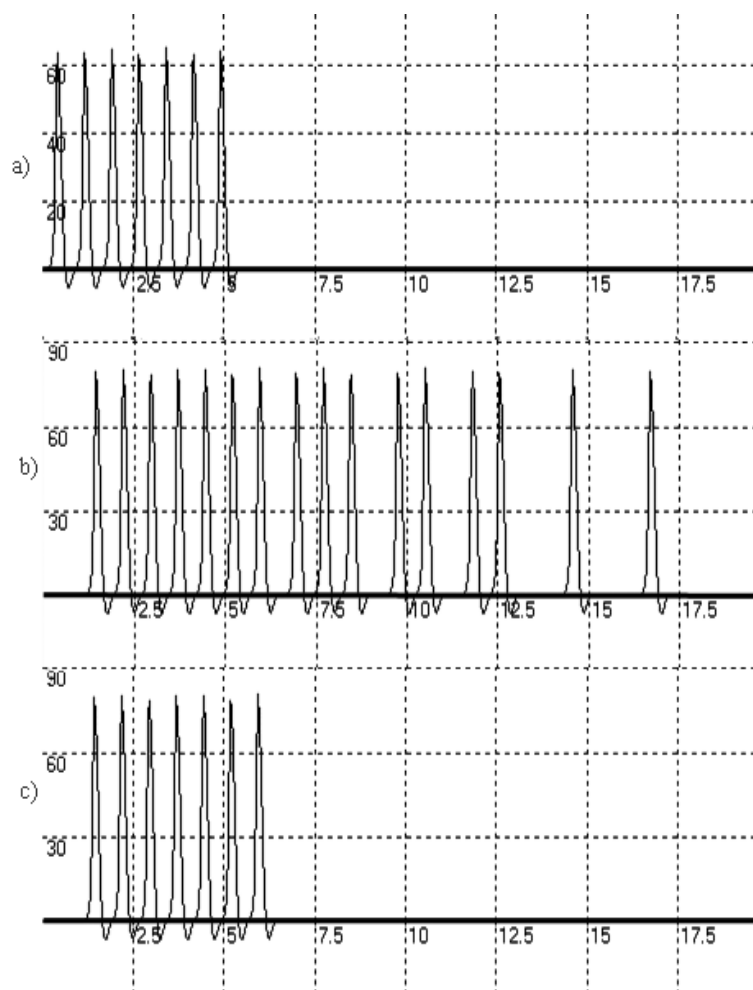


Fig. 2. Model's work result of pattern recognition process:
 a) Inputs to Memory onto elementary conceptors (outputs of receptors)
 b) Lower lever elementary conceptors' output with presence of backward links
 c) Lower lever elementary conceptors' output with presence of broken backward links

Thus, it is hypothetically claimed that recognition of the demonstrated pattern is determined with the secondary spike of exciting the relevant structure as its remembrance.

This hypothesis is supported by Modeling of the components of the olfactory sensory system (performed by neurophysiologist G.S. Voronkov (Moscow State University, Russia). Results of computational experiment represented on Fig. 2 were obtained by PhD students (Tkachuk. S, Iamborak R., Iamborak V.), with assistance of biological network Modeling tools developed by them (the secondary spike doesn't occur if the existing reverse bonds in the olfactory sensory system are interrupted and it obviously occurs if the reverse bonds exist, i.e. there is the full Model of the demonstrated pattern in the Memory).

Since exciting processes can be both probabilistic and possibilistic, the results are not defined in full and misoperations (e.g. due to associative bonds (cdef) between the Models of two patterns) are certainly possible in a recognizing process. But this indeed takes place in fact.

"Recognizing" in the presented above interpretation is the function implemented quite automatically in any living organism, which has the relevant nervous system. The implementation of this function in the broad sense of this term already including "comprehension" should relate to the thinking process in which described actions are implemented only as its first stage. During the construction of mathematical Models of Memory patterns the apparatus of growing pyramidal networks [5] can be effectively used, as a type of semantic networks.

Memory and Solving of Problems

Introduced conception of pattern structures in the Memory as their Models is general for all thinking functions since it is a basis for organizing all the Memory.

It is very important for Modeling the human thinking processes to consider the Memory as a whole system consisting of two subsystems: sensory one, lingual one [2] and higher associative subsystem, which store the patterns and their lingual notations and notions. The structures of these subsystems are interrelated by direct and reverse bonds, which define a correspondence between them and their mutual effect by transfer of the excitation. Note, that language variety is realized by the additional lingual subsystems, whose structures wouldn't bind with the sensory system structures but interact with it only by the structure of subsystem of single language. The type of bonds between sensory and one or another lingual subsystems defines capability and the level of recognized thinking in one or another language.

The process of human thinking, as specified above, is determined by interaction between the sensory and lingual subsystems of the Medium at the cognitive and intuitive (as uncognitive) levels.

The cognitive thinking is organically bound with the lingual expression of thoughts, i.e. individual talks, as it were, with himself or herself. Thus, the cognitive thinking is called verbal although the language wouldn't be a speech. For example, the relevant signals even enter the organs of speech in the first dominating case.

The principally sequential character of cognitive thinking results from it, because it is impossible to pronounce more than one thought at the same time.

In general, the cognitive thoughts are represented by the so-called "complete" dynamic structures, which integrate the relevant excited structures of the sensory and lingual subsystems at different levels of their hierarchy.

Excitement of incomplete structures is related to uncognitive thinking, which isn't restricted by strong interaction of structures of the sensory and lingual subsystems.

Therefore, such dynamic structures can arise at once at different levels of these subsystems not resulted in "pronouncing" the excited "sense".

So, the amount of information processed (even spontaneously) can be much greater here than during cognitive thinking.

Furthermore, such combinations can arise at the intuitive thinking level, which do not have lingual equivalents and so they don't rise to the consciousness level (e.g. savage thinking).

Therefore, the component of uncognitive intuitive thinking is of great importance besides the cognitive component of the purposeful process of solving the problems (man does think!).

The following hypothesis will be quite natural in accordance with aforementioned facts [1].

The Problem to be solved is specified in the Memory by the Models of original and goal situations, and its solution is an activated chain of cause-effect bonds that results in transforming the first one to the second one. The process of constructing the chain consists of two interrelated processes operating at the same time: sequential cognitive process (as reasoning) and spontaneous activation of the structures in the Memory by their associative bonds with the Models of the original and goal situations. We shall ignore below the "Model" term and terminologically equate the structure in the Memory to the situation itself.

Realizing the problem to be solved (the Problem situation) creates, some "tension" in the Memory, and so the special "problem generator" (PG) [1] term is very useful for obvious illustrating and considering the process specified in the hypothesis, which poles are the original and goal situations and its "tension" maintains the existence of the problem situation.

Creating the activated chain, which locks these poles and means solving the Problem, liquidates this "tension", i.e. terminates the PG existence. The links of the specified chain are intermediate situations between the original and goal situations (Fig. 3) and they can be defined not only by single-sided transformation but also by cross-transformation of these situations. However, the locking chain wouldn't be created in the continuous process (e.g. if there isn't enough knowledge in the Memory) that promotes creating the new intermediate PG which defines the break in the constructed chain of its poles locking, i.e. a new pair of original and goal situations.

The Problem solution can result in creating the new structure (i.e. the new knowledge) in the Memory due to beating the new bonds between its components. If there are enough intension and lifetime of the dynamic structure, this process is similar to conversion of the information dynamically stored (i.e. as a short-term memorizing in the statistically fixed Memory).

As the "distance" between the original and goal situations decreases due to creating the links of the required chain, which locks them, increase of the activity of the second process and the process as a whole can result in avalanche sudden locking of the PG poles, i.e. solving the Problem as a result of enlightenment. Furthermore, it can occur quite unexpectedly and accidentally just as a result of the second process, only if the first process which is the cognitive reasoning doesn't exist. The second process occurs nevertheless because PG is already excited.

In general, enlightenment is a property of creative processes, which can be schematically considered as a sequence with step-by-step domination of cognitive and intuitive thinking [6].

In the first case, the obtained result is comprehended and the new intermediate chain (sub-chain) is proposed. In the second case (i.e. at the next stage), this sub-chain is already reached and changed, if possible, up to obtaining the final result. Thus, the total process of solving the problem is probabilistic (or possibilistic) with a wide range of its quantitative characteristics. As such its speed and the time depends on the complexity of the problem being solved and the level of excitement of *PG*. The first factor is stipulated with length of the chain of interconnected structures, which communicate the initial and target situations (i.e. 'the distance' between them). The second factor is stipulated mainly with how strongly a human is dedicated to the problem in concern, i.e. how the emotion of interest is involved into its solution.

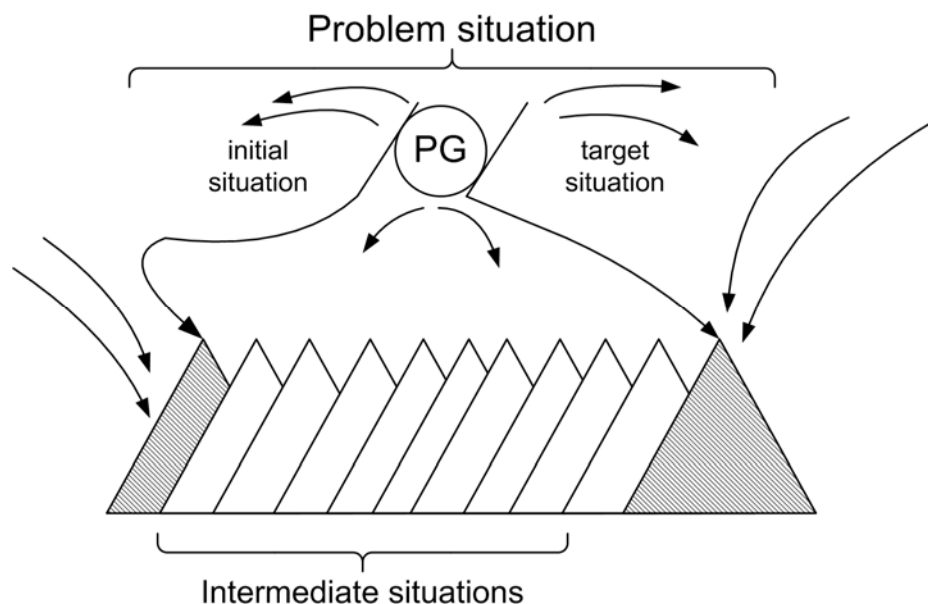


Fig. 3. Chain of the problem solving as a pattern situations transmission

Memory and Emotions

As long as the procedure of information processing in memory (in general in neural system) is characterized not only with sense but also with emotional part, let us according to the subject of the report define the major features of interaction between these contributors.

Division of a whole neuron network into separate fields and preparation of informational signal-receptors and memory environment, which accepts these signals, hold also in case, when emotional components are presented. Such components perform emotional influence by creation and transmission of specialized mediators.

These influences, which are established and transmitted in the whole hierarchy of memory, define its particular emotional state (e.g. depression or alternatively inspiration). In turn this state represents a background for mental processes taking place inside the memory. In other words, it guides the activation and interaction of memory structures.

Consequently, the emotional part actively participates in mental process and influences its functional performance. Nevertheless such performance, embodied with corresponding neuro-physiological indicators, naturally effects the emotional condition. For instance, when mental function is involved for solution of a complex problem, as it has been already stated, the emotion of interest (or even inspiration) plays the major role. Moreover, when theoretical problem is solved (the poles of PG are connected) with sudden conjecture, the emotion of extreme joy can appear.

As such, information processing inside the memory can be defined as emotional and sense simultaneously. And this processing in its conceptual representation can be easily represented in terms of described principles of memory organization.

Naturally, major emotional organs are located on the memory level, which accepts 1:1 receptor signals. It means, that during perceiving a pattern by memory from outside they will be organically included into its formed structure.

During the pattern recognition according to the main hypothesis all components of memory will be excited, i.e. the mental pattern obtains the "emotional colouring".

Consequently, memory as a system with structured organization during the information processing creates two independent results in thinking – sense and emotional (correspondingly – idea and humour, which stipulates the state of memory).

Emotional organs are located in neural system and outside memory. They participate in interaction with memory similarly to guided fulfilling mechanisms (like, moving apparatus).

I.e. emotional mediators are presented not only in internal loops of memory structures, but also in reflective loops of its connections with outside (in respect to memory) environment (see above).

Also mutual emotional influence appears between them in such interaction. In other words memory does not only manage, but also is managed by external environment in respect of its adjustment to a particular condition.

Concerning the emotional part of information processing it is necessary to stress, that it especially reflects in subconscious intuitive human thinking and at the same time has a significant value in his/her conscious thinking (for example, in speed-up of searching for particular information in his/her internal database).

As a whole, the introduced Conceptual Model explains a lot of psychological phenomena, which are related to processes of thinking, as well as clarifies the material substance of its mechanisms (including human's capability, erudition < smartness, inspiration etc). It supports our sureness in its plausibility.

It is worth to pay special attention to the fact, that though perceptive meaning is introduced in the Model, the Model itself can serve as a sufficient basis for its further advanced concretizations.

About Practicability of Conceptual Model Bionic Use

Conceptual Model (*CM*) has already essential bionic value [1]. But it makes no sense to apply nature as a whole to machines (e.g. legs and wheels). For example, when implementing the analogues of *CM* characteristics in computer architecture, it is necessary to remember its destination first of all.

For developing the universal high-performance and high-intellectual computers (i.e. computers which have enough advanced internal intelligence), it is quite reasonable to reflect the following characteristics in their architectures (as some analogues of the main *CM* principles) [8]:

- Distributed processing the information and its operational storage (i.e. processing part of the machine is to be some memory-processor_medium).
- The two-component machine computational process: first, the successive one which perceives the user's tasks, initiates, organizes and controls the process of their performing; and second, parallel one which is the component of the total computational process and is responsible for performing the tasks in each own branch.

- Machine tasks and knowledge representation as semantic and associative networks realized by graphs and their hierarchical processing; knowledge is represented by complex data structures at its upper level and in details at the lower level.
- Possibility to adapt to tasks and to organize the total computational process step-by-step with its dynamic scheduling and controlling the results obtained at each step.

The universal computer with the architecture built on the basis of specified principles must promote the effective realizing of different information technologies of alternative classes: a symbolism and connectionism including neural-computer ones. But, in the second case the technologies are realized at the program Models, which can also have sufficiently high characteristics (e.g. a great number of neuron-like elements) and can be structurally realized in part by paralleling processing in memory-processor medium. Furthermore, such computer must promote the effective technology realizing and integrating different technology processes.

A new class of multimicroprocessor cluster computers with specified properties (the so-called intellectual solving machines (ISM)) and, in particular, its Models for broad using was developed in the Institute of Cybernetics of NAS of Ukraine) (this project was supported by the grant from the USA chief of the project – Prof. Koval V, beside him the main authors Prof. Bulavenko O. and Prof. Rabynovych Z.) [9, 10].

ISMs in accordance with above-mentioned fact combine the distributed information processing with the internal higher-level language (which has the developed means of knowledge presenting and processing) and dynamic centralized-decentralized (successive and parallel respectively) control. Exactly this set of characteristics stipulates the belonging of ISM to the new class.

The high level of machine intellect structurally realized in their cluster architectures contribute the essential increasing the efficiency of user-machine interaction and possibility to perform, at that, complex computations which need the deep fractalibility of processing data. It provided by using in programming the high and very high level languages and automatic hierarchical organization of program transformation and performance.

Bibliography

- [1] Rabynovych Z. L.: A particular bionic approach to structural Modeling of purposeful thinking. // Cybernetics, No 2.(1979) 115–118
- [2] Voronkov G. S., Rabynovych Z. L.: Sensor and lingual system - two forms of knowledge representation. // News of artificial intelligence. (1993) 116–124
- [3] Rabynovych Z. L.: About Thinking Mechanisms and Intelligent Computers. // Cybernetics and system analysis, No 3. (1993) 69–78
- [4] Haken H., Haken-Krel M.: Mystery of perception. // Translation from German, Moscow: Institute of computer researches (2002)
- [5] Gladun V.P.: Decision planning. //Kyiv: Nauk. Dumka (1987) 167p.
- [6] Glushkov V.M., Rabynovych Z. L.: Problems of deductive constructions automation. // Information management and intelligence. Moscow (1976) part 4, chapter 2, 300 – 326.
- [7] Geoffrey E. Hinton mapping part-whole hierarchies into connectionist networks. //Artif. Intellig. 46 (1990) No 1/2, 47–75
- [8] Rabynovych Z.L.: About artificial intelligence concept and its development. // Cybernetics and system analysis, No 2 (1995) 163–173
- [9] Koval V.N., Bulavenko O.N., Rabynovych Z.L.: Intellectual solving machines as a basis of highly productive computational systems. // Controlling systems and machines. 36 (1998) 43–52.
- [10] Koval V., Bulavenko O., Rabynovych Z.: Parallel Architectures and Their Development on the Basis of Intelligent Solving Machines. // Proc. of the Intern. Conf. of Parallel Computing in Electrical Engineering. - Warsaw, Poland, September 22–25 (2002) 21–26.

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