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POPULATION CODING WITH PARALLEL-HIERARCHICAL NETWORK APPLICATION FOR PATTERN RECOGNITION

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Introduction

From recent neurobiological research it has been known that in order to code sensor information the human brain applies the approach referred to as population coding. Within its frame the information is represented by the whole population of active neurons [1].

This important property was demonstrated by the experiments carried out by D. Sparks. Analyzing the way the ape's brain controls the motion of the eyes, the conclusion was reached, that the needed motion is being coded by the population of cells, each of them represents motion, that slightly differs from others. The motion, performed by the eye, corresponds to averaged motion, coded by active cells. As the experiments carried out by M. Young and S. Yamane with temporal cortex of monkey's brain, population coding proves to be valid not only for the motion of eyes but also for features of the face. According to the idea of population coding, the current image, being recognized, must be compared. Taking into account certain averaging, whys representation of reference image – average by all current images otherwise along the whole learning sample on the base of averaging of parallel – hierarchical (PH) networks parameters [2,3].

Problem Statement

Application of suggested hypothetic module of information structuring in cortex of cerebrum based of PH network, represented in details in [3], for its teaching while images recognition.

The aim of the paper

The aim of the given researches is realization of the model of neurobiological information processing on the base of parallel-hierarchical network.

Population coding with PH network application

Formation of multistage PH network assumes the process of sequential conversion of correlated spare regions and creation of decorrelated in time elements of neural network while transition from one stable state into another.

Main peculiarity of the suggested method is study of dynamics of space-correlated mechanism of conversion current elements of neural network and formation resulting elements of this network. Such mechanism permits to apply new approaches to the problem of processing in neural network as the process of parallel-serial conversion of various components of image and the record of temporal characteristics of conversion. Physical content of input elements of neural network, participating in the process of correlation, decorrelation, such as amplitude or frequency, phase or energy of signals, connectivity or texture of images is determined by the type of conversion applied, its choice being dependent on the class of problems being solved.

In general form the concept of multistage approach to the problem of images processing can be formulated in such a way. The analysis of image is serial conversion of coincident and filtration of non coincident components of image while transition of neural network elements from current energy states with less energy, having other space coordinates such process of image analysis occurs at different stages, each of which comprises the execution of above - mentioned procedure. The condition of image components transition at a higher level is available dynamics of mutual coincidence of intermediate results of processing in time in equal channels of lower level. The result of image analysis is formed from isolated in space-temporal region elements of image.

Let's consider the mathematical model of parallel decomposition of the set $\mu = \{a_i\},\ i = \overline{1, n}$ [2], which is applied in each branch of PH network.

$$\sum_{i=1}^{n} a_i = \sum_{j=1}^{R} \left(n - \sum_{k=0}^{j-1} n_k \right) \left(a^j - a^{j-1} \right), \qquad (1)$$

where $a_i \neq 0$, R – dimensionality of the given set. Form subsets from similar elements, elements of one set designate by a^k, $k = \overline{1,R}$, n_k - number of elements in k[th] subset (i.e. multiplicity of a_k) a^j – random element of the set $\{a^k\}$, chosen at j[th] step, $j = \overline{1,R}$, $a^0 = 0$, $n_0 = 0$.

Lets apply the idea of population coding [1], having constructed the model of any final action, being performed by all current actions. It is obvious, that on the level of neural network branches given final action corresponds to averaged parameters of this network. For PH network the number of elements in the branch of each level determined on the base of the module (1) and values of the element itself can be such averaged parameters. In this case current image, being recognized will be presented by current PH network and will be compared with reference PH network with averaged parameters.

Let's designate mean value of random element of the first level as $\overline{a}^1_{i,j}$, second level – $\overline{a}^2_{i,j}$, third level - $\overline{a}^3_{i,j}$ etc. k[th] of the last level $\overline{a}^k_{i,j}$, also mean number of elements of the first level - $N_{\overline{a}^1_{i,j}}$, second level - $N_{\overline{a}^2_{i,j}}$, third level - $N_{\overline{a}^3_{i,j}}$ etc. k[th] level - $N_{\overline{a}^k_{i,j}}$ we can form PH network with averaged parameters.

Synthesized in such a way the structure of PH network with averaged parameters is shown in Fig.1.

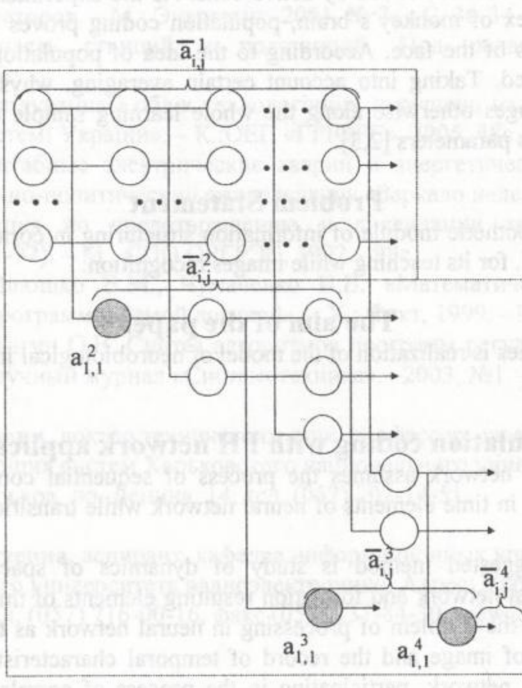

Figure 1 - Structure of PH network [4] with averaged parameters

Current image or sample being investigated, processed by PH network with current parameters $a^1_{i,j}$, $a^2_{i,j}$, $a^3_{i,j}, \ldots, a^k_{i,j}$ і $N_{a^1_{i,j}}$ $N_{a^2_{i,j}}$ $N_{a^3_{i,j}} \ldots N_{a^k_{i,j}}$ is being compared with reference image or image of the norm, processed by PH network with averaged parameters - $\overline{a}^1_{i,j}$, $\overline{a}^2_{i,j}$, $\overline{a}^3_{i,j}$, ..., $\overline{a}^k_{i,j}$ and $N_{\overline{a}^1_{i,j}}$, $N_{\overline{a}^2_{i,j}}$, $N_{\overline{a}^3_{i,j}}$, ..., $N_{\overline{a}^k_{i,j}} \ldots$

Tree-shaped model of program realization with formation of computing structure of PH network is presented in Fig.2.

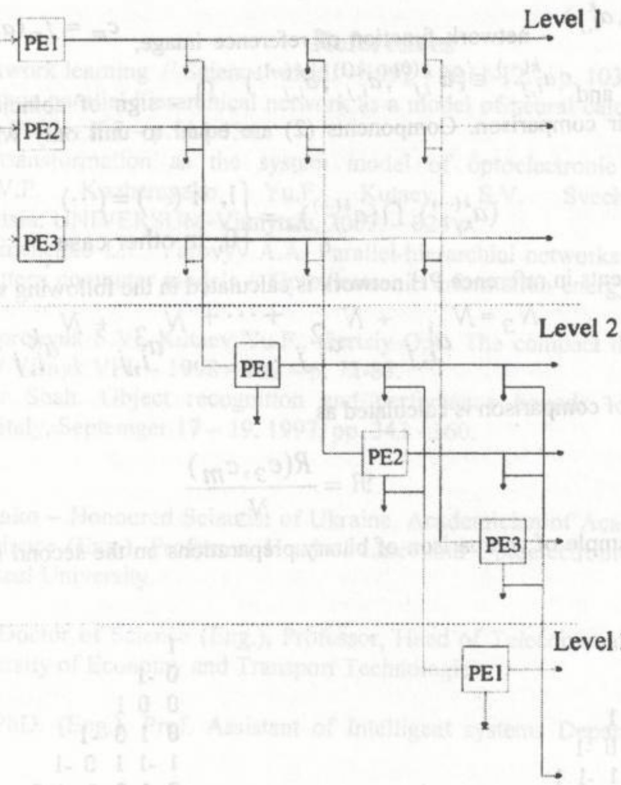

Figure 2 - The sample of formation of PH network with current parameters

If we make use if cutting section of elements of PH network for each level [5], then proceeding from averaged parameters $\overline{a}_{i,j}^{1}$, $\overline{a}_{i,j}^{2}$, $\overline{a}_{i,j}^{3}$,..., $\overline{a}_{i,j}^{k}$ we can pass by means of three-level coding to their representation by binary means (-1,0,+1). That is for random averaged parameter, such transition can be represented by three types of preparations: $a_{i,j}^{o}$, $a_{i,j}^{1}$, $a_{i,j}^{-1}$. In this case PH network with numeric counting becomes PH network with binary countings $a_{i,j}^{o}$, $a_{i,j}^{1}$, $a_{i,j}^{-1}$. Then the procedure of comparison of binary countings of current and reference PH networks is considerably simplified.

In order to form references it is necessary to teach them within the frame work of teaching sample. For this purpose while each teaching it is necessary to make averaging by elements of the branch of each level, that is, form averaged elements $\overline{a}_{i,j}^{1}$ $\overline{a}_{i,j}^{2}$ $\overline{a}_{i,j}^{3}$,..., $\overline{a}_{i,j}^{k}$ further passing to binary preparations $a_{i,j}^{o}$, $a_{i,j}^{1}$, $a_{i,j}^{-1}$. Hawing completed above-mentioned actions we can form PH network with reference parameters for reference and current images.

Having formed PH networks with reference parameters for current and reference images we can compare it with PH network, that uses current parameters. PH network with current parameters we refer to PH network with current values of its elements $a_{i,j}^{1}$, $a_{i,j}^{2}$, $a_{i,j}^{3}$,..., $a_{i,j}^{k}$ with transition to binary preparations $a_{i,j}^{o}$, $a_{i,j}^{1}$, $a_{i,j}^{-1}$, and current number of elements in the branches of each level $N_{a_{i,j}^{1}}$, $N_{a_{i,j}^{2}}$, $N_{a_{i,j}^{3}}$,..., $N_{a_{i,j}^{k}}$... Procedure of comparison of PH network with reference parameters and PH networks with current parameters comprises its topographic overlapping of one on another and calculation of the number of coincidences of the same binary elements.

Two binary PH network coincide; if by pair all countings of each of preparations located in the network are equal. In case of can coincidence of dimensionality of PH networks being compared, it is necessary to introduce in its branches additional nodes with coding of the fourths state. In order to evaluate the result of binary PH networks comparison let's introduce quantitative index, that characterizes the degree of their coincidence.

$$R(c_{э},c_{m}) = \sum(a_{i,j}^{1(\cdots)})_{э} \cap (a_{i,j}^{1(\cdots)})_{m} + \cdots + \sum(a_{i,j}^{k(\cdots)})_{э} \cap (a_{i,j}^{k(\cdots)})_{m}, \quad (2)$$

where $c_э = f_э(a_{i,j}^1, a_{i,j}^2, \cdots, a_{i,j}^k)$ - network function of reference image, $c_m = f_m(a_{i,j}^1, a_{i,j}^2, \cdots, a_{i,j}^k)$ - network function of current image, and $a_{i,j}^{k(\cdots)} \in \{a_{i,j}^{k(0)}, a_{i,j}^{k(1)}, a_{i,j}^{k(-1)}\}$, $\cap$ - sign of coincidence of the same binary preparations in case of their comparison. Components (2) are equal to unit only when the same preparations coincide. That is,

$$(a_{i,j}^{k(\cdots)})_э \cap (a_{i,j}^{k(\cdots)})_m = \begin{cases} 1, \text{ if } (\cdots) = (\cdots) \\ 0, \text{ in other case} \end{cases}$$

Total number of elements in reference PH network is calculated in the following way:

$$N_э = N_{a_{i,j}^1} + N_{a_{i,j}^2} + \cdots + N_{a_{i,j}^3} + N_{a_{i,j}^k}$$

Normalized measure of comparison is calculated as

$$\Re = \frac{R(c_э, c_m)}{N_э}$$

Let's consider the example of comparison of binary preparations on the second level for two PH networks (Fig.3).

a)

```
1
0 -1
-1 0 1
0 1 0 1
1 -1 0 0 -1
0 1 0 1 -1 1
```

b)

```
1
0 -1
0 0 1
0 1 0 -1
1 -1 1 0 -1
0 1 0 0 -1 0
```

Figure 3 - The sample of comparison of binary preparations on the second level for reference PH networks (a) and current PH networks (b)

Lets calculate for this example (Fig.3) the degree of coincidence $R(c_э, c_m)$ and normalized degree of comparison $\Re$ for the second level of current and reference PH networks.

$$R(c_э, c_m) = (1) + (1+1) + (1+1) + (1+1+1) + (1+1+1+1) + (1+1+1+1) = 16.$$

Total number of elements in PH network on its second level $N_э = 21$.

Then normalized degree comparison $\Re$. While networks for there second level will be the following.

$$\Re = \frac{R(c_э, c_m)}{N_э} = \frac{16}{21} \approx 0{,}762$$

It is obvious that normalized degree of comparison of two PH networks is determined within the following limits

$$0 \le \Re \le 1.$$

Very important factor is that normalized degree of comparison can be calculated not only separately for each of two levels, but also common for both PH networks, this improves the probability of formation of recognition result.

Conclusions

The paper suggests for teaching of the network, using the idea of population coding in artificial neural network, and its approaching to natural neural networks to represent current image by current PH network with current parameters and convert them on the base of generalized contour preparation in binary preparations with further comparison on the base of normalized degree of comparison with reference PH network of reference image with averaged parameters, the elements of which are binary preparations parameters, the elements of which are binary preparations. Unlike known structures of artificial neural networks [6], where non-normalized (absolute) similarity criteria are used, the given teaching method uses normalized criterion. In this case, normalized degree of comparison is suggested to be calculated not only separately for each of two levels, but also calculate common for both PH networks; it will improve the accuracy of recognition results formation.

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