THE MODEL OF ASSOCIATIVE MEMORY OF INTELLIGENT SYSTEM

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Abstracts. The model of associative memory is proposed in this paper based on concept of association between images and associative search. This model may be used for connect concept of inference with associative processing in neural networks.

Keywords. Intelligent systems, knowledge base, associative memory, associative search.

A main problem of knowledge processing in intelligent system, is the problem of search of relevant knowledge or, in other words, recovery of a fragment of knowledge (image) on its fuzzy or noisy sample.

In Prolog-similar systems the search of relevant knowledge is implemented as unification. In frame systems the problem of search is implemented as comparison (matching) of the frames. In semantic networks the search implements by comparison of fragments of a network and graph-inquiry.

All these methods of search can be reduced to one, which is, apparently, implemented in natural intelligent systems, - associative fuzzy search of knowledge by its fragment. Knowledge here is meant as associative connections between images.

Let be follows:

- Set of features $K=\{p_i\}|\ i=1,N^p$, describing state of environment and self intelligent system in time t, where N^p – the number of features,
- Set of combination of values of features on set K $P^0=\{P_j\} \mid P_j=\{p_{ij}\} \mid j=1,N^o,\ i=1,N^p$, describing concrete images, where N^o – number of images,
- Set of real images (not full set of features) $\mathbf{P}=\{P_{kj}\} \mid j=1,N^o$ and k is integer from $(1,N^p)$,
- Query (image, initializing associative search) $P \in \mathbf{P}$,
- Image-result of associative search $R \in \mathbf{P}$.

The definition of “real” images $\mathbf{P}$ at contra to set of “ideal” images P^0 have principle mean. Natural intelligent system practically always deals with not full data about environment and internal state. Based on ones she restores missing data and restore associatively connected with ones another images (last or next in time). This process based on associative restoring is the principle of thinking. Must be selected two different processes:

- The process of restoration of image by partially determined features. Usually this process is simulated in different models of associative memory;
- The process of searching of associatively connected images linked with other moments of time. These images matter as reasons or consequences of initial image.

First variant is implemented in natural intelligent systems in sensor subsystems of brain. Second – in neocortex and is main for forecasting and thinking of animal or man. Below the model of this variant is proposed.

The features of set K may be considered as numbers determined on metric scales.

Definition 1. The pair of images (P,R) refers to as association A or $A(P,R)$, predicate $X(P^a,R^a,T^a)$, describing process of restoring of $R^a \mid R^a \subseteq R$ by $P^a \mid P^a \subseteq P$, is called as associative search, P^a – initial image of associative search and R^a - final image of associative

search, T^a – duration of associative search. For all P^a and R^a $X(P^a,R^a,T^a)=true$, if $P^a=P$ and $R^a=R$, $X(P^a,R^a,T^a)=false$, if $P^a=\varnothing$. If intelligent system acts in discrete time, then T^a $\hat{I}(1,N)$.

Definition 2. Set of associations $A=\{A_i(P_i,R_i)\} \mid i \hat{I}(1,M)$ forms memory or knowledge base of intelligent system.

Definition 3. Such associative search $X(P^a,R^a,T^a)$, as it use only one association from memory $A=(P,R) \mid P^a \acute{I} P$, $R^a \acute{I} R$,, refers to as elementary associative search. In case of discrete time to elementary associative search there corresponds duration $T^a=1$ (One step). In this case the elementary associative search may be described as $X(P^a,R^a)$.

Definition 4. The associative search accepting value *true* let's name successful and *false* – Unsuccessful.

To every association $A=(P,R)$ corresponds set of successful associative searchs $W=\{X_i(P_i^a,R_i^a,T^a)\}$, where $P_i^a \subseteq P$ and $R_i^a \subseteq R$. Formation of this set depends from features of implementation of associative memory (in particular, match of initial image of associative search P_i^a with P). Predicate describing matching of two images let's designate as $\approx$.

Definition 5. Association, to which there corresponds set of successful associative searches W, which capacity is equal 1, refers to as the determined association. If the capacity of set W is more 1, the association refers to as fuzzy.

Definition 6. Let's name association and associative search connected, if on attributes the following restriction is imposed:

$$P \subseteq R$$

Definition 7. Let's name association and associative search free, if any restrictions on sets P and R is not imposed.

The set from N of associations $(P_i,R) / i \hat{I}(1,N)$, in which as set of features R the same internal image is selected, is an elementary tree and element of hierarchical structures used for classification of images.

The process of thinking in the certain above terms of associations and associative search can be presented as associative search (process of restoring) images initiated by an initial entrance image, consisting from external features. Generally it can be presented as associative search displayed in a chain or a tree of elementary associative searches. The tree turns out, if on the next step there are associations, alternative for application.

May be selected two kinds of chains:

1) A chain with forgetting, when all images restored as a result of the previous associative searches, are not taken into account during current associative search;
2) A chain with storing, when an initial image for the current associative search is the image being a composition (in the elementary case, addition) of final images received on the previous steps of associative search. And let be parameter m - depth of storing the limiting account of a history of associative search (at m=0 a chain with storing turns to a chain with forgetting).

At a chain with storing the size m associates with concept of capacity of short-term memory used in psychology. It is considered, that volume of short-term memory makes 5-7 images.

The chain with forgetting can be presented as:

$$\Xi(P_1^a, P_n^a, T^a) = \Xi(P_1^a, P_2^a, T_1^a), \Xi(P_2^a, P_3^a, T_2^a), ..., \Xi(P_i^a, P_{i+1}^a, T_i^a), ..., \Xi(P_{n-1}^a, P_n^a, T_n^a),$$

where:

$$\Xi(P_i^a, P_{i+1}^a, T_i^a) = True \ , \forall i \mid i = \overline{1, n-1}$$

$$T^a = \sum_{i=1}^{i=n} T_i^a ,$$

The chain with storing can be presented as:

$$\Xi(P_1^a, P_n^a, T^a) = \Xi(P_1^a, P_2^a, T_1^a), \Xi(P_2^{a+}, P_3^a, T_2^a), ..., \Xi(P_i^{a+}, P_{i+1}^a, T_i^a), ..., \Xi(P_{n-1}^{a+}, P_n^a, T_n^a),$$

where:

$$T^a = \sum_{i=1}^{i=n} T_i^a,$$

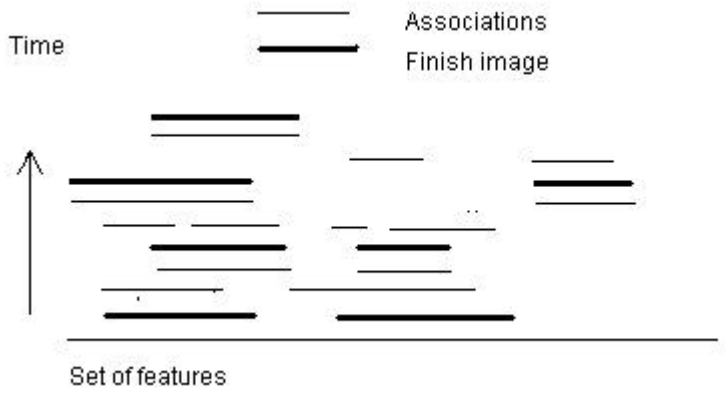
$$\Xi(P_i^a, P_{i+1}^a, T_i^a) = True, \forall i \mid i = \overline{1, n-1},$$

$$P_i^{a+} = Comp\ (P_i^a P_{i-1}^a, ..., P_{i-m}^a),$$

Comp – the composition of images,

m - depth of storing .

In figure the process of associative search is represented in case of a chain with storing with depth of storing m=1.



It is possible to understand a composition in the elementary case association of images. In this case identical features of images with different values coexist together. However, more real represent variant when the different values of images of the same feature cooperate among themselves. For simplification of formalization and further realization of model the following variant of a composition of images from *(i-m)*-th to *i*-th is offered:

$$P_i^{a+} = \{p_{ik}\},$$

where:

$$p_{ik} = \frac{\sum_{j=i-m}^{i} p_{ik}}{m_k},$$

m_k - the quantity of images, in which is present an feature p_{ik},

p_{ik}=0, if *ê*-th feature is absent in *i*-th image.

It in essence means calculation average arithmetic among the values, present in images, k-th of an feature. In case of a binary feature (with values from a range {0,1}) as its value at a composition of images it is necessary to consider last value.

It is possible to present probable variants of development of associative search in case of presence of alternative associations or set of alternative successful associative searches appropriate to associations, as a tree similar to a tree of the decisions in the classical theory of artificial intelligence. However, is a static picture, which can be applied only to convenience of understanding by the external observer. Actually, the receipt of external images initiating

process of associative search, occurs at the any moments of time. Therefore it is necessary to speak about parallel associative search, the growth of which quantity is limited to volume of short-term memory (parameter m).

In natural intelligent systems (in contrast majority of AI models) the process of learning is not separated from process of reasoning or associative search.

Let's try to describe this process in the terms determined above.

The associations in memory arise constantly during perception of all new images of the external world. But are remembered not all from them, but only what are supported during the associative search, caused by them. It is possible to tell, that the process of storing is supervised by earlier stored information.

During associative restoring at using of the next association (P, R) it becomes active on time mT^a (in a case $T^a=1$ this size can be becomes replaced on m - volume of short-term memory). The reinforcement of association $A=(P_1,R_1)$ at using of the next association $B=(P_2,R_2)$ during associative search occurs in case the following conditions are satisfied: 1) the association A is active and 2) $P_2 \approx R_1$.

That disappears under the term “the reinforcement of association", depends on concrete implementation of associative memory (as well as the relation of provisional equality of images.

If at receipt of some image from the external world the associative search, initiated by it does not result in success, the image is remembered as a final image R_1 of association $A=(P_1,R_1)$, an initial image from which P_1 is the previous image. This association becomes active on time mT^a . If it is not supported during this time, this association is erased from memory. So occurs at primary forming of associative memory. Thus on the initial stage, when still memory contains a few associations, the size of short-term memory m can have the large value and decreases in process of forming of associative memory.

The model proposed in this paper may be used for development of architecture of hybrid intelligent systems joining logical and associative processing of knowledge, in particular so-called “semi-sphere intelligent systems”, proposed by author [1-3].

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