PROCESSOR ON BASIS OF ASSOCIATIVE MEMORY IN RESTORATION OF IMAGES

Igor Mardare

Department of Design and Manufacturing of Electronic Apparatus,
Technical University of Moldova, Stefan cel Mare Av, 168, Chisinau
MD2012, Republic of MOLDOVA, E-mail: mardarei@mail.md,

Abstract **–** Field of researches is the process of revealing of homomorphous displays between objects. Such functions are capable to carry out the suggested 3-rd order objects. By its nature search of associative objects is isomorphic to the problem solved by 3-rd order object. Thus, the processors created on basis of 3-rd order objects can be realized as associative memory. Using theory of high order objects and associative memory allows to solve effectively problems of restoration of defective images of objects.

***Key words* -** restoration of images, associative memory, Kohonen networks

I. INTRODUCTION

Restoration of objects can be carried out not only by control, realized by dominant object, but also due to comparison of defective object with set of true images with the subsequent finding of true image, most similar to defective object, which will be considered as the restored one. The 3-rd order object of the 2-nd type $\boldsymbol{x}_{\mathrm{n}}^{3.2}$ is capable to compare objects by equivalent parameters and to find similar true images for examined defective image of 1-st order object.

II. DEFINITION OF FUNCTIONS OF 3-ORDER OBJECTS OF THE 2-ND TYPE

Let's define 3-rd order object of the 2-nd type $\boldsymbol{x}_{n}^{3.2}$ as the object representing the result of comparison of two 1-st order objects $\boldsymbol{x}_{n-1}^{1}$ and $\boldsymbol{x}_{n}^{1}$. It is supposed, that the object $\boldsymbol{x}_{n}^{1}$ is more complex than object $\boldsymbol{x}_{n-1}^{1}$, what means that power of set of all possible states of object $|\boldsymbol{x}_{n}^{1}|=|x_{n1}|\cdot|x_{n2}|\cdot\ldots\cdot|x_{nK}|$ is more than that of object $|\boldsymbol{x}_{n-1}^{1}|=|x_{n-11}|\cdot|x_{n-12}|\cdot\ldots\cdot|x_{n-1K}|$: $|\boldsymbol{x}_{n}^{1}|>|\boldsymbol{x}_{n-1}^{1}|$. Comparison is carried out by criterion of similarity of equivalent parameters of objects $\boldsymbol{x}_{n-1}^{1}=(x_{n-11}, x_{n-12}, \ldots, x_{n-1K})$ and $\boldsymbol{x}_{n}^{1}=(x_{n1}, x_{n2}, \ldots, x_{nK})$ by means of the comparator. As criterion of similarity it can be used Euclidian distance between vectors of examined objects $\boldsymbol{x}_{n-1}^{1}$ and $\boldsymbol{x}_{n}^{1}$:

$$d(\boldsymbol{x}_{n-1}^{1}, \boldsymbol{x}_{n}^{1})=\sqrt{\sum_{k=1}^{K}(x_{n-1k}-x_{nk})^{2}}. \tag{1}$$

At small number of conterminous values of parameters $x_{n-11}, x_{n-12}, \ldots, x_{n-1K}$ and $x_{n1}, x_{n2}, \ldots, x_{nK}$ of objects $\boldsymbol{x}_{n-1}^{1}$ and $\boldsymbol{x}_{n}^{1}$ their degree of similarity ***d*** is less than established threshold **T**. In this case result of comparison will be the empty set – 0-th order object $\boldsymbol{x}^{0}$. If the degree of similarity ***d*** of objects $\boldsymbol{x}_{n-1}^{1}$ and $\boldsymbol{x}_{n}^{1}$ is higher than threshold **T** then less complex object $\boldsymbol{x}_{n-1}^{1}$ is transformed homomorphously in more complex object $\boldsymbol{x}_{n}^{1}$, and the result of comparison of two objects $\boldsymbol{x}_{n-1}^{1}$ and $\boldsymbol{x}_{n}^{1}$ will be an object $\boldsymbol{x}_{n}^{1}$. Function of comparator of 3-rd order object of the 2-nd type is realized by operator of comparison ***S*** of objects $\boldsymbol{x}_{n-1}^{1}$ and $\boldsymbol{x}_{n}^{1}$. Then the 3-rd order object of the 2-nd type $\boldsymbol{x}_{n}^{3.2}$ is described as follows:

$$\begin{cases} \boldsymbol{S}(\boldsymbol{x}_{n-1}^{1}, \boldsymbol{x}_{n}^{1})=\boldsymbol{x}^{0}, & \text{if } d<\mathbf{T}, \\ \boldsymbol{S}(\boldsymbol{x}_{n-1}^{1}, \boldsymbol{x}_{n}^{1})=\boldsymbol{x}_{n}^{1}, & \text{if } d>\mathbf{T}. \end{cases} \tag{2}$$

In problems of image restoration for any defective image of object $\tilde{\boldsymbol{x}}_{i}^{1}$ it is required to find from set of various true images $x_{nE}^{1}=\{x_{1E}^{1}, x_{2E}^{1}, \ldots, x_{NE}^{1}\}$ the unique homomorphous display $\tilde{\boldsymbol{x}}_{i}^{1} \rightarrow \boldsymbol{x}_{iE}^{1}$. For this purpose it is necessary to compare defective object $\tilde{\boldsymbol{x}}_{i}^{1}$ with each true image $\boldsymbol{x}_{1E}^{1}, \boldsymbol{x}_{2E}^{1}, \ldots, \boldsymbol{x}_{NE}^{1}$. Comparison is carried out by criterion of similarity ***d*** of equivalent parameters of objects $\tilde{\boldsymbol{x}}_{i}^{1}=(\hat{x}_{i1}, \hat{x}_{i2}, \ldots, \hat{x}_{iK})$ and $\boldsymbol{x}_{nE}^{1}=(\hat{x}_{n1E}, \hat{x}_{n2E}, \ldots, \hat{x}_{nKE})$ by means of operator of comparison $\boldsymbol{S}_{\mathrm{i,\,n\,E}}$. If $\boldsymbol{d}$<**T** then examined true image of object $\boldsymbol{x}^{1}_{\mathrm{n\,E}}$ is not homomorphous to defective one of object $\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}$. If the degree of similarity of objects $\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}$ and $\boldsymbol{x}^{1}_{\mathrm{n\,E}}$ is higher than a threshold (***d*>T)**, then these objects are homomorphous.

Process of restoration of defective images is described as follows:

$$\begin{cases} \boldsymbol{S}_{\mathrm{i,\,n\,E}}(\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}, \boldsymbol{x}^{1}_{\mathrm{n\,E}}) = \boldsymbol{x}^{0}, & \text{if } \mathrm{d} < \mathbf{T}, \\ \boldsymbol{S}_{\mathrm{i,\,n\,E}}(\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}, \boldsymbol{x}^{1}_{\mathrm{n\,E}}) = \boldsymbol{x}^{1}_{\mathrm{i\,E}}, & \text{if } \mathrm{d} > \mathbf{T}. \end{cases} \tag{3}$$

On this principle of comparison of two objects and search of similarity between them associative memory is organized. Associative memory is capable to restore the defective image of object by finding of true image on basis of a fragment of true one or noisy true image, or makes the conclusion about discrepancy of given defective image to compared true one. As associative memory can be used, for example, Hopfield neural network. Then, associative memory can be naturally installed in 3-rd order object of the 2-nd type $\boldsymbol{x}^{3.2}_{\mathrm{n}}$ for performance of functions of operator of comparison $\boldsymbol{S}_{\mathrm{i,\,n\,E}}$.

Change of vector of defective image $\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}$ by time under the law

$$d\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}} = \sum_{\mathrm{n}=1}^{\mathrm{N}} \boldsymbol{x}^{1}_{\mathrm{n\,E}}(\boldsymbol{x}^{1}_{\mathrm{n\,E}}, \tilde{\boldsymbol{x}}^{1}_{\mathrm{i}})\, d\mathrm{t} \tag{4}$$

will lead to concurrence of vector $\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}$ to the most similar true image $x^{1}_{\mathrm{nE}} = \{x^{1}_{\mathrm{1E}}, x^{1}_{\mathrm{2E}}, ..., x^{1}_{\mathrm{NE}}\}$ and on outputs of a network will appear the vector $\boldsymbol{x}^{1}_{\mathrm{i\,E}}$ i.e. required association $\boldsymbol{A}_{\mathrm{i,E}}$ between two similar objects will be found:

$$\boldsymbol{x}^{1}_{\mathrm{i\,E}} = \boldsymbol{A}_{\mathrm{i,E}}(\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}). \tag{5}$$

Associative memory allows by a fragment of object $\tilde{\boldsymbol{x}}^{1}_{\mathrm{i}}$ to extract from memory all required information. Therefore if set of true objects $x^{1}_{\mathrm{nE}} = \{x^{1}_{\mathrm{1E}}, x^{1}_{\mathrm{2E}}, ..., x^{1}_{\mathrm{NE}}\}$ is stored in associative memory as binary vectors $\boldsymbol{w}_{\mathrm{n}}=\{\boldsymbol{w}_1, \boldsymbol{w}_2, ..., \boldsymbol{w}_{\mathrm{N}}\}$, then defective images $\tilde{x}^{1}_{\mathrm{n}} = \{\tilde{x}^{1}_{\mathrm{n1}}, \tilde{x}^{1}_{\mathrm{n2}}, ..., \tilde{x}^{1}_{\mathrm{nH}}\}$ according to expression

$$\begin{cases} \boldsymbol{x}^{1}_{\mathrm{1\,E}} = \boldsymbol{A}_{\mathrm{1,E}}(\tilde{\boldsymbol{x}}^{1}_{\mathrm{1\,h}}) \\ \boldsymbol{x}^{1}_{\mathrm{2\,E}} = \boldsymbol{A}_{\mathrm{2,E}}(\tilde{\boldsymbol{x}}^{1}_{\mathrm{2\,h}}) \\ \quad \cdots \\ \boldsymbol{x}^{1}_{\mathrm{N\,E}} = \boldsymbol{A}_{\mathrm{N,E}}(\tilde{\boldsymbol{x}}^{1}_{\mathrm{N\,h}}), \end{cases} \tag{6}$$

where $\boldsymbol{h}$ – number of versions of defective image $\tilde{\boldsymbol{x}}^{1}_{\mathrm{n}}$, h=1, 2..., H.

are capable to extract true images $\boldsymbol{x}^{1}_{\mathrm{n\,E}}$ corresponding to them. Thus, "restoration" of various defective images is carried out. The submitted associations $\boldsymbol{A}_{1,\mathrm{E}}, \boldsymbol{A}_{2,\mathrm{E}}, \ldots, \boldsymbol{A}_{\mathrm{N,E}}$, corresponding to homomorphous presentation of different variations of defective objects $\widetilde{\boldsymbol{x}}^{1}_{\mathrm{n1}}, \widetilde{\boldsymbol{x}}^{1}_{\mathrm{n2}}, \ldots, \widetilde{\boldsymbol{x}}^{1}_{\mathrm{nH}}$ of separate true object $\boldsymbol{x}^{1}_{\mathrm{n\,E}}$, are unequivocal associations and exist for not crossed classes of objects (some classes can adjoin).

III. CONCLUSION

In each class of objects all parameters of defective and true images are equivalent. Such situation corresponds to search of association between these images according to expression (6). As objects $\widetilde{\boldsymbol{x}}^{1}_{\mathrm{1h}}$ and $\widetilde{\boldsymbol{x}}^{1}_{\mathrm{2h}}$ belong to different classes, which form not crossed sets, then objects are described by different number of parameters and, hence, restoration of each objects $\widetilde{\boldsymbol{x}}^{1}_{\mathrm{1h}}$ and $\widetilde{\boldsymbol{x}}^{1}_{\mathrm{2h}}$ will need separate associative memory. The quantity of inputs, neurons and outputs in each associative memory corresponds to quantity of equivalent parameters of defective and true images. Hopfield network during restoration of images is capable only to change (without generation or deleting) values of equivalent parameters of defective image and to reduce them to corresponding values of true image $\boldsymbol{x}^{1}_{\mathrm{n\,E}}$.

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