Computer-Brain Model Memory and Decision-Making

Michail Kozlov

Abstract
In article, based on the analysis of the mechanisms of memory and making decision of man is considered a complex subject-oriented computer-brain model of memory, learning and decision-making procedure to them and the usefulness of such model for the creation of complex engineering systems, including data mining systems and systems with artificial intelligence, working in conditions of uncertainty, and for which is important operativeness and situational reliability decision-making.

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Introduction
In complex systems operating in an environment in case of insufficient certainty for optimal processing of input information are trying to use the Data Mining. It is equally important for such systems, acceptance robust and adequate decisions situation. These tasks are in many ways similar to the problems solved permanently living organisms and the nature of the crown of creation–man. Therefore, given the relative newness of these problems for complex systems and waste in the evolution of living organisms to perfection appropriate mechanisms of memory and decision-making, greater interest in the analysis of these mechanisms in living organisms and their emulation to create complex technical systems.

In the process of perception of incoming information by man, its awareness and decision-making (DM) of his memory plays a key role, and therefore his actions and intentions. Therefore, the organization of human memory, in addition to behavioral neuroscientists and psychologists, are actively interested professionals in the field of cognitive psychology and decision theory, as well as the creators artificial neural networks, neurocomputers and systems of artificial intelligence (SAI).

Analysis of Researches and Publications
There are three main stages of information processing in human memory: getting information from the external environment and its encoding, storage of information in memory and retrieval from memory.

On the basis of the options retrieve from memory, distinguish implicit (unconscious) and explicit (conscious) memory types. The processing of the information signal in parallel, as on an unconscious level, work-related implicit memory such and on a conscious level that is associated with explicit memory, and the response to a signal from the brain regions associated with these levels, comes in two nerve pathways in the amygdala limbic system, wherein the control signal by external systems is formed. In this case, processing of information at the unconscious level is much faster and the difference between implicit and explicit reactions can reach 500 ms, and, if the brain does not make decisions on the basis of criteria established by them about the priority of an explicit reaction, the amygdala generates a control signal based on more fast implicit reaction. In experiments with conflicting stimuli were fixed the subjects using an implicit skill in a situation where conflict stimuli were up to 25%, and when their number were in 75%, the subjects began to use only explicit knowledge. Usually, most of the time, human behavior is on automatic unconscious level.

By duration storage and the volume of memorized information usually distinguish two different types of memory: short-term memory (STM) and long-term memory (LTM). This separation was reinforced by the...
number of models of memory based on the computer metaphor, through which makes an analogy between data transformation in the computer and the cognitive processes in the brain humans. At the same time, the computer metaphor itself was developed on the basis of cognitive metaphor used in cognitive psychology, through communication between experts in computer science, neuroscience, computer science and artificial intelligence. 

Enough popularity till now is the memory model Aktinsona et al,11 in which the current input information from the environment arrives on the sensors where the remains about 300 ms. This information is scanned and by signal from the control system (CS), the selected data are transferred to the STM where their coding. Volume STM is limited and everyone entering to the STM new pattern will update the state of the memory and can displace the earlier pattern. A storage patterns in the STM to 30 seconds. With STM information on a signal from the CS enters to the LTM, where can be stored permanently, and in large volumes. Between LTM and STM have feedback, which allows by the control signal from the CS renew the previously obtained information in the STM.

According to the data given in Solso et al,10 the storage of information in sensors from 250 ms to 4 s, the duration of storage of information in the STM, without its renewal, 12 s and the playback time of each pattern 35 ms.

Based on research to identify opportunities for storage in the STM, Miller12 defined the limit of throughput of STM human through number 7 ± 2 chunks (“magic number 7 ± 2”), where a chunk is semantic image (pattern) that can be, for example, as memorized a letter or a whole phrase. Later Simon,13 the volume of STM was determined in the range of five to seven chunks. Subsequent cognitive experimentation the limit ability STM has been reduced to four chunks14 and in Glassman et al15 is shown in the range of three to four chunks, if not disregard the rehearsal component of STM.

As shown Sternberga et al10 experiments, as increasing the number of patterns simultaneously processed, may reduce the processing speed and vice versa. Research by visually counting numbers of items in the visual field showed that such a calculation is very fast and accurate for numbers of items from one to four, but slowly and with errors for greater numbers of items.16 For process of fast determine numbers of items in Kaufman et al17 was introduced the concept of “subitizing”, and for a range of fast counted objects “subitizing range.” For numbers of items that fall within the subitizing range, time spent on counts of items is in the range of 40 to 100 ms on item, and for the numbers of items on the numbers of more than four - 250 to 350 ms.

A study by Milner,18 have shown that of patients with lesions of the hippocampus works fine STM, but does not retain new information in the LTM. Further Milner’s studies showed that only damaged the long-term explicit memory and persists long-term implicit memory, which is linked to learning of perceptual and motor skills.18 Thus, confirmed the need for separation of STM and LTM, and the allocation of implicit and explicit memories.

In accordance with the views of the majority of cognitive psychologists simple dichotomy of memory, represented in the model,11 is not enough and with the STM link processes decision making and work of explicit memory. She consciously controlled by humans and is involved in short-term storage and processing of verbal and visual information.19 Taking into account active nature of this temporary memory associated with the processing of incoming information in it together with the previously recorded in the LTM, this kind of memory called working (WM). Baddeley et al,20 developed the first model of WM consisting of three components: the phonological loop (PL), responsible for the temporary storage of phonological information, the visuo-spatial sketchpad (VSS), responsible for the repetition of images and their short-term storage stores visual and spatial information, and the central executive (CE) is coordinating the work of processing incoming information, storage and retrieval of information from the LTM.

Later Baddeley,21 developed a new the multi-component model of WM, shown in Figure 1, by introducing a fourth component, the episodic buffer (EB), which provides a temporary interface between the PL, VSS and LTM. EB is able to store information in a multi-dimensional code and managed by the CE. At the bottom of Figure 1 shows the procedure of the formation of the cognitive system, which is capable of accumulating long-term knowledge through the exchange of data between the visual semantics (VS), the episodic long-term memory (ELTM) and verbal information (VI).

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**Figure 1.** Multi-component model WM

| Abbreviations: CE, central executive; VSS, visuo-spatial sketchpad; EB, episodic buffer; PL, phonological loop; VS, visual semantics; ELTM, episodic long-term memory; VI, verbal information. |
Neurophysiologists in the analysis of the central nervous system has been found that the formation of the LTM occurs with time delay, and, conditionally, we can talk about the presence of between STM and LTM intermediate secondary memory. In the secondary memory the information coming from the STM can accumulate from several minutes to several years, partially erased and converted before storing it in the LTM. One feature of the secondary memory is that time address to it is considerably greater than when accessing to STM and LTM. As a result, the memory model was developed based on the 3 kinds of information storage time. Information from the sensory memory enters the primary memory and there may be repeated by feedback from the output to the input of the primary memory, or to be forgotten, or transferred to secondary memory. In the secondary memory is also supplied from the sensory memory the part of the implicit information. From the secondary memory the information comes in tertiary memory in which information is stored during the whole life.

In living systems, the emotions aimed at the survival of the individual and of its kind, and the study of brain functioning has shown the important role of emotions in human decision-making. It was also found that with the defeat of the amygdala of the limbic system in patients is a violation of the formation of instantaneous (primary), emotional reaction, and if damaged ventromedial sector of the prefrontal cortex violation of the formation of secondary emotional response, that generated on the base of previous experience, which suggests the presence of emotional memory. Studies show diverse impact of emotion on work cognitive domain of memory and as a result of the identified bi-directional communication between the limbic system, responsible for the production of emotions, and cortical centers that regulate emotions, cognitive psychologists are moving to more complex models of DM.

To construct the whole variety of emotions using a number of basic emotions, that at different specialists ranges from 2 to 14. On the basis of data research the centers of emotions in humans, conducted by Damasio et al and other cognitive psychologists, in Kozlov et al for the SAI in the form of emotional intelligent agents (EIA) for basic artificial emotions are encouraged to use the six analogues of emotions: fear, pleasure, disgust, suffering, admiration, anxiety.

Emotions are important in making decision at a rapid, automatic, unconscious level. And from the adequacy of emotions the situation and richness of their tones will depend the optimal response. Each of emotions plays a special role. Thus, fear and pleasure can be attributed to the dynamic fast emotions with respect to the external environment. Formation disgust to anything can be delayed in time and made on the basis of extracting information from temporary memory. Suffering related with the assessment of the internal state, but in a society on its base can be formed an external emotion compassion for someone. Admiration is a external emotion that stimulates imitation and is an important factor in learning. On its basis, can be formed an emotion of dominance. At repetition several times of negative stimuli generated state of anxiety. This emotion transforms organism into a state of high alert and, at the same time, significantly limits the number of options when MD.

In Kozlov, it is assumed that such a base of emotions would allow to EIA, based on the set of its potential opportunities, environmental conditions and goals, to create an individual matrix of emotions for its successful functioning. The combination of basic emotions helps EIA to avoid dangerous situations, to stimulate the achievement of the objectives and ensure the necessary energy resources, monitor the technical condition of the individual parts and the state of software. The emotion of admiration, encouraging imitation in combination with be happy would to provide rapid absorption of new skills, and anxiety emotion will rebuild the system of decision-making of EIA at operational, more rapid response to external stimuli with some decrease in the estimated reliability of the expected results.

Due to the existence emotional memory, it should be noted that in addition to associated with input information (sensations) sensory types of memory, also has an output with respect to the brain of some short-term memory, which reflects on the face emotional state, and through feedback supports this state than the reduced load on the work of the cognitive system. Such a memory, associated with the muscles of the face, can be designated as the mimic. In Strack et al presents experimental data of psychologists with two test groups. One group watched cartoons with a pencil clamped between his teeth, so that it does not touch the lips. This imitated smiling. Another group watched cartoons with a pencil clamped only by lips. This made the expression frowning face. Group that imitated smiling with a pencil, comics appreciated more funny than that group that “frowned”. This example may illustrate the feedback action between the mimic memory and brain. Thus, «keep smiling» can be seen as an aid, but, of course, not defining a means of maintaining a good mood.

**Purpose of Work**

The main purpose of this work is to build a computer-brain model of memory and formation decision-making in complex systems, analysis of its operation and application possibilities.

**Presentation of the Base Material**

Of considered above is seen that memory models presented do not reflect the many aspects of its operation. Moreover, computer memory models developed for the analysis of human brain activity, little provide information for the development of complex technical systems, including
SAI. On the other hand, received information about the activity of the brain, including through the use of computer models, provides a wealth of material to specialists in the field of artificial intelligence, and it is time to use the metaphor of the brain for develop the SAI. Based on this, consider the construction of a computer-brain model formation of memory, learning and decision-making, allowing on the one hand more comprehensively to model the processes occurring in the brain, and on the other can help to create complex technical systems.

When constructing computer-brain model will take into account the characteristic feature of living organisms associated with the fact that they, like of supposed SAI, constantly works in the conditions of considerable uncertainty of the environment.

Figure 2 shows a subject-oriented comprehensive computer-brain model of memory and decision-making (CBMMDM), which represents somewhat integrated the previously proposed by the author model.32

The incoming person external information and information about his condition in view of the emotional vector is estimated by apperception system (AS) and entered into short-term (working) memory. At the same time sensory memory sensors adapted to current sensations under control of apperception system. AS performs function of analysis and processing as a external data and data on the state of the subject. Sorted in AS information through STM goes into the temporary memory (TM). In the STM from AS also entered required to process the previously received data patterns from TM, LTM and the quasi-persistent memory (QPM).

The QPM includes genetic33 and epigenetic memory34 and defines basic emotions (innate reactions to the environment) such as “Displeasure-Pleasure” and innate skills and provides a genetic predisposition of appointments separate parts of the brain. The name of this type of memory is quasi-persistent, primarily determined by the properties of epigenetic memory.

The executive motor memory, includes a motor, mimic and other types of peripheral memory. In conditions of high uncertainty of the external environment for complex systems the role of the executive motor memory becomes less noticeable and can sometimes decrease.

Dispatching of all processes in the system and development of solutions is produced by the decision-making system (DMS). The current state of the system through the AS enters the DMS for adjusting the decision-making.

In the AS is produced almost simultaneously recognition of incoming pattern, classification, and taking into account existing in the TM, LTM and QPM data, fast procedure of selection of subject-oriented approximation model of pattern with the necessary recovery of model on partially given attributes of the pattern. Models of the pattern (pattern referred in text) $P_s$, on the basis of several criteria, assigned a vector marker $m_j$ dimension $j$

$$m_j = [m_{i1}, m_{i2}, \ldots, m_{ik}],$$

where $j$ is determined by the amount of the assessment criteria for the pattern, $j \in [1,k]$, $k$ - the maximum possible number of the criteria.

At the same time on one of the many components of the vector marker $m_j$ is produced emotional evaluation of pattern, and on the other binding to time, for which, for example, the human brain uses biological rhythms. Each constituting $j$ of marker is characterized by two parameters—the type and magnitude. Further vector marker $m_j$ can be used to determine address of pattern in the cluster memory space.

By components of the vector marker carried mapping pattern in the memory space (mapping). And thus, it is possible, on the basis of multiple criteria $j$, by which evaluating the pattern, have a plurality of corresponding mappings of pattern, what corresponds to the spatial organization of the memory of living organisms.7,10 Self mapping of the pattern can also be a vector of smaller dimension.

Work AS, together with the STM and TM, by the processing of the input data can be, to some extent, to
compare with the work HTM (Hierarchical Temporal Memory),\textsuperscript{35} that represents a 6-tiered hierarchical layers with a large number of feedbacks simulating hyper vertical column of the neocortex, engaged in the processing and accumulation of information. For this variant the markers will have hierarchical a multidirectional structure.

Time storage of the current information in the STM little longer its assessment in the AS and, after processing, a formed mapping of pattern or transferred to TM or pattern, because of the limited storage capacity of STM, supplanted by the new information.

Incoming in the TM the implicit information is also marked in the AS on its criteria. Based on these data in TM with help AS, STM, LTM and QPM are produced subjective models of skills (SMS), and then they are fixed in the LTM.

AS carries out the role of gatekeeper of Freud, which conditionally placed it in the human brain between the entrance hall, in which all sensory information is received, and the second room, which contains the consciousness. In this case gatekeeper censor this information and transmits selected a conscious part, based on its emotional preferences. But if we use the analogy of Freud, then for considered the AS, the gatekeeper should be raised to the position of administrative assistant, laid out in folders (clusters) incoming current information, giving it a certain emotional coloring. It produces sorting, selection and storage of data in clusters, thus producing intelligent data processing, and, of course, 2-room apartment Freud should be expanded by adding a third intermediate space for offices, which role for AS are performed by STM and TM. In this case CRMMDM can be considered as subject-oriented. In the SAI to implement functions of gatekeeper to data estimation can be used neural network constructed on the basis of adaptive resonance theory (ART model).\textsuperscript{36}

In Kandel,\textsuperscript{7} a number of experiments, the formation of learning during classical conditioning and sensitization was shown the importance of repetition to secure in memory the information with partition of number of repetitions in a series and their temporal spacing. On the other hand, it was noted during the reaction habituation a decrease of response on do not carry important information external signals, and such information will not be stored for a long time.

Incoming in TM the patterns mapping are checked for their relevance with the help provisional short-term of time-frequency filtration (TFF), by determining their importance, based on the value emotional estimation assigned of marker, frequency and time of receipt. An analogue of such TFF can be considered in Kozlov\textsuperscript{37} filtering in the intermediate memory of SAI by a discrete linear convolution values marker assessment Qv(n) of pattern v with discrete-time weight function W(n)

\[
W(n) = \frac{A}{1 + e^{kn}}
\]

applied in neural networks the sigmoid function of the form where k is the coefficient slope weighting function; β is the exponent; A is the normalizing factor.

Exponent β determines the shape of the weighting function W(n). Selecting β influences the robustness of assessment v.

Based on the emotional evaluation and concomitant factors, a output data TFF by incoming similar patterns are regarded as addictive reaction, sensitization or associative learning. In this case the vectorial marker may be adjusted as for the output patterns and for incoming to STM a similar patterns.

For technical systems habituation reaction to the input patterns can be seen as anti-spam filtering in TM insignificant or interfere to work of the information system. And sensitization reaction and associative learning, when assigning AS to input patterns of certain emotional coloring, as signs of further use of these patterns for learning. According to some emotional estimates of patterns, at excess of the excitation threshold in the TFF, produced the formation in DMS the state of high alert of system.

Based of assigned to the AS of classification marker, passed through the TFF statistical processing the mapping of patterns come in corresponding clusters TM.

On the basis of all received new information resources in the TM, with use the data of STM and LTM, produced complication and formation of new clusters and creation on this basis space of subject models of knowledge (SMK). In space of SMK is deployed in time the adaptive iterative procedure generation of the SMK attractor by increasing the weight more subject-reliable of models knowledge and suppression of others belonging to this class of SMK.

Given the process of formation of SMK it can also be called the subjective attractor of knowledge. Each time the SMK entering to the STM is produced their new emotional assessment, carrying out as if their new awareness and AS through STM enters the SMK in the corresponding cluster TM with the new vector marker. In the process of generating of more complex SMK occurs weight gain more reliable for subject a models of knowledge and suppression of other SMK. Thus, over time as come new of patterns, are formed more concentrated (high-Q) attractors SMK and thus increases their reliability. This is typical of experts who accumulate data for many years.\textsuperscript{13}

Through circuits of feedback from TM and LTM in registers STM come patterns of SMK. This limits the capacity of the STM for the input data and can hinder
operative reaction to changes in the environment. This factor should be taken into account when analyzing the work of an integrated system, that carries out procedures recognition of input data, accumulation knowledge, forecasting and decision-making.

On the other hand a procedure of formation complex SMK is complicated at active human response to external signals in the waking state because of limited throughput STM. However, nature has found the perfect solution to improve the efficiency of the intellectual apparatus. During sleep, or in a period of prolonged rest the brain goes into default mode. In this case autogeneration of a complex SMK will occur in the inner contour of the brain through circuits of feedback, coming from different memory areas in the STM and not on the basis of incoming external information. In a resonantly tuned (in respect to the stimulus), subject-oriented decision-making system an input information about the stimulus would represent only a small fraction of all the information being processed to form complex SMK. To consolidate the SMK need have the emotional evaluation of events, the default mode of brain function, and the time on the formation of SMK in this state. This may explain the results of investigations emotionally shocking effects on humans,\(^ \text{38} \) that shows for them might make on the basis of CBMMDM using neuro-fuzzy networks\(^ \text{4} \) and the HTM.\(^ \text{35} \)

The appearance of high concentrated main attractor SMK differs from it (modified) by any parameters. At an early age in humans, with a small amount of knowledge, like that for the SAI in the early formation of knowledge models, in the evaluation of the input data are used a basic emotions, stored in the QPM, and the reaction will take place at implicit way. But in the further, as
processing of the incoming data, with the help of the EP are formed in the memory of the more complex emotions and development of reactions in the IDB can occur consciously for an explicit way. Thus, subjective model decisions (SMD) - originally constructed by the vector emotions of small dimension, for example, by the above six basic emotions, and with time, based on their subjective experience, formed by multi-criteria base of assessments in the form of multi-dimensional emotional vector. This is equivalent to the transition from the categories of Aristotelian logic to the categories of fuzzy logic. With help the SMK going development of subject-model of decisions (SMD) and on this base the response signals, and multi-criteria evaluation serve as the error estimates between SMK and the response of the environment. Based on these estimates, there is a correction SMK. Developing of corrected SMK is also possible by the inner loop of the system by receipt of information with AS with STM, TM and LTM.

In the DMS is converted of sets SMS and SMK in the set of SMD. At receipt an input signal, for develop solution, DMS controls the two existing response mechanism-automatically, based on SMS implicit memory, and more complex mechanism of conscious processing based on SMK explicit memory. At the same time ready to quickly respond to the input signal is an automatic mechanism can be locked at a certain degree of uncertainty in the decision on the basis of SMS with respect to the input stimulus, and will be included considerably longer mechanism of explicit data processing. In this case the DMS via the AS will manage the process of forming more reliable SMD until it is will not be, with its position, adequate SMD, then the response signal is generated.

The element of awareness of with explicit treatment will a response of brain to a request for uncollected automatic response to a stimulus, explaining that it is necessary to wait, as by an explicit path is formed more complex SMD, development of which is on order of longer than the implicit reaction.

Depending on the system state $S_t$ and incoming $P_t$ data, using the DMS, from the set of all possible SMS and SMK made the formation of an admissible set $SMD_{d}$, by treating each vector $SMD_j$ set of all $SMD_j$ solutions using adaptive dynamic non-linear weighting function, represented as a vector $W_a$, weight vector is produced in the DMS based on the current state of the subject and the resources available to it, the allowable time to react, the planning horizon, and other important factors. As a result of multiplying the element-wise all vectors $SMD_j$ by vector $W_a$ for further analysis obtained vector $SMD_{w_j}$

$$SMD_{w_j} = W_a \ast SMD_j$$

where * the symbol operations of elementwise multiplication vectors.

$$SMD_{w_j} \subset SMD_d$$

Of the set $SMD_{w_j}$ by operation of choice Sel selected dominating set of solutions $SMD_d$ for example, Pareto optimal set.

$$SMD_d = sel(SMD_{d})$$

After this from a set $SMD_d$ is done sometimes difficult enough, the selection of the final solution, for example, as is done in Kozlov for solving multiobjective problems, and further is triggered response mechanism.

When the input signal is received, by which on output of the TFF is exceeded the threshold of anxiety, in DMS formed high state of alert of system. In this case, requirement to the threshold of reliability SMD will be lowered and due to the change of weight vector $W_a$ the response signal in DMS can be generated faster.

With the accumulation of information in the TM clusters occurs SMK the complication and increase their capacity. Formation of SMK in the specific field of human activity, for quite a long time, leads to the formation of expertise and presented in Simon estimate of the number of initial elementary chunks of information to one area of activity can range from tens of thousands to 1 million. As a result, the accuracy of the solutions produced by an expert in a particular area is significantly higher than that of a layman.

Accumulated in the TM the sustainable SMK are recorded in the LTM, at the same time because of their complexity, they will already be wearing the subconscious character and does not lend themselves to verbalization. Access to this knowledge, as opposed to access TM, fast enough, in view of their storage in LTM. In Kihlstrom it is also contemplated that for a quick search of knowledge is performed their indexing.

Given the complexity of awareness the data stored in the LTM, and the speed of access to it LTM attributed to the store of implicit memory.

The Figure 3 shows the formation the SMD from the incoming signal input patterns (IP). From the input patterns on the upper path shown in the Figure 3, are formed SMK that are used to generate decision. With the accumulation of knowledge will be a transition of explicit knowledge in implicit skills and so formed the models of SMS. In the future for similar patterns decision-making procedure will be carried out by the lower much more rapid way, based on SMS. So is carried out the evolutionary chain of information perception as the Unconscious - Conscious - Subconscious. Here, in particular, we can speak of the primacy of intelligence with respect to developed at its basis of the newly acquired instinct.

Based on the foregoing, intelligent systems, for which is important operativeness and situational reliability in the development and decision-making, can operate follows. When receive a signal the formation and decision-making is done by two ways at the same time on implicitly and explicitly. At the DMS the first comes by the fastest
and the pursuit to the lowest energy state and the mechanism of trial and assessments reflect the dynamic stability and variability of elements and connections.

Conclusion

The proposed comprehensive subject-oriented a computer-brain model memory, learning and decision-making, as well as the given information allows to improve the process of creating complex technical systems, including systems, data mining, with consideration subject-oriented databases, and SAI, working in conditions of uncertainty, for which is important efficiency and situational authenticity in decision-making.

CBMMDM, which takes into account a capacity limitations of the STM and increased time of recognition and extraction of new knowledge from the TM, compared with implicit processing, can also be used in the analysis of the processes of learning a man, memory use, and decision-making and practical use of the data this analysis and can be useful when creating a model of the human brain.

References
