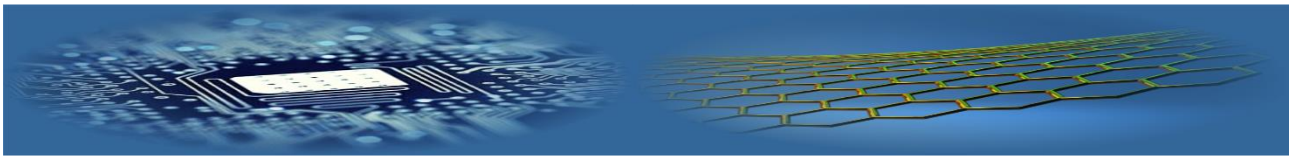

Improvement of learning efficiency of the neural networks, intended for recognition of graphic images in systems of biometric authentication

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Abstract

Article is devoted to a problem of use of neural network technologies in the field of biometric authentication of users. It is shown that one of important the shortcomings of application of neural networks technology on the basis of a multi-layer perceptron for recognition graphic images in systems of biometric authentication of users is insufficient quality of processing of statistical data which are used when forming parameters of educational examples. It is offered to increase quality of educational examples due to use of the procedure of neural network coding of value of the expected output signal of educational examples which allows consider closeness of standards of the recognized classes in this signal. The coding procedure of the expected output signal providing use of a probable neural network is developed. The appropriate mathematical devices are created. As a result of numerical experiments it is shown that application of the developed procedure allows reduce the number of the computing iterations necessary for achievement of the given error of training by 30-50%. It specifies prospects of use of the proposed solutions for improvement of learning efficiency of the neural networks, intended for recognition of graphic images in systems of biometric authentication.

Keywords:

neural network,
information security,
learning,
biometric authentication

1 Introduction

The proved ability of neural network models (NNM) to effectively recover unknown multivariate table valued functions provided their broad application during creation of systems of recognition in different fields of science and technology [1, 2]. Application of NNM is especially urgent when the task of recognition is poorly formalized, and the result of its decision is highly responsible. A characteristic example of such tasks is application of NNM for recognition of graphic images in systems of biometric authentication of users of information systems. Though the practical experience of use of the known neural network systems and the analysis of sources [1, 2] also specifies rather powerful scientific and practical practices in this direction, but the same analysis specifies also insufficient learning efficiency of NNM on the basis of a multi-layer perceptron which are a basis of the specified systems. Because of this shortcoming time of creation of neural network system improvement and the accuracy of recognition of unknown input images decreases. Let's mark that NNM like a multi-layer perceptron is adjusted for training by the method "with the teacher" are considered. Today in technical systems generally such models are read the most approved. The main advantage of the multi-layer perceptron is high computational capability and as the shortcomings refers complexity and duration of training. Key parameters which define learning efficiency of NNM is the time and an error of training [2]. Values of these parameters directly depend on quality of educational examples which in case of the given statistical selection shall be provided due to different processing procedures of statistical data.

2 Analysis of the known approaches to processing of statistical data

On the basis of data [1, 2] is defined that the majority of the known approaches to processing of statistics assume performing procedures which realize centering, normalization, scaling and/or scaling of input and output parameters of educational examples. For output parameters the main objective of the specified procedures is coercion of definition boundaries of variables of a real object to a certain interval. When using sigmoidal function of neurons activation of an output layer this interval is restricted to zero and unit, and when using a hyperbolic tangent limits of an interval from -1 to +1.

Thus, the listed procedures only adapt output parameters of educational examples to the look suitable for application in neural network models, but aren't intended for impact on time and an error of training. At the same time results [3] are specified to reduce time and an error of training it is possible due to reflection in the expected output signal of educational examples of closeness of standards of the recognized classes. In the same operation [3] it is shown that it is possible to realize such display by means of the procedure of expert assessment of closeness of the specified standards. However use of the offered procedure is related to need of attraction of highly enough qualified experts for specific application area use of neural network system. In many cases it is impossible. Also it is possible to apply algorithmic criterion for evaluation of closeness of standards for implementation of display. However development of qualitative criterion requires considerable efforts and its existence levels needs use of NMM. At the same time the task of assessment of closeness of a limited set of standards of classes can be considered in a perspective use of low-resource neural networks for prospecting data analysis [2, 5] that allows assuming prospects of neural network coding of the expected output signal of educational examples of a multi-layer perceptron.

3 Formulation of the problem

The purpose of the real research is development of the procedure of application of low-resource neural networks for coding an output signal of educational examples of a multi-layer perceptron which at the expense of the accounting of closeness of standards of the recognized classes allows increase efficiency of its training.

3.1 DEVELOPMENT OF CODING PROCEDURE OF THE EXPECTED OUTPUT SIGNAL

We detail the task of reflection in an output signal of educational examples of closeness of standards on a specific example of neural network recognition of uppercase printing letters of the Ukrainian alphabet which are displayed in black color on a white background. The classical coding procedure of parameters of standards of letters illustrated with Figure1 consists in sequential implementation of five stages.

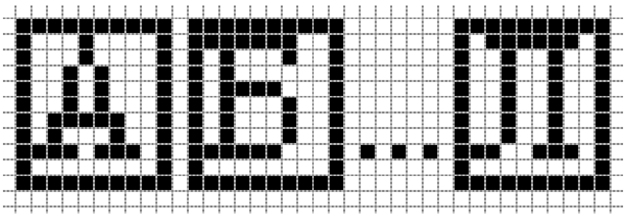

FIGURE 1 Illustration of coding procedure

1 stage. Every letter accommodates in a separate rectangle of the fixed size which is partitioned into cells by a grid chart. The quantity of these cells determines the number of input parameters of neural network model. In Figure 1this quantity is equal:

$$K = a \times b = 11 \times 10 = 110, \tag{1}$$

where a and b – height and width of a rectangle which describes a letter. Within a separate rectangle each cell assigned certain number which corresponds to number of the entering parameter of neural network model.

2 stage. For a separate letter i value of input parameter is equal 1 if appropriate i a cell is filled in black color, and is equal 0 in case it is filled in white color.

3 stage. Letters register and numbered in alphabetical order. For example, as it is shown in figure 1, to a letter A there corresponds n = 1, to a letter B there corresponds n = 2, and a letter L - n = 13.

4 stage. Number of a letter in the alphabet defines the raw value of the expected output signal of neural network model. Thus, for a letter A the raw value of the expected output signal is equal 1, for a letter B - 2, and for a letter L - 13.

5 stage. For each letter the raw value will be transformed to the look suitable for use in neural network model. Let's consider basic model with sigmoidal function of activation. Depending on structure of neural network model two options of conversion are possible.

Option 1. The output signal of neural network model is defined by one output neuron. In this case for an educational example of a standard of n-y of a letter the expected output signal decides on the help of the following expression:

$$y(n) = \overline{y}(n) / N = n / N, \tag{2}$$

where $\overline{y}(n)$ – the raw value of an output signal of a standard n-oh letters, n – number of a letter in the alphabet, N – quantity of letters in the alphabet.

Option 2. The output signal of neural network model is defined by a set of output neurons which amount is equal to quantity of letters in the alphabet. At the same time number of output neuron is equal to number of the appropriate letter in the alphabet. Therefore for an educational example of a standard n-oh of a letter the expected output signal is defined so:

$$\begin{cases} y_n(n) = \overline{y}(n) / n = 1 \\ y_k(n) = \overline{y}(n) - n = 0,\ k = 1,..N, k \neq n \end{cases}, \tag{3}$$

where k - number of output neuron.

Expression (3) can be interpreted as follows, n-oh of a letter for n-go of output neuron the expected output is equal in an educational example of a standard 1, and for all remaining neurons the expected output is equal to 0. Let's mark that concerning the first option of conversion the second option more general. Therefore only the second option will be considered further.

The basic lack of the described coding procedure is that the value of the raw expected output signal defined at the fourth stage badly corresponds to geometrical closeness of the recognized images. It is obvious that the image of a letter A is much more similar to the image of a letter L, than to the image of a letter B. At the same time the classical option of coding contradicts this fact. Afterwards in case of implementation of the 5th stage this error doesn't allow to consider geometrical similarity of images correctly.

For elimination of this shortcoming it is offered to use low-resource NMM which training doesn't require determination of the expected output signal in a numerical look for assessment of closeness of standards. First of all, this type of network includes the NMM which is capable self-learning. Classical representatives of this type are networks on the basis of Kokhonen's card and Boltzmann's machine. However a hindrance to their application is the low generalizing ability which involves an erratic possibility of reference of different standards to one cluster. More perspective is application of the PNN network in which educational examples the expected output signal represents not number, but the name of a class [2]:

$$\{x\}_K \to Name_Y \,, \tag{4}$$

where $\{x\}_K$ – a set of input parameters, $Name_Y$ – the name of a class to which this educational example belongs.

For an example in Figure 2 the structure of the PNN network which is intended for correlation of unknown black-and-white graphic images to one of three classes - A, B or C is shown. It is supposed that each of graphic images is placed in a separate rectangle by the size of $a \times b$ pixels. Thus, the amount of input neurons (input parameters) correspond to number of signs of a class and decide on the expression help (1).

The network consists of four layers of neurons: input - Ln_{in}, images – Ln_0, adding – Ln_s and a day off – Ln_{coll}. The quantity of elements of a layer of images is equal to quantity of educational images. The input layer and a layer of images make full-meshed structure. The quantity of elements of a layer of summing is equal to quantity of classes. The element of a layer of images is connected only to that element of a layer of summing to which corresponds the class of an image.

Generally both the quantity of classes and quantity of educational examples can be arbitrary number. For the example shown in Figure 2, the amount of neurons of a layer of adding is equal to 3. To each neuron of a layer of adding there correspond two neurons of a layer of images, that is to each class there correspond two standards - educational an example.

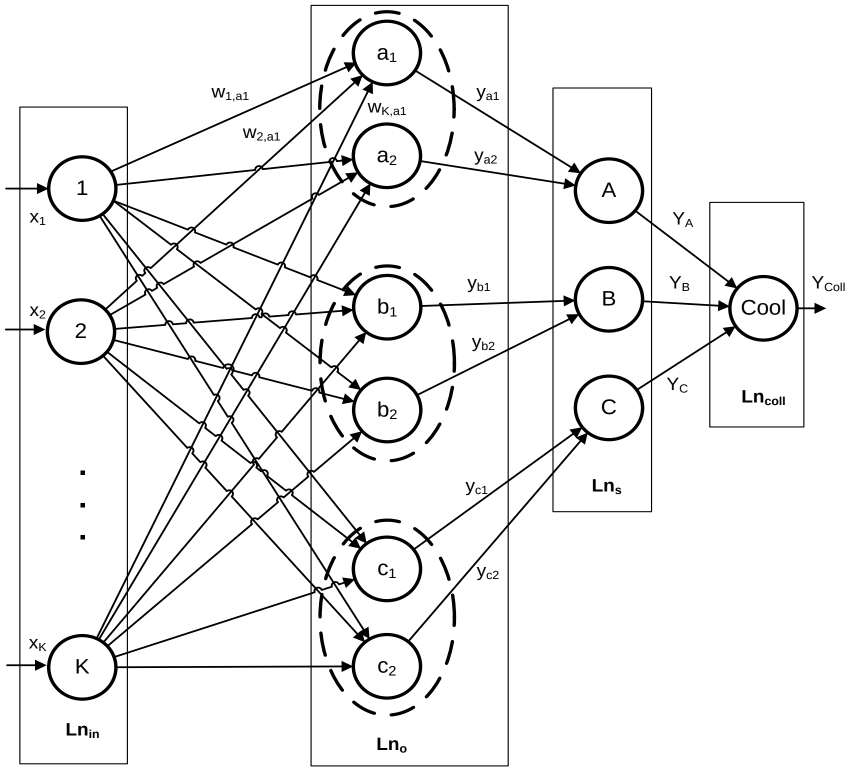

FIGURE 2 Example of structure of the PNN network

For the communications entering neuron of a layer of images, weight factors are set same as components of the appropriate educational vector of an image. So, if for an educational example a1 a set of parameters $\{1, 0, \ldots\}_K \to As$, that $w_{1,a1} = 1$, and $w_{2,a1} = 0$. Entering of this example into a network is realized soconnection between neuron a_1 and neuron A an adding layer is established:

1. the new neuron a1 is added to a image layer;
2. weight factors of the entering communications are set;
3. connection between neuron a1 and neuron A an adding layer is established.

Let's mark that weight factors of the communications entering neurons of a layer of summing and an output element are equal to 1. Thus, all PNN parameters directly are defined by educational data, and training of such NNM happens rather quickly. The important positive point of training activity of the PNN network is presence only of one controlling parameter of training which value is selected by the user. Actually this parameter is the radius of function of Gauss which value not considerably influences quality of recognition. The output signal of an arbitrary j is neuron of a layer of images is calculated like:

$$y_j = \sum_{k=1}^{K} \exp\left(\frac{-(w_{k,j} - x_k)^2}{\sigma^2}\right), \tag{5}$$

where x - unknown image, x_k – k of a component of an unknown image, $w_{k,j}$ – weight factor of communication between k input neuron and j neuron of a layer of images, K – quantity of components of an input image, σ – radius of function of Gauss.

In neurons of a layer of summing the linear function of activation is used. The output signal of n-go of neuron of a layer of summing (Y_n) is calculated so:

$$Y_n = \frac{\sum_{i=1}^{I} y_i}{I}, \tag{6}$$

where I – amount of neurons of a layer of the images connected to n neuron of a layer of summing, y_i – activity i neuron of the layer of images connected to n summing layer neuron.

Value of activity of neuron of a layer of summing is equal to probability of reference of an input image to a class which corresponds to this neuron.

The task of an output element is only determination of neuron of a layer of summing with the maximum activity. Therefore in practice the output element can be realized without use of neural network technologies. Let's mark that though only the name of the most probable class is result of recognition of the PNN network, but values of output signals of a layer of summing are specified probability of belonging of an unknown input example to one of the recognized classes.

The offered procedure of use of the PNN network for coding of the expected output signal is as follows:

1. by means of expression (4) the set of educational examples which correspond to a set of standards of the recognized classes is created;
2. learning of a network is implemented;
3. on an input of the trained network standards of the recognized classes sequentially move. For each standard the help of expressions (5, 6) values of output signals of neurons of a layer of summing are calculated. If necessary these values should be scaled. For this purpose it is possible to apply results [2, 4]. The scaled values will also be the expected output signal of a multi-layer perceptron for educational examples of the appropriate class.

Let's consider application of the developed coding procedure on a specific example of recognition of 5 abstract black-and-white figures shown in Figure 3.

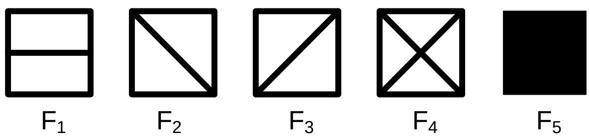

FIGURE 3 Recognized figures

Each figure is written in a square 3x3 i.e. the number of input parameters of NNM is equal to 9. Each figure is accepted in the form of a standard of the recognized class. The set of input and output parameters of educational examples of the specified standards created based on expression (4) is provided in table1. Let's mark that 3 boundaries of squares shown in figure in educational examples aren't considered.

TABLE 1 Parameters of educational examples

Input parameter	Name of reference				
	F_1	F_2	F_3	F_4	F_5
x_1	0	0	1	1	1
x_2	0	0	0	0	1
x_3	0	1	0	1	1
x_4	1	0	0	0	1
x_5	1	1	1	1	1
x_6	1	0	0	0	1
x_7	0	1	0	1	1
x_8	0	0	0	0	1
x_9	0	0	9	1	1

The structure of the built PNN network is shown in Figure 4. Accept $\sigma = 0,5$.

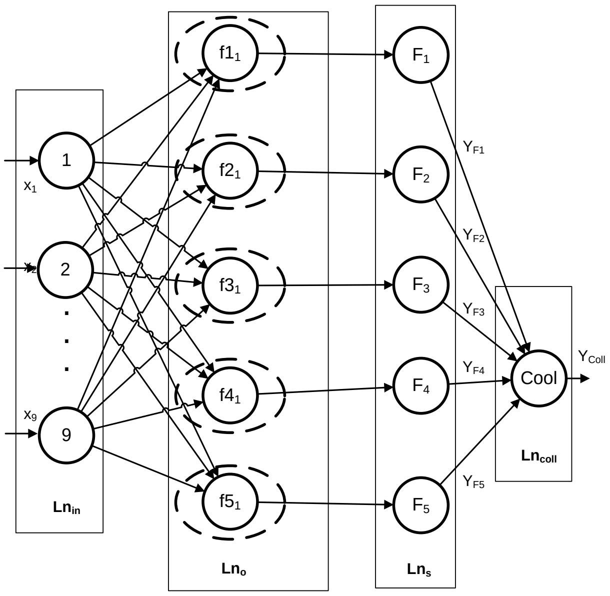

FIGURE 4 Structure of the PNN network for recognition of the abstract figures

Application of the built network allowed is to carry out coding of an output signal for each of standards. So, for example, for F1 figure standard not scaled expected output signal $Y_{F1} = \{9; 5{,}073263; 5{,}054947; 3{,}109894; 3{,}109894\}$. After scaling the expected values of an output signal are used when forming educational examples for a two-layer perceptron. The made comparative experiments showed that use of such educational examples allows reduce by 30-50% the number of computing iterations concerning examples in which the well-known coding is used. Thus, in a basic case, proved can read prospects of application of the developed coding procedure.

4 Conclusion

It is shown that one of important shortcomings of application of neural networks technology on the basis of a multi-layer perceptron for recognition of graphic images in systems of biometric authentication of users is insufficient quality of processing of statistical data which are used when forming parameters of educational examples.

It is offered to increase quality of educational examples due to use of the procedure of neural network coding of value of the expected output signal of educational examples which allows to consider closeness of standards of the recognized classes in this signal.

The coding procedure of the expected output signal providing use of a probable neural network is developed. The appropriate mathematical apparatus is created.

As a result of numerical experiments it is shown that application of the developed procedure allows reducing the number of the computing iterations necessary for achievement of the given error of training by 30-50%. It specifies prospects of use of the proposed solutions for increase in learning efficiency of the neural networks intended for recognition of graphic images in systems of biometric authentication.

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