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NEUROBIOLOGICAL PROPERTIES OF THE STRUCTURE OF THE PARALLEL-HIERARCHICAL NETWORK AND ITS USAGE FOR PATTERN RECOGNITION

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Abstract. *The paper presents the analysis of neurobiological data on the existence of the structure of a parallel-hierarchical network. Discussed method of parallel-hierarchical transformation based on population coding and its application for the pattern recognition task. Based on the analysis, we can conclude that using the methods proposed, it is possible to measure the geometric parameters and properties of images, which can significantly increase the efficiency of processing, in particular estimating the center of mass based on moment characteristics. Experimental results demonstrate that due to various destabilizing factors, accurately measuring the energy center coordinates of laser beam spot images is challenging. However, training the PI network and classifying the fragments into "good" and "bad" can considerably enhance the accuracy of these measurements.*

Keywords: parallel-hierarchical network, population coding, pattern recognition task, laser, center of images, proceeding of images

NEUROBIOLOGICZNE WŁAŚCIWOŚCI STRUKTURY SIECI RÓWNOLEGŁO-HIERARCHICZNEJ I JEJ WYKORZYSTANIE DO ROZPOZNAWANIA WZORCÓW

Streszczenie. *W artykule przedstawiono analizę danych neurobiologicznych dotyczących istnienia struktury sieci równoległo-hierarchicznej. Omówiono metodę transformacji równoległo-hierarchicznej opartej na kodowaniu populacyjnym i jej zastosowanie do zadania rozpoznawania wzorców. Na podstawie przeprowadzonej analizy można stwierdzić, że za pomocą zaproponowanych metod można mierzyć parametry geometryczne i właściwości obrazów, co może znacznie zwiększyć wydajność przetwarzania, w szczególności szacowania środka masy na podstawie charakterystyki momentu. Wyniki eksperymentalne pokazują, że ze względu na różne czynniki destabilizujące, dokładny pomiar współrzędnych środka energii obrazów plamki wiązki laserowej jest trudny. Jednak szkolenie sieci PI i klasyfikowanie fragmentów na „dobre" i „złe" może znacznie zwiększyć dokładność tych pomiarów.*

Słowa kluczowe: sieć równoległo-hierarchiczna, kodowanie populacji, zadanie rozpoznawania wzorców, laser, centrum obrazów, postępowanie z obrazami

Introduction

Neuroscience research has demonstrated that the brain utilizes a technique called population coding to encode sensory information. The method of population coding is utilized by the brain to represent information through the activation of a population of neurons [1, 7, 9]. D. Sparks conducted experiments on monkey brains to demonstrate this property, where the movement of the eyes was controlled by a population of cells that represented slight variations of the required movements. The resultant movement was the average outcome of all the movements encoded by the active cells. Thanks to experiments carried out by M. Yang and S. Yamane on the temporal cortex of monkeys, it was found that this concept is also used to recognize facial expressions. Following the idea, the image that is recognized can be compared with the average mapping of the reference image. It is possible to build a model of such an average display of the reference image – the average overall current images (otherwise – over the entire training sample) based on averaging the parameters of a parallel-hierarchical (PI) network [2, 6, 13].

The article studies a theoretical framework for organizing information in the brain, utilizing the PI network as expounded in [3, 4, 10], specifically for resolving pattern recognition issues. The creation of a multi-step PI network is a sequential conversion of interconnected dimensional zones, which generates temporally decorrelated neural network components as it transitions between two stable states. The fundamental characteristic of the suggested approach is the dynamic nature of the dimensional correlation mechanism that transforms input data and creates the resulting neural network elements [5, 11]. This processing algorithm allows you to process images of laser beams using a neural network in the form of parallel-sequential conversion of various components of the image, taking into account their temporal characteristics of the transformation [8, 17].

The physical content of the neural network input elements that take part in the correlation-decorrelation processes, such as amplitude or frequency, phase or energy of signals, connectivity, or image texture, is determined by the type of transformation used, the choice of which depends on the class of problems being solved [12, 14].

1. Mehtod on the based of PI network for pattern recognition - images of laser beam images

The evaluation of the image involved a sequential transformation of the match while identifying and filtering out image components that didn't match during the move from states with high energy and one-dimensional coordinates in states that are characterized by fewer images and geometric phenomena. What is the general condition for the transition to a new level between intermediate processing outcomes of dynamic correlation over time in the corresponding lower-level channels. The output of the image analysis consists of isolated image components within the Spatio-temporal region [15, 16].

Let's examine a model that describes the simultaneous breakdown of a set $\mu = \{a_i\}$, $i = \overline{1, n}$ into multiple components, used for all branches of a parallel-hierarchical network

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

where $a_i \neq 0$, R – dimension of the set, a^k, $k = \overline{1, R}$ – the elements of subsets of the same elements, n_k – the number of elements in the k subset , $j = \overline{1, R}$, $a^0 = 0$, $n_0 = 0$.

We can apply the concept of population coding [18, 20] to build a model that represents a final action carried out on all the ongoing actions. In this scenario, the present image that requires recognition will be projected by the current PI network and contrasted with the reference PI network possessing averaged parameters [17, 18]:

$$\bar{a}_{i,j} = \frac{1}{NM}\sum_{i,j} a_{i,j} \tag{2}$$

Let us determine the average value of the elementary level of the subsequent element of the level as $\bar{a}^{k}_{i,j}$, as well as the average number of elements as $N_{\bar{a}^{k}_{i,j}}$. The structure of the parallel-hierarchical network synthesized in this way is shown in Fig. 1:

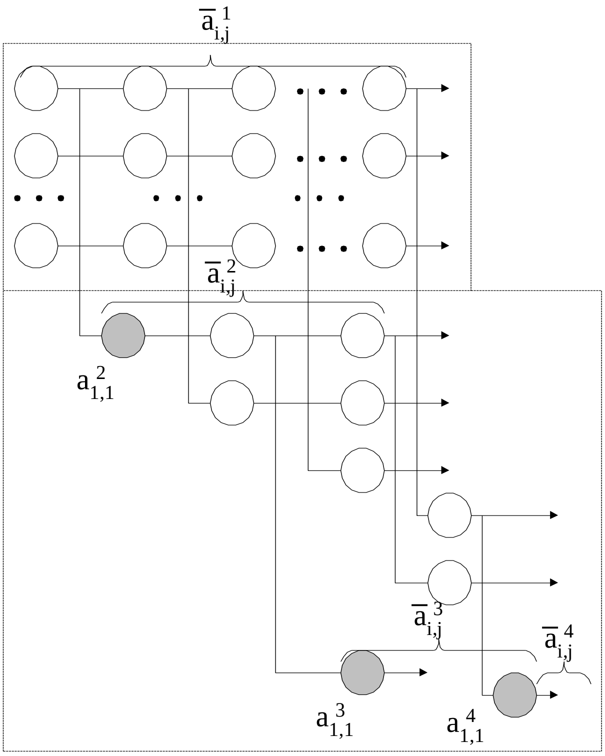

Fig. 1. The arrangement of the parallel-hierarchical network

In this image, what is currently being processed using the PI network with parameters $a^{1}_{i,j}, a^{2}_{i,j}, a^{3}_{i,j}, \ldots, a^{k}_{i,j}$ is compared with the reference image, which is processed by the PI network with averaged parameters – $\bar{a}^{1}_{i,j}, \bar{a}^{2}_{i,j}, \bar{a}^{3}_{i,j}, \ldots, \bar{a}^{k}_{i,j}$.

In accordance with the proposed algorithm, it is necessary to use the stage of preparing PI network elements for all levels, then we can move from the averaged parameters $\bar{a}^{1}_{i,j}, \bar{a}^{2}_{i,j}, \bar{a}^{3}_{i,j}, \ldots, \bar{a}^{k}_{i,j}$ based on coding to their display by binarized view (-1, 0, +1). Afterward, sets of differences in the element are established using the value of brightness (average) of the information components of a partition of an image (or part of an image) in which the information fragment of the processed image is located. For any average parameter, the distribution variables of substance indicators are determined: zero, negative, positive. In this case, the original PI network with number samples is converted into a PI network with samples in the form of binary logic, which significantly speeds up the process of comparison with correlation analysis between the binarized values of the reference and current PI network. For the formation of image standards, it is necessary to conduct training within the sample. To average over the elements of the branches of a hierarchical network at each level, it is necessary to make averaged elements. $\bar{a}^{1}_{i,j}, \bar{a}^{2}_{i,j}, \bar{a}^{3}_{i,j}, \ldots, \bar{a}^{k}_{i,j}$, after this, carry out measures for binarization of preparations $a^{0}_{i,j}, a^{1}_{i,j}, a^{-1}_{i,j}$. After the PI network is finally created with the reference parameters for the images and compared with the original PI network that uses the current parameters, the correct analysis model is carried out. $a^{1}_{i,j}, a^{2}_{i,j}, a^{3}_{i,j}, \ldots, a^{k}_{i,j}$ with the transition of preparations in the form of binary logic $a^{0}_{i,j}, a^{1}_{i,j}, a^{-1}_{i,j}$ and the number of elements currently in branches of all levels $N_{a^{1}_{i,j}}, N_{a^{2}_{i,j}}, N_{a^{3}_{i,j}}, \ldots, N_{a^{k}_{i,j}}$.

It should be noted that correlation coefficients can be determined not only between levels, but also between two network PIs, which

It should be noted that correlation coefficients can be determined not only between levels, but also between two network PI, which allows you to obtain more reliable results when processing images [11].

2. Experimental results

Let us consider the identification of dynamic patterns using images of laser beam spots. (The initial signals are considered using the example of sequences of image series of extended laser paths [12].)

This problem can be determined based on tunneling [17] by averaging correlation coefficients when comparing the reference image with a separate path chunk. In the table Samples of control images and distinct segments of elongated ray trajectories (1–10) – bitmaps of 1000 in every individual path that were used during experiments [18], and correlation comparison graphs between spot and reference images from various trace segments using PI networks at different levels [8].

The reference image is created based on 10% of path fragments (Fig. 2).

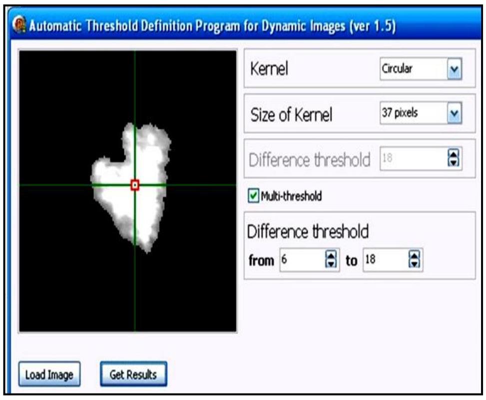

Fig. 2. Reference image

The first 10 chunks of trace for comparison (Fig. 3).

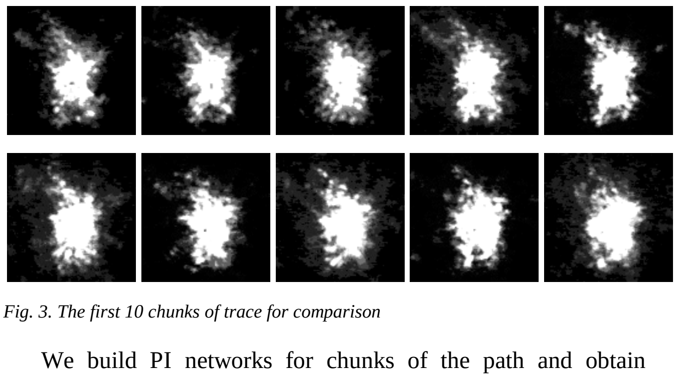

Fig. 3. The first 10 chunks of trace for comparison

We build PI networks for chunks of the path and obtain correlation comparison curves for the PI network levels (Fig. 2).

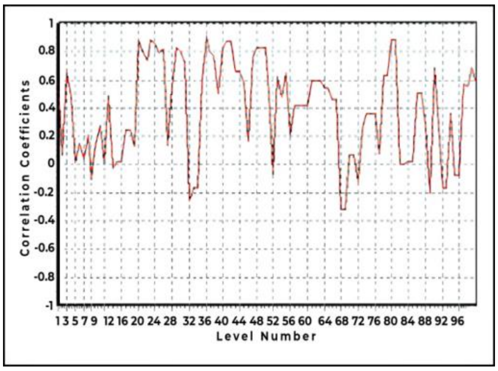

Fig. 4. The instance of correlation comparison based on different PI network levels

For Fig. 4, PI network consists of a total of 18 levels. Next, we plot the correlation coefficients that were averaged over these levels (Fig. 5).

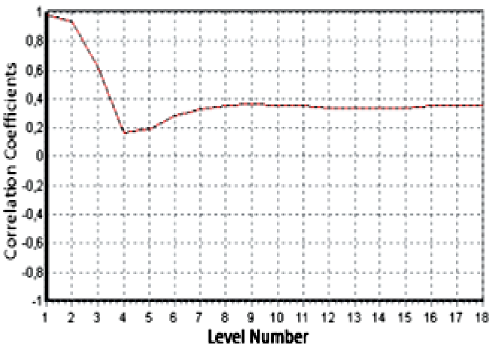

Fig. 5. Graph of average correlation coefficients by levels

Thus, the average dynamic dependence coefficient for the PI network levels is determined, which is equal to 0.41 and is in the selected ratio within the range – [0.41...1].

We determine the "good" chunks of the path and optimize the weights for them according to formula (3) [11], thereby computing coordinates of image centers that characterize the properties of laser beam spots [9].

$$
\begin{aligned}
x_{ec} &= \frac{1}{M}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} w\big(f(x,y)\big)\cdot\left(x+\delta_X\right) \\
y_{ec} &= \frac{1}{M}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} w\big(f(x,y)\big)\cdot\left(y+\delta_Y\right)
\end{aligned}
\qquad (3)
$$

where w=1, 2, ... , N, $f(x,y)$ – the brightness, δ_x, δ_y is offset of the centers along the X and Y axes, respectively.

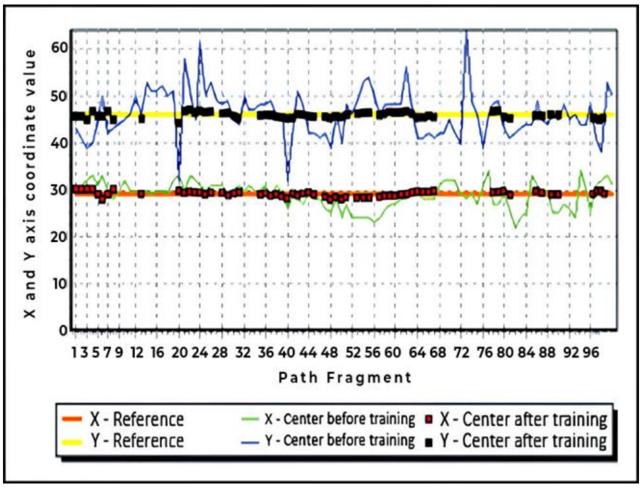

Fig. 6. Graph of the result of determining the coordinates of the centers when analyzing images before and after training the PI network

3. Discussions

For the described PI network, all the listed axioms are satisfied. These are the hierarchy of the structure due to the multi-level architecture of the PI network, the topographic nature of the display due to the display of information, as it saves the space configuration of specific alarm points, the parallelism of different signals due to the organization of parallel computing at the level of its branches, the mosaic structure due to the local processing of information of input numerical fields, forming a mosaic character of calculations, delaying the flow of information, so that the information on the nodes of the branches is transferred from the delay for a time of the operations in the nodes. In addition, in the PI network and neural networks, there are horizontal and vertical ways of promoting information, and links are organized between adjunctive lines.

When employing a parallel-hierarchical model for dynamic pattern recognition tasks, network training revealed that approximately 50% of the path fragments classified as "good" had their weights optimized. The optimization of these weights led to improvement in the accuracy of determining the energy center coordinates of the laser beam spot images.

Experimental results demonstrate that due to various destabilizing factors, accurately processing the coordinates of the energy center when analyzing digital images is sufficient for processing the images

However, training the PI network and classifying the fragments into "good" and "bad" can considerably enhance the accuracy of these measurements.

4. Conclusions

A comparative analysis reveals that the proposed methods can measure the energy center coordinates of images of laser beam spot with an accuracy of no more than 1.2 decomposition elements for determining the anchor point. This level of accuracy is nearly ten times better than that of the existing methods, such as the one based on moment characteristics for determining the center of mass.

Physical modeling of the method for determining the energy center coordinates of images of laser beam spot using a TMS320C5510 signal processor, which operates at a clock frequency of 200 MHz and performs 400 million operations per second, indicates that processing one image takes approximately 10.65 milliseconds. This processing time is sufficient for implementing the proposed method for processing laser trace television images.

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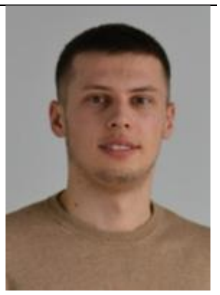

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