MULTI-LAYER SOM NEURAL NETWORK FOR IC-ITEMS DETECTION ON PHOTO-SNAPSHOT IMAGES OF POLY-SILICON LAYER

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Abstract. The structure of multi-layer SOM neural network for structural items detection on a gray scale image of an integrated circuit (IC) is considered. The IC-items shape distortions invariant neural network structure and training rule are represented. The comparative outcomes of recognition have shown an advantage of neural network approach.

Introduction

The papers [3, 4] were published by D.H. Hubel and T.N. Wiesel in 1962, 1965. In this papers the biological neural networks structure in the cat's and monkey's visual pathway in visual cortex been analyzed. The investigation has shown the changes of visual information taking place in the visual pathway of the animal brain.

The several facts are discussed in the papers:

1. The incoming light transformed into electrical activity of the retina neurons creates the representation of the initial image.
2. The image representation is subject of the visual pathway layer-to-layer reduction.
3. The neurons detecting the same image feature in each layer are grouped in the local area. The neuron feature detection implies the maximal activation of neuron if the image contains the feature. For example the group of neurons detecting line part feature is activated when an original image is hatched.
4. Larger image features are detected from layer-to-layer.
5. The receptive fields of the neighboring neurons have overlapping regions. These neurons are contained it the receptive field of the complex neuron. The complex neuron fires if its receptive field contains at least one active neuron. As the result of simple and complex neurons connection the activity of complex neuron is invariant to the small shifts of the detecting feature. The overlapping regions of receptive fields define the magnitude of the possible shifts.

D.H. Hubel & T.N. Wiesel visual pathway structure is represented in the fig. 1.

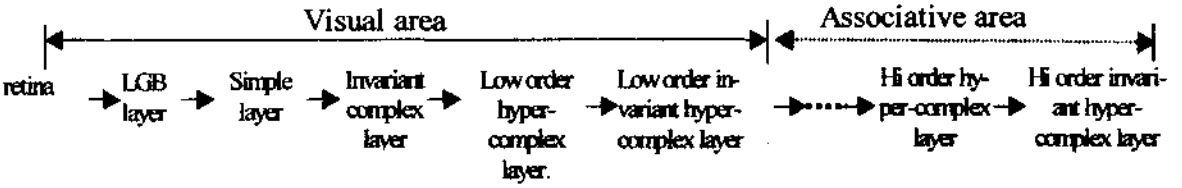


Fig. 1 The visual cortex structure of the layer-to-layer information transform.

Inspired by this investigation K. Fukushima has created the model of artificial neural network "necognitron" [1, 2]. K. Fukushima has proposed structure of neural network model "neocognitron" that was in a close correspondence with its biological analog. As a result the structure was nonoptimal for machine realization. So it leads to the low-level recognition performance and accuracy.

This paper represents a new approach to the neural network structure simulation based on the multi-layer SOM (self-organizing map) neural network model. The multi-layer SOM neural network model is more optimal than "neocognitron" model.

Image local feature detection

The structure of the neuron detecting the image local feature is the same as the structure of SOM network neuron [5-7].

The training rule for the neuron is defined as the dynamical mean:

$$w(t+1) = w(t) + \frac{1}{t+1} \cdot \left[b(t+1) - w(t)\right] \tag{1}$$

The activation rule is defined as the angular metric distance:

$$D = \arccos\left(\sum_i b_i \cdot w_i \Big/ \sqrt{\sum_i b_i^2 \cdot \sum_i w_i^2} \right), \tag{2}$$

where $B = \{b_i\}$ is the local part of the image, $W = \{w_i\}$ are the corresponding weight coefficients of the neuron.

These training and activation rules reduce the calculation complexity of the model in comparison with the original K Fukushima's model.

Detection of the shifted feature

The way of detecting the invariant shifted feature is represented in the fig. 2.

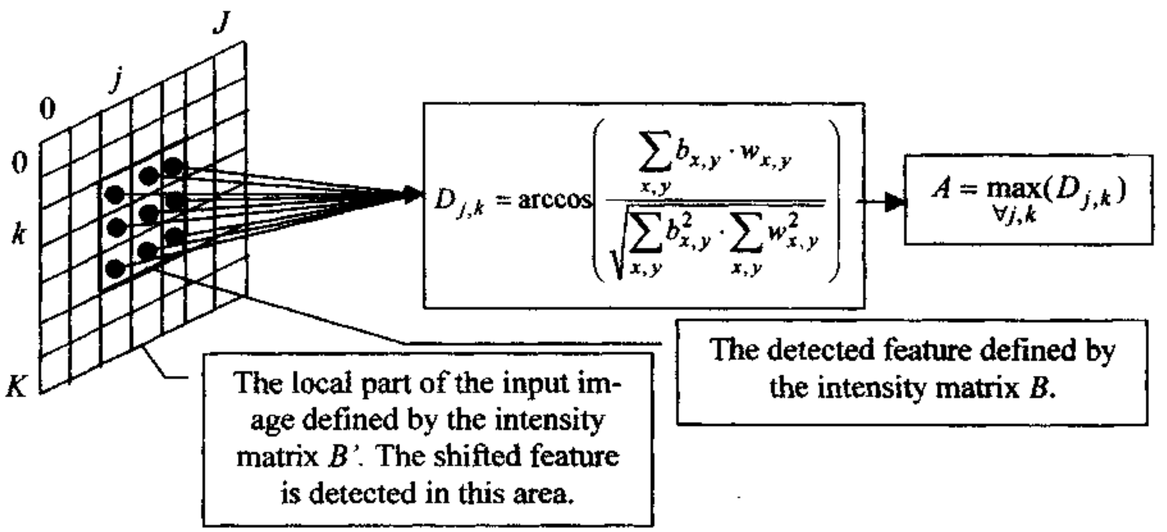


Fig. 2 – The structure of the shifted feature detection.

The values (X, Y) are the sizes of the sliding matrix B and the values j, k are its left upper coordinates lying in the ranges $[0, J\text{-}X]$, $[0, K\text{-}Y]$ accordingly. The result sizes of the matrix A are equal to $(J\text{-}X, K\text{-}Y)$. Hence picture 2 represents the neuron that is able to detect the sifted feature in the range $\left(\pm\frac{J-X}{2};\pm\frac{K-Y}{2}\right)$.

Grouping of neurons that detect the same image feature

The neurons detecting the same feature are combined into the same group. The position of the neuron in the group is defined by the position of the detected feature. Thus the map of the detected image feature is formed. This principle is illustrated in the figure:

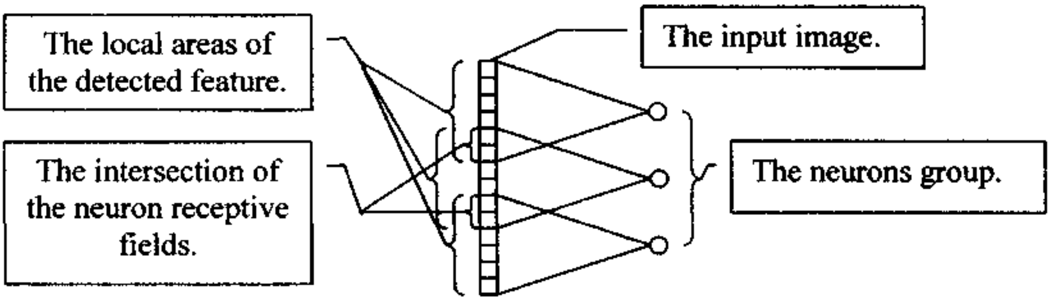


Fig. 3 – The combination of the neurons into one group.

The detected feature size is greater than the size of the neuron receptive fields intersection and less than the detection area of the local feature. The neurons are arranged in two dimensions array if the input data are two-dimensional. Thus the neuron group forms the map of the local detected feature distribution in the image.

Grouping of neurons that detect the same image feature

Let the neuron groups are combined into one layer if the neurons receptions fields are equal. That is the feature of the same size is detected in the layer. The layer-to-layer information processing is organized so that each next layer detects the feature of the bigger size. Thus the last layer detects the feature of the same size as the size of the classified pattern. This assumption allows realizing the algorithm of automatic or semiautomatic creation of the neuron groups. This algorithm is based on the following statements:

1. As the neurons of one group have the same set of weights coefficients the whole group can be represented as one neuron and network layer can be represented as SOM neural network.
2. The sizes of the pattern used to train this SOM network are equal to the sizes of the feature detected in the layer. If the automatic training mode is applied (without teacher) then the patterns are generated from the original image using the sliding window with 1 pixel step. If the semiautomatic mode is applied then the training set also contains the patterns added by the operator. These patterns are named in accordance with the classes they belonging to.
3. The initial number of the neurons for the SOM network is equal to zero. The training algorithm for the layer from the multi-layer SOM network is defined using the training algorithm for the extensible SOM neural network [7].
4. After training the SOM neural network is used as the prototype for creating the needed network layer. The number of the SOM network neurons is equal to the number of the neuron groups. The weights coefficients of the SOM network neuron are in accordance with the weights coefficients of the group.

Multi-layer SOM neural network structure

The neural network structure is outlined in the fig. 4. The receptor layer is responsible for the transform of the input image pixels intensity to the neurons activity. The internal layers realize layer-to-layer information reduction. Output layer gets a result of the input pattern classification. Each neuron group of the output layer is generated from the single neuron. Thus the maximal activity of the neuron from the output layer defines the class of the input pattern.

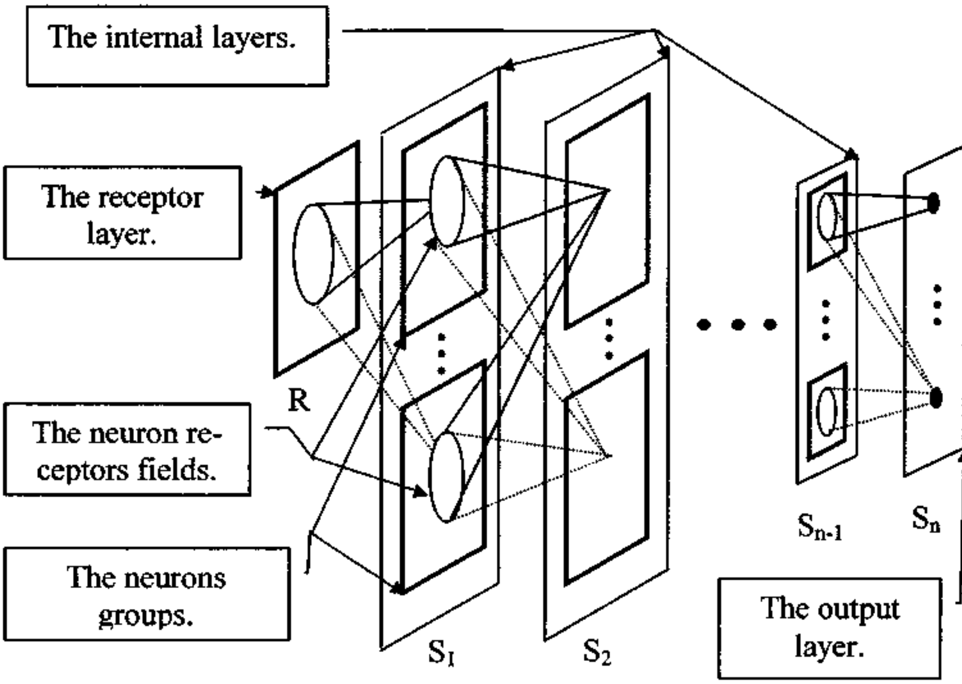


Fig 4. The neural network structure.

Testing of multi-layer SOM neural network

The task of the IC-items identification was used as the tests for the multi-layer SOM neural network. Examples of the integrated circuits photo-snapshots are in the figure.

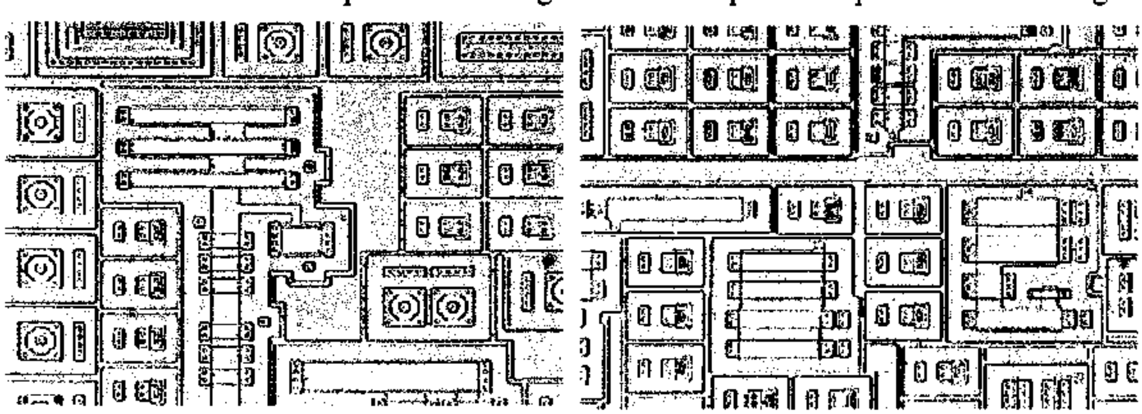
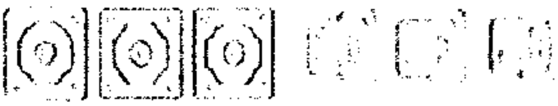


Fig. 5 – Halftone snapshots of the poliselicon integrated circuits layers.

The objects to be recognized are in the fig 6.



Type 1 Type 2

Fig. 6 – The objects to be recognized

The neural network classifiers were compared with the classifier based on angular metric measure. The scanning method of the initial image was applied using sliding window with 1 pixel step.

The angular distance between the images is calculated in the following way:

$$\mu = \frac{\sum_{x,y} a_{x,y} \cdot b_{x,y}}{\sqrt{\sum_{x,y} a_{x,y}^2 \cdot \sum_{x,y} b_{x,y}^2}}, \quad (3)$$

where x, y are the pixels coordinates to be compared and a, b are the pixels color values for the averaged template image and image in the sliding window accordingly.

The testing results are shown in the table 1. The tests show that the neural network approach gives the better recognition results. This advantage takes place because of the neural network invariance to the pattern form distortions.

Object Type	Accuracy		
	Angular metric	One layer SOM network	Multi-layer SOM network
1	81,4	92,3	98,5
2	84,2	96,2	99,0

Table 1. IC images object identification

References

[1] K. Fukushima, S. Miyake, T. Ito, "Neocognitron: A neural network model for a mechanism of visual pattern recognition", *IEEE Trans. Syst., Man, Cybern.*, SMC-13 (1983), 826-834.

[2] K. Fukushima, N. Wake, "Handwritten alphanumeric character recognition by the Neocognitron", *IEEE Trans. on Neural Networks*, **2**, 3, (1991), 355-365.

[3] D.H. Hubel and T.N. Wiesel, "Receptive fields, binocular interaction and functional architecture in cat's visual cortex", *J.Physiol (London)*, v.160, (1962), 106-154.

[4] D.H. Hubel and T.N. Wiesel, "Receptive fields and functional architecture in two nonstriate visual area (18 and 19) of the cat", *J. Neurophysiol*, v.28, (1965), 229-289.

[5] Teuvo Kohonen, "Self-Organizing Maps", *Springer-Verlag*, 1995.

[6] J. Moody, and C.J. Darken, "Fast learning in networks of locally-tuned processing unit", *Neural computation*, **1**, 2, (1989), 281-294.

[7] M. E. Vatkin, "Hand-written symbols recognition based on modified SOM neural network model", *Proceedings of the I International conference "Informational systems and technologies"*, (Minsk), Part 2, (2002), 201-206.