Neural Network Training Method In Hyperbolic Wavelet Transformation Space for Recognition of Photomasks

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***Abstract* – During deployment of existing hardware-software complexes for controlling of photomasks quality in the conditions of small production lots of microelectronics leads to unjustified quality cost increase. In case of lowering of requirements to the software of such complexes, noise on the photomasks images inevitably appear, which leads to the decrease of credibillity of recognition of reference signs, which are located on the images, and to the decrease of credibillity of control results. Therefore, with the purpose of increase of credibillity of recognition it is proposed to execute recognition of reference sings on the bases of nose-eliminating of neural network training in the space of hyperbolic wavelet transformation.**

Key words – neural network, hyperbolic wavelet transformation space, reference sign, photomask, recognition.

I. Introduction

Pending the process of microelectronic production, one of the most important technological operations is execution of control of photomasks quality – data carriers about size and configuration of product. The essence of this procedure is the detection of adequacy of photomasks for further usage in microelectronic production, and in case of their fail – detection of their defects. This problem is solved with the help of hardware-software complexes, which include sub-systems of formation, registration and recognition of images [1]. One of the methods of controlling of photomasks quality is positioning of image of production mask relative to the master sample. Positioning is fulfilled by means of reference signs, which are marked on the surface of a photomask. At the same time complex mechanics and expensive illumination-focusing equipment are used, which provide high production and credibillity of photomasks controlling results. Usage of such complexes is grounded in the large-scale production. But during last years necessity in production of small and average lots, intended for usage in the hardware of special purpose and in scientific experiments, appears more often.

II. Description Problem

Usage of existing hardware-software complexes for short- production leads to the unjustified cost increase of photomasks control. Such contradiction can be settled by means of lowering of requirements to technical parameters of used equipment in such complexes, which in it turn leads to the appearance of undesirable multiplicative and adaptive nose on the images of photomasks and is negatively reflected on the credibillity of recognition of reference signs. Thereby, with the purpose of increase of credibility of reference signs recognition, it is proposed to execute this procedure on the basis of noise-eliminating method of neural network training. As a model of neural network was chosen of multilayer perceptron. For training of multilayer perceptron back error-propagation algorithm based on the gradient assessment, is used [2]. Taking into consideration that gradient methods have some disadvantages (starting point sensitivity, complication of gradient assessment in the noise environment), it is to proposed to carry out training of multilayer perceptron in the space of hyperbolic wavelet-transform [3,4].

III. Solving Problem

Method of neural network training in hyperbolic wavelet transformation space consists of the following steps:

1. Forward pass. The following are brought to the input of multilayer perceptron: identification attribute vector of fiducial marks $\mathbf{x} = (x_1, x_2, ..., x_n)$, where n – number of attributes; output classification vector of reference signs $\mathbf{y} = (y_1, y_2, ..., y_\mu)$, where μ – quantity of classes of reference signs. Direct signal propagation is determined.

2. Backward pass. For weighting coefficients $\mathbf{w}_{ji}$ and displacements $\mathbf{w}_0$ of knots of output layer:

– length of carrier of hyperbolic wavelet-function and iteration step ϕ are determined empirically;

– depending on the length of carrier of wavelet function (WF) in both directions from initial approximation $\mathbf{w}_{ji0}$ test alteration of one of the coefficients $\mathbf{w}_{ji}$ is carried out according to:

$$\mathbf{w}_{ji} = \mathbf{w}_{ji0} \pm s\Delta\mathbf{w}, \tag{1}$$

where $s = 1, \dots,$ length WF; $\Delta\mathbf{w}$ – alteration of weighting coefficient ($\Delta\mathbf{w} = 0{,}2 \cdot s$ is proposed);

– the value on neuron yield is calculated during each fixed test alteration of one of the coefficients $\mathbf{w}_{ji}$ (before each test alteration, the neuron net comes back to the initial position);

– error function $EF(\mathbf{w}, i)$, received during test alteration of weighting coefficients $\mathbf{w}_{ji}$ and displacements $\mathbf{w}_0$ is calculated;

– error function $EF(\mathbf{w}, i)$ with hyperbolic wavelet function $G_1(i)$ are weighting up:

$$HWT(\mathbf{w}) = \frac{1}{s}\sum_{i=1}^{s} EF(\mathbf{w}, i) \cdot G_1(i) \tag{2}$$

– with consideration of received subgradient assessment $HWT(\mathbf{w})$ weights $\mathbf{w}_{ji}$ and displacements $\mathbf{w}_0$ are corrected as consistent with:

$$\mathbf{w}_{ji}[k+1] = \mathbf{w}_{ji}[k] + \phi[k] HWT(\mathbf{w}_{ji}[k]), \tag{3}$$
$$k = 0,1,2......K,$$

Where $\mathbf{w}_{ji}$ – connection weight, passing from i to j element; k – iteration number; K – is determined by the conditions of algorithm of minimum search of quality functional.

In case of updating of weighting coefficients and displacement of buried layer for formation of error function $EF(\mathbf{w}, i)$ direct signal propagation through the whole net carried out.

Recognition of reference signs in operation mode is carried out on the basis of this noise-eliminating method of neural network training.

Information technology which executes this developed method, uses the following algorithm:

1. To create neural network where number of inputs corresponds to the number of attributes, and number of outputs – to the number of reference signs classes.
2. To determine initial data for net training: training (iteration) stride parameters, training accuracy, number of iterations, number of neurons in buried layer (selected experimentally), parameters of hyperbolic function (length of carrier, sampling frequency and scale factor Fig. 1.
3. To execute network training on basis of method selecting and result is saving into the database with parameters.
4. On recognition stage on network entry is coming identifier of bundle which received in noise conditions.

On output of network is receiving of vector with component: zeros and ones, accordingly of index class of reference signs.

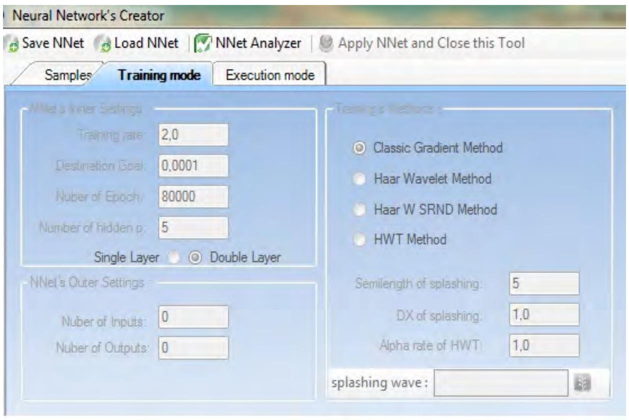

Fig. 1. Interface of program for preparing to training of network

As example was recognition of five reference signs on basis of offered algorithm. Learning sample was included of some variation of signs for each photomask of reference signs at different noise level, from image of etalon template to image in range of quotient signal/noise 7 (in power) Fig 2.

Received vector on output:

$$y_1 = 1{,}675011\text{E}-06;\quad y_2 = 0{,}0001642315;$$

$$y_3 = 0{,}009735282;\ y_4 = 0{,}03100435;\ y_5 = 0{,}9800086\ .$$

This result is satisfactory, because inaccuracy at comparison with target vector not exceeding than 0,05.

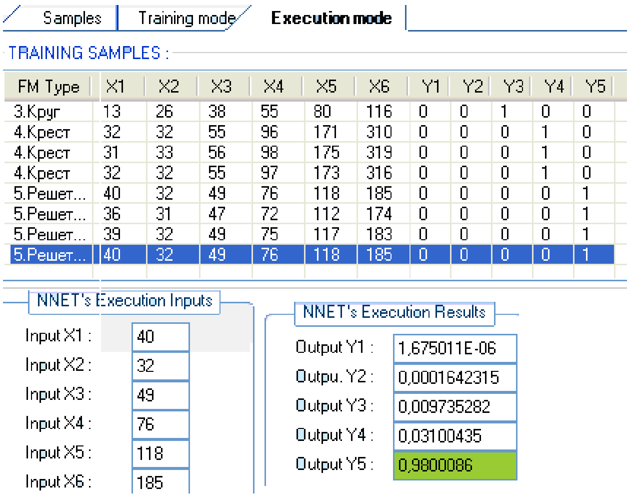

Fig. 2. Control recognition of fiducial marks "grid"

During estimating of recognition quality discount errors of first and second sort is offered [5]. Received: probability correct recognition - signal/noise diagram for additive noise and probability correct recognition - signal/noise diagram for multiplicative noise.

Conclusion

Experiments confirmed, that after recognition of reference signs on photomasks on basis of noise-immune method of network training credibility of recognition in noise conditions in range of quotient signal/noise 10..20 (in power) up to 1,3 times in comparison with gradients methods and amount 0,92.

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