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ENHANCEMENT OF SENSITIVITY OF THE IMAGE SEGMENTATION BY KOHONEN'S NETWORK BASED ON THE MODULATION TRANSFORMATIONS

Annotation. The abilities of the enhancement of the visual segmentation of the low-contrast images by self-organized Kohonen's maps subject to the method of the multidimensional input vector forming based on the modulation transformations of the source intensities were considered.
Keywords: segmentation, Kohonen's map, low-contrast images, modulation transformations, preprocessing.

Introduction. The number of practical tasks that are solved by digital processing of images that are the result of the applying standard research methods in the different fields of human activity, for example, medicine, geophysics, ecology and others are permanently grown. The image segmentation is one of the most important and ambiguous procedures that belong to high level processing methods [1]. This procedure must provide the splitting of the source data on the component parts with the homogeneous properties. The matter of this splitting is objects of interest detection for the father visual analysis. The required segmentation detail level is defined by the image quality and solved task, and the success of the analysis is depend of the accuracy of this phase.

The ability of sensitivity and reliability enhancement of the image segmentation consists in solving of the task of expansion the dimensions of the input space attributes by input data transforming, for example, by local contrast analysis of the separate elements. This procedure requires using the processing methods in the multidimensional space. The choice of the different types of transformations and methods leads to different results [2].

The absence of clear criteria of the obtained results optimality (the visual estimate is often used) leads to necessity of comparison of the different processing methods, specifically, the input data forming variants. The implementation of the preliminary quality enhancement procedures is needed for the noisy low-contrast images.

Research urgency. The peoples have exceptional ability of the 3-dimensional patterns identification, but they can not detect the simplest multidimensional patterns. The modern approach of solving task of the multidimensional data analysis with the conditions of the ambiguity is based on using neuronet [3] and fuzzy [2] methods. The advantages of the approach based on self organized Kohonen's maps (SOM) [3] are consisted in the adaptability, the ability of multidimensional informative characters processing with the minimum a priori knowledge and the guaranteeing 2-dimensional mapping of the multidimensional data.

So far as beforehand the utility of the input variables for the outputs "prediction" is not known often that the temptation of the input characters dimensions expanding appears. But in this case the results accuracy and interpretability suffers. Thus the number of inputs must be strictly limited, and the choice of the most informative input variables is the important step of the data preparation for the analysis. The complexity consists in the uncertainty of the utility of characters for the additional sensitivity enhancement with the viewpoint of the solving task. On the other hand the negative factors when expanding the input vector dimensions may be:

– the existence of the correlation between input characters;

– processing time increasing;

– the appearance of the artifacts.

Problem definition. The matter of this article is the research of the dependence of the informative abilities of visual sensitivity enhancement of the low-contrast images segmentation by using SOM from the method of the multidimensional input vector forming by modulation transformation of the source intensities.

Research results. The architecture of the neuronet that called discrete Kohonen's map, is shown on the fig. 1. The neurons of this net formed 2-dimensional grid and linked to all nodes of the input layer. With the applied viewpoint SOM is self-sufficient methods that form the net learning rules by the topology of the input data distribution and naturally quantizes the input space of the analyzing characters with the ability to submit these characters in effective form for the visual analysis [3].

We define next steps for the image segmentation by the SOM:

1. the definition of the preprocessing method for the analyzing images and determination relevant set of the input vectors subject to space distribution of the source intensities values accordingly to the task of analysis;
2. the choice of the net dimensions and the learning parameters;
3. the learning of the net;

4. the segmentation is the definition of the method of the clustering results mapping to the 2-dimensional space.

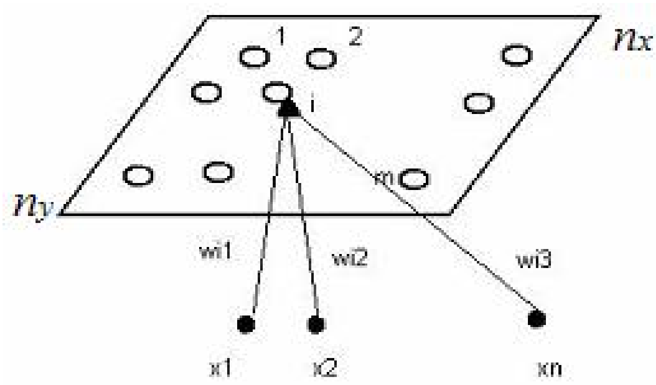


Figure 1 – Kononen's map architecture:
($n_x \times n_y$ – the total number of the map nodes; ($x_1, x_2, ..., x_n$) – inputs;
$W_i = [w_{i1}, w_{i2}, ..., w_{in}]^T$ – the weight vector of the i-th node

The experiments shown that total quantity of the neurons (limits the maximal number of the clusters) and the number of the neurons n_x, n_y by x and y axes, accordingly, influence to the clustering error during image processing sufficiently. It is provoked by the topological properties of analyzing data. The choice of the values n_x and n_y must be defined based on the number of gray levels for the image view and their geometrical size. The usage of the excess neurons leads to the artifacts appearance. The maps of the small size promote forming of the large clusters, thus such maps provide certain universality that may be useful in the some cases, for example, in case of the noisy data.

The error squared e_k^2 for the cluster k is the sum of Euclidian distances squares between characters of the cluster k and its center v_k

$$e_k^2 = \sum_{i=1}^{N} z_{ik} (x_i - v_k)^T (x_i - v_k). \quad (1)$$

The total clustering error squared is the sum of all clusters (K) error squared

$$E_K^2 = \sum_{k=1}^{K} e_k^2 . \quad (2)$$

The typical view of the clustering error values subject to the net dimensions is shown on the fig. 2. By using this figure we can determine the optimal net dimensions, when the condition $n_x \times n_y \leq 256$ is true (the area of possible values is selected on the figure by white rectangle, where $n_x > n_y$).

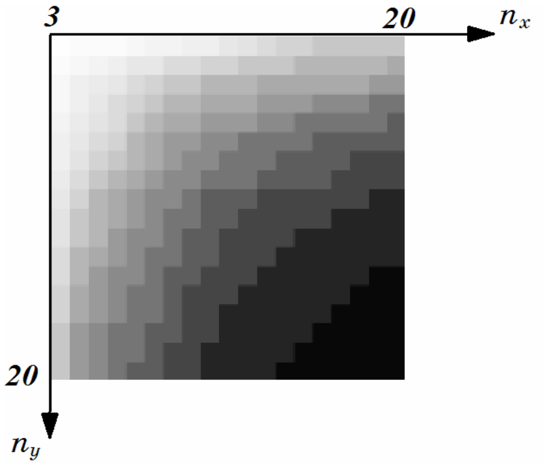


Figure 2 – Clustering error dependence from the neuron numbers in the Kohonen's map

The experiments were implemented with the next parameters: used two learning phase – rough and exact and Gaussian neighbourhood function. The optimal range of the neurons influence radius changing of the rough phase is defined as the integer part of the value $r_1 = \sqrt{(n_x^2 + n_y^2)}$ and for the exact phase by expression $r_2 \approx r_1/5$.

The clustering results visualization is performed in two ways: by the clusters centers pixels to belong and by the mean square deviation of the pixels in the range of each cluster. In the sequel the most corresponding to assigned task method was used.

The influence of decorrelation procedure was estimated by using singular decomposition method (SVD), which is widely used for the multidimensional information processing, specifically, for the solving tasks of the compression.

The analysis of the eigenvalues matrix in the our experiments shown that the removal of the constant component of the analyzing source images influenced on its values sufficiently and led to sensitivity enhancement of the clustering results. Without using the decorrelation procedure the removal of the constant component does not influence to the final result of the neuronet segmentation based on SOM

The set of the input vectors for the clustering procedure was formed by using the original images transformation methods developed by author.

To achieve this goal in the paper [5] the modulation transformation was proposed which describes by the next expression

$$R(x,y) = I(x,y)e^{j\pi\frac{I(x,y)}{\lambda}} = \mathrm{Re}\{R(x,y)\} + j\,\mathrm{Im}\{R(x,y\} = |R(x,y)|e^{j\Phi(x,y)}, \qquad (3)$$

where $I(x,y)$ is the source image and λ is the modulation parameter.

With the mathematical viewpoint this transformation is a transition from real intensities space to the complex values space with the ability to use the mathematical apparatus of the theory of the complex variable functions. The distinctive feature of $R(x,y)$ function is the correspondence of the its amplitude-space characteristic (magnitude $|R(x,y)|$) to the source image $I(x,y)$. But its phase-space characteristic (argument $\Phi(x,y)$ is the rotate angle of the vector in the complex plane) depends on ratio $I(x,y)/\lambda$. The changes of the parameter λ influence to the variability of the phase characteristic $\Phi(x,y)$ and let to receive the virtual images that have different sensitivity to the pixels intensity changes.

Another way is forming the new input vector based on next expression

$$\vec{A}(x,y) = \exp\left[j\pi I(x,y)/\lambda(x,y)\right] = \operatorname{Re}\left\{\vec{A}(x,y)\right\} + j\operatorname{Im}\left\{\vec{A}(x,y)\right\}, \tag{4}$$

where λ is the transformation constant and it depends on the current pixel coordinates.

The transformation algorithm consists in next steps.

1. In the vicinity of every pixel the sliding window with size $(L \times L)$ is formed. This window lets to take into account the influence of the closest neighbours (for the many applications value $L = 3$ is sufficient).

2. For every pixels of the analyzing image $I(x,y)$ in the sliding window the parameter of modulation is calculated by next formula

$$\lambda(x,y) = I_{L,\max} - I_{L,\min} + k, \tag{5}$$

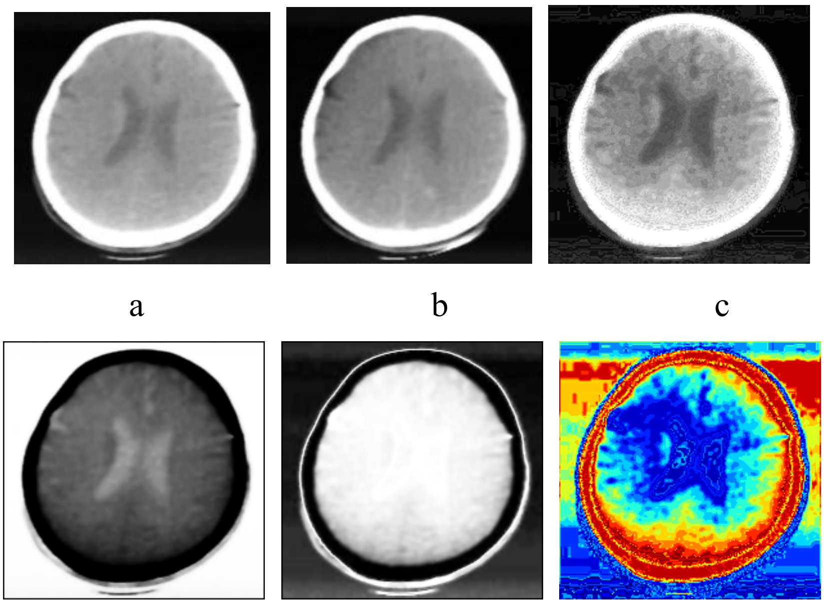
where k is stabilize coefficient which is determined empirically. The choice of its value depends on the range of the source dynamic intensities. The experiments shown that in the most cases for the window 3x3 value $k = 0.2 \div 0.4$ is the optimal.

The experimental results of the ability to enhance the segmentation sensitivity of the low-contrast images by using SOM subject to method of the forming of the multidimensional input vector based on modulation transformation were obtained for different grayscale and multidimensional images of the various physical natures.

The X-ray tomogram of the head is shown on the fig. 3 a. The analysis goal for this image is the detection of the domain of influence of the hematoma (selected by arrow). For the tomogram quality enhancement radiopaque substance is used traditionally. It is injected into the vein, but this procedure is expensive and detrimental for health and has low efficiency in our case (fig. 3 b). The segmentation results of this image by SOM based on amplitude-space and phase characteristics of the expression (3) are shown on the fig 3 c and f, accordingly. Neither real, nor imaginary parts of the modulation transformation (fig. 3 d, e, accordingly) don't solve the task of the detection of the hematoma domain of influence. But its using during SOM clustering (fig. 3 f) enhances the segmentation sensitivity sufficiently (specifically, film granularity is detected) and allows to solve assigned task.

The additional simple abilities of the SOM sensitivity enhancement are ensured the usage of the expression (4). In this case the usage of four characteristics: the magnitude and arguments of the sum and difference of the virtual vector fields is possible with father forming of the resulting image by using SOM.

The example of analysis of the image of the gravity field (fig. 4), which corresponds to the area of the Earth surface with salt mines (fig. 4 b), demonstrates that the usage of such approach enables to enhance the SOM sensitivity. As the result of the geophysical model building the isoline map was formed (fig. 4 c). The fig. 4 d shows the results of the SOM segmentation directly to source image.



a b c

d e f

Figure 3 – Tomogram processing results by SOM: a − source image; b – with radio-opaque material; c – the segmentation fig. 3 a; d, e – the real and imaginary parts of the modulation transformation, accordingly; e – the segmentation by the modulation transformation characteristics

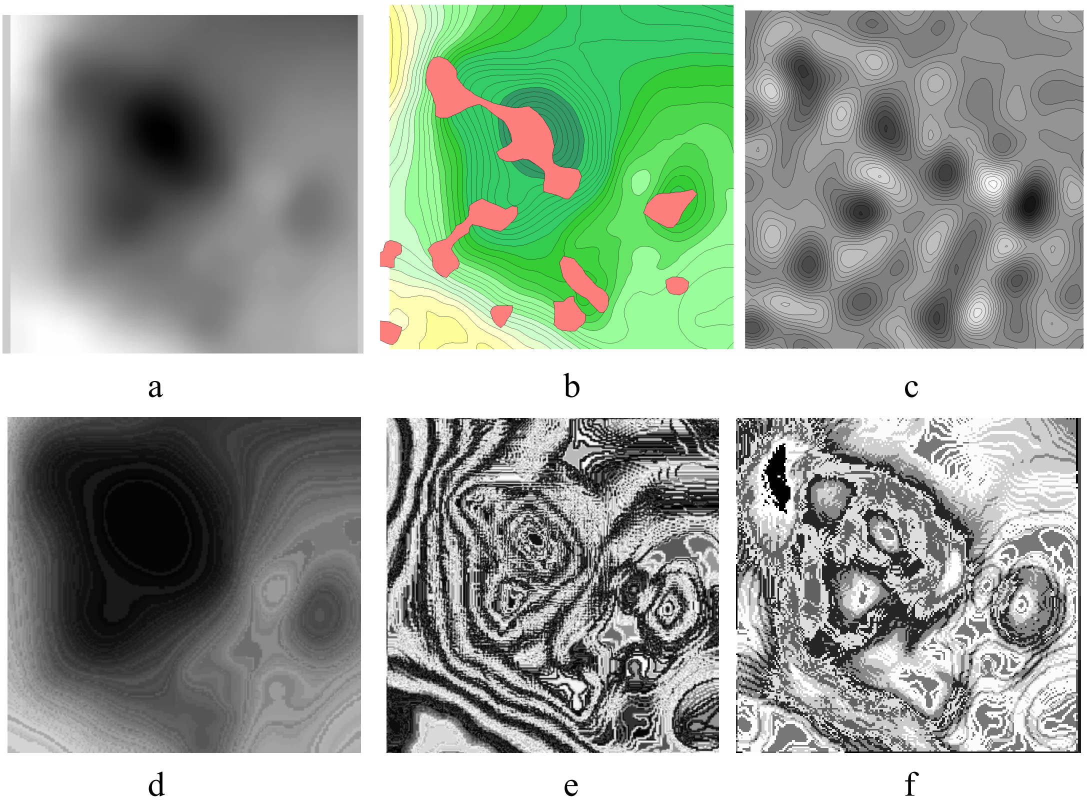


Figure 4 – SOM segmentation of the gravity field (a): b – the map of the salt mines; c – the geophysical model; d – by the source data; e – the properties of the transformation (4); f – by the phase characteristic of the expression (3)

The analysis shows that only perceptible on the source image (fig. 4 a) anomalous areas are revealed in this case. For this example good results were obtained by using SOM for processing of the synthesized characteristics of the adaptive interference method ($\lambda = 0.05$, fig. 4 d) and the phase characteristic of the holographic transformation ($\lambda = 0.17$), which is applied to the gradients that reveal almost all field anomalous corresponding to the real structure.

Conclusion. The SOM is the effective method of segmentation and forming the composite image based on multidimensional data. The method of forming of the informative characters space is defined by the physical nature, the intensity characteristics of the source image and the analysis task. The usage of the modulation transformations characteristics of the input vectors allows to enhance the sensitivity of the SOM segmentation significantly.

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