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ENCODING OF NEURAL NETWORK MODEL EXIT SIGNAL, THAT IS DEVOTED FOR DISTINCTION OF GRAPHICAL IMAGES IN BIOMETRIC AUTHENTICATE SYSTEMS

Abstract. Article is devoted to a problem of enhancement of technologies of application of neural network models for recognition of graphic images in the biometric authentication systems. It is shown that a significant shortcoming of modern technologies is the insufficient efficiency of training neural network models, which is associated with the insufficient quality of statistical data processing. One of the important reasons of it is absence of correlation between the expected output signal of educational examples and closeness of standards of the recognized classes. 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. Feasibility of application of a probable neural network is defined proceeding from low resource intensity of its training. Besides, in its educational examples the expected output signal can be provided not by number, but the name of the expected class. The appropriate mathematical apparatus is created. As a result of numerical experiments it is shown that application of the developed procedure allows to reduce by 30-50% the number of the computing iterations necessary for achievement of the given error of training of a multi-layer perceptron which is basic neural network model for recognition of graphic images in the systems of biometric authentication. It specifies prospects of use of the proposed solutions for increase in efficiency of the neural network technologies applied in the systems of biometric authentication.
Keywords: neural network model, training, educational example, biometric authentication.

Introduction. The proved ability of neural network models (NNM) to effectively approximate multivariate table valued functions provided their broad application for recognition of graphic images in the systems of biometric authentication (SBA) [1-3]. Though the practical experience of use of the known neural network systems and the analysis of sources [4-20] specifies rather powerful scientific and practical practices in this direction, but the same analysis specifies also insufficient learning efficiency of NNM which are a basis of the specified systems. We will mark that in the modern SBA the greatest distribution was gained by NNM like a two-layer perceptron, a convolution and deep neural network. In fact these NNM are modifications of a classical multi-layer perceptron. Key parameters which define learning efficiency of such models is time and an error of training [7-10, 21]. 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 [15, 17].

Results [4, 6, 7, 16, 19] demonstrate that the majority of approaches to processing of statistics assume performing procedures which only adapt parameters of educational examples to the look suitable for application in NNM. At the same time [8] specify data that 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 work [8] 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 connected to need of involvement of highly qualified experts for specific application area that in many cases is impossible. Also it is possible to apply algorithmic criterion for evaluation of closeness of standards to implementation of display. However development of qualitative criterion requires the considerable efforts. At the same time the task of assessment of closeness of a limited set of standards can be considered in a perspective of use of low-resource neural networks for prospecting data analysis [5, 12]. It is necessary to mark that for coding of an output signal of educational examples of a multi-layer perceptron isn't found in the analyzed literature of researches of the low-resource neural networks directed to creation of the procedure of application. Besides it is possible to formulate an output that the majority of the modern scientific and practical operations are devoted or to questions of adaptation of neural network architecture to conditions of an objective of recognition or questions of formation of learning selection. So in robots [5, 10] the method of determination of optimum type of architecture of NNM is developed. This work [11] is devoted to the task of enhancement of structure and an algorithm of training of the multi-layer perceptron intended for use in systems of information security. The purpose of the work [7] is development of models and algorithms for creation neuro indistinct genetic systems of recognition of graphic images and its application for automation of operation of mail service. Within implementation of a goal the modified model of the indistinct neural network intended for image identification is developed and also it is developed modified genetic an algorithm of training of such network. It is shown that application of the proposed solutions allows to reduce time of training of a neural network. In work [4] is claimed that, the correct formation of learning selection often has crucial importance in tasks of machine training. It is also shown that in the modern literature on machine training in questions of formation of learning selection attention is almost not paid, the theoretical basis is practically absent. Further in article different methods of formation of a learning set are considered, their advantages and shortcomings are analyzed. The list of possible errors when forming a learning set is provided, methods of adding of data in a learning set are considered. On the example of training of decision trees importance of the correct formation of a learning set is shown. At the same time the question of coding of the expected output signal remains open. The work [13] is devoted to survey comparing of efficiency of image understanding by convolution deep neural networks, which parameters of educational examples were set by experts, or were calculated with the help of the formalized procedures. The hypothesis that when using multi-layer/deep neural networks, it is necessary to get rid of a row of the ideas inherited from the past about manual separation of signs is made. It is specified that beforehand it is necessary to initialize detectors of the first convolution layer algorithmically, in a special way analyzing all turned-out patches patterns of the small-sized size "cut" from all reference images. After that the found values of weight factors should be specified in together with training of the subsequent layers of a network. Article [6] is devoted to development of a method of formation of representative learning selection of images for training of a subsystem of automated recognition of objects of air reconnaissance. The method assumes use of a convolution neural network. It is claimed that application of the developed method allows providing a representativeness of learning selection at the expense of the accounting of the parameters influencing results of recognition of objects on aerial photographs. In this case the representativeness is understood as compliance of characteristics of learning selection to characteristics of population of statistical data in general. In the done researches the accent is delivered only on determination of the informative input parameters of educational examples.

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.

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 Russian alphabet which are displayed in black color on a white background. The classical coding procedure of parameters of standards of letters illustrated with Figure 1 consists in sequential implementation of five stages.

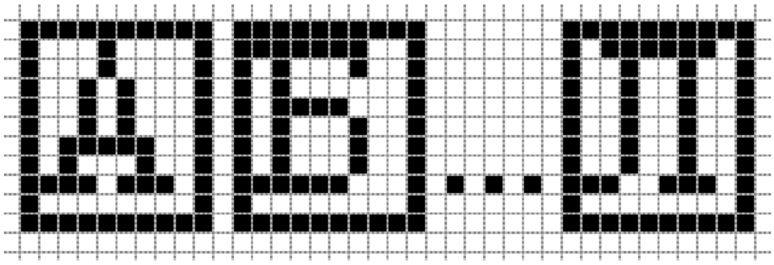

Figure 1 – Illustration of coding procedure

1. 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 1 this quantity is equal:

$$K = a \times b = 11 \times 10 = 110\,, \qquad (1)$$

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

3. Letters registered and numbered in alphabetical order.

4. 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 Б - 2, and for a letter Л - 13.

5. For each letter the raw value will be transformed to the look suitable for use in neural network model. Depending on structure of neural network model are possible two options of conversion.

Option 1. The output signal of neural network model is defined by one output neuron. In this case for a standard of *n*-th letter the expected output signal is determined using the following expression:

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

where $\overline{y}(n)$ – the raw value of an output signal of a standard *n*-th 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. Therefore, for an educational example of a standard *n*-th of a letter the expected output signal is defined so:

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

where k - number of output neuron.

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.

To solve this disadvantage, it was proposed to use the probabilistic neural network PNN to estimate the proximity of the standards, in which educational examples the expected output signal represents not number, but the name of a class [21]:

$$\{x\}_K \rightarrow Name_Y\,, \qquad (4)$$

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 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. The number of PNN inputs is equal to the number of class features and is determined using (1).

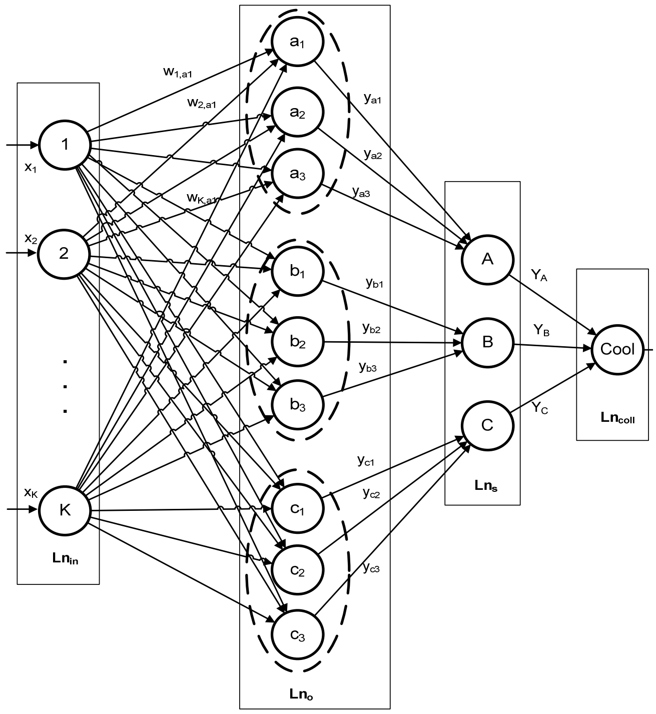

Figure 2 – Example of structure of the PNN network

The network consists of four layers of neurons: input - Ln_{in}, images – Ln_0, adding – Ln_s and a output – Ln_{coll}. The number of neurons in the layer of images is equal to the number of training examples, and the number of neurons of the summation layer is equal to the number 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. When learning for links that are in the neuron of the image layer, the weight coefficients are set to the same as the constituent parts of the corresponding learning vector. The weight coefficients of the links entering the neurons of the summation layer and the output element are equal to 1. Thus, all PNN parameters are directly determined by the training data. The output signal of an arbitrary *j*-th neuron of the image layer is calculated as follows:

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

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

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

$$Y_n = \frac{\sum_{i=1}^{I} y_i}{I} , \quad (6)$$

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

The value of Y_n is equal to the probability of assigning the input image to a class that corresponds to a given neuron. The task of an output element is only determination of neuron of a layer of summing with the maximum activity. Although the result of PNN recognition is only the name of the most probable class, but the Y_n values indicate the probability that an unknown input example belongs to one of the recognizable classes.

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

– by means of expression (4) the set of educational examples which correspond to a set of standards of the recognized classes is created;

– learning of a network is implemented;

– 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.

The scaled values of these signals will also be the expected output signal for an NNM based on a multilayer perceptron.

Will consider application of the developed coding procedure on a specific example of recognition of 8 abstract black-and-white figures shown in Figure 3.

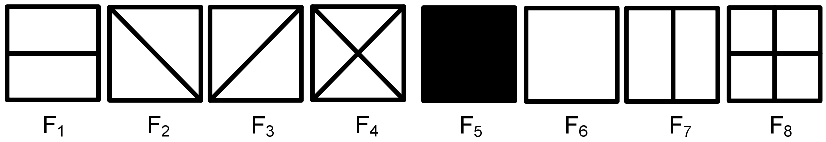

Figure 3 – Recognized figures

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. With the help of the expression (4), many input and output parameters of the training examples of these standards are formed. For example, $F_1 = \{0,0,0,1,1,1,0,0,0\}$. After that, the structure of the PNN network shown in Figure 4 was constructed. Accept $\sigma = 0{,}5$.

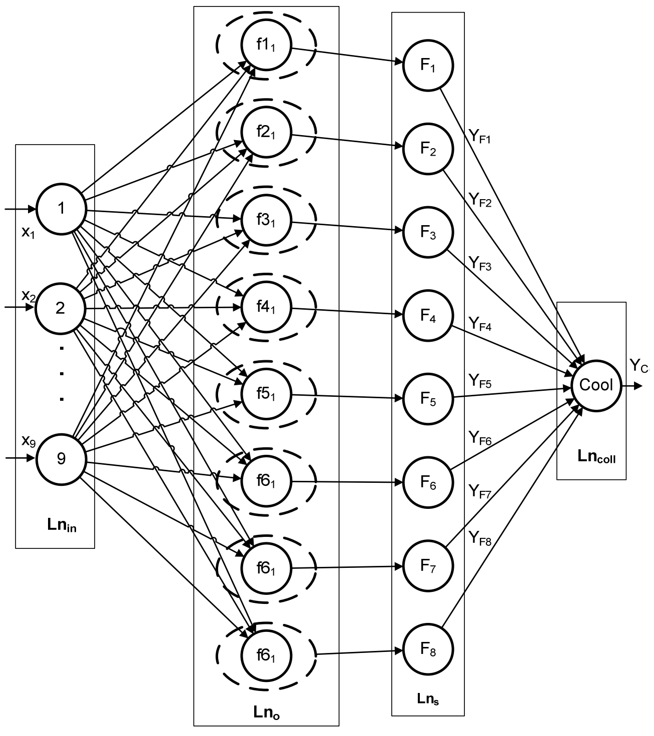

Figure 4 – Structure of the PNN network for recognition of the abstract figures

Application of the built network allowed is to carry out coding of an output signal for each of standards. Value of these signals are provided to table.

Value of the expected output signals

Output signal	Name of references							
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8
Y_{F1}	9,00	5,07	5,07	3,11	3,11	6,05	5,07	7,04
Y_{F2}	5,07	9,00	5,07	7,04	3,11	6,05	5,07	3,11
Y_{F3}	5,07	5,07	9,00	7,04	3,11	6,05	5,07	3,11
Y_{F4}	3,11	7,04	7,04	9,00	5,07	4,09	3,11	1,15
Y_{F5}	3,11	3,11	3,11	5,07	9,00	0,16	3,11	5,07
Y_{F6}	6,05	6,05	6,05	4,09	0,16	9,00	6,05	4,09
Y_{F7}	5,07	5,07	5,07	3,11	3,11	6,05	9,00	7,04
Y_{F8}	7,04	3,11	3,11	1,15	5,07	4,09	7,04	9,00

For use of the received results in the educational examples oriented on neural networks with sigmoidal function of activation it is necessary to carry out their scaling in the range [0,1]. It is for this purpose possible to use shown in [5, 6] expression:

$$y = \frac{y_{in} - y_{\min}}{y_{\max} - y_{\min}} \quad , \tag{7}$$

where y - the scaled value of an output signal, y_{in} - original value of a signal, $y_{\max}$ and $y_{\min}$ - maximum and minimum value of the original output signal.

After carrying out the appropriate calculations using (7), the obtained scaled values of the expected output signals were used in the formation of training 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.

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, which allows to consider closeness of standards of the recognized classes.

The coding procedure of the expected output signal providing use of a probable neural network is developed. As a result of numerical experiments, it is shown that the application of the developed procedure allows reducing by 30-50% the number of computational iterations necessary to achieve a given error in the training of neural networks intended for recognition of graphic images in biometric authentication systems.

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БИОМЕТРИЯЛЫҚ АУТЕНТИФИКАЦИЯ ЖҮЙЕЛЕРІНДЕ ГРАФИКАЛЫҚ ҮЛГІЛЕРДІ ТАНУҒА АРНАЛҒАН НЕЙРОЖЕЛІЛІК МОДЕЛЬДЕГІ ШЫҒЫС СИГНАЛЫН КОДТАУ

Аннотация. Мақала ақпараттық жүйелердегі пайдаланушыларды биометриялық аутентификациялау жүйелерінде графикалық үлгілерді тануға арналған нейрожелілік модельдерді пайдалану технологияларын жетілдірудегі проблемаға арналған. Қазіргі заманғы технологиялардың негізгі кемшілігі, оқу мысалдарын қалыптастыру кезіндегі статистикалық деректердің сапасыз өңделуіне байланысты, нейрожелілік модельдерді оқыту кезінде тиімсіз екендігі көрсетілген. Мұның маңызды бір себебі, оқу мысалдарындағы күтілген шығыс сигналдарының арасындағы корреляцияның болмауы және танылатын кластардың эталондарының жақындығы. Оқу мысалдарының күтілген шығыс сигналының шамасын нейрожелілік кодтау рәсімі арқылы оқу мысалдарының сапасын арттыру ұсынылған, ол танылатын кластардың эталондарының жақындығын қарастыруға мүмкіндік береді. Ықтималды нейрондық желіні қолдануды қарастыратын күтілген шығыс сигналын кодтау рәсімі әзірленген. Ықтималды нейрондық желі қолдану мақсатына сәйкестігі, оның төмен ресурс сыйымдылығымен анықталған. Сонымен қатар, оқу мысалдарында шығыс сигналы санмен емес күтілген класс атауы түрінде болуы мүмкін. Сәйкесінше математикалық аппарат құрылды. Көптеген тәжірбиелер нәтежиесінде, әзірленген рәсімді қолдану графикалық үлгілерді тануға арналған биометриялық аутентификация жүйелері негізгі нейрожелілік модельдің көпқабатты персептронды оқытуға керекті тапсырылған қатені есептеу итерациясы көлемін 30-50% азайтуға болатынын көрсетті. Бұл ұсынылған шешімдердің биометриялық аутентификация жүйелерінде қолданылатын нейрожелілік технологиялардың тиімділігін арттыруға қолдану келешекті екенін көрсетеді.

Түйін сөздер: нейрожелілік модель, оқу, оқу мысалдары, биометриялық аутентификация

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КОДИРОВАНИЕ ВЫХОДНОГО СИГНАЛА НЕЙРОСЕТЕВОЙ МОДЕЛИ, ПРЕДНАЗНАЧЕННОЙ ДЛЯ РАСПОЗНАВАНИЯ ГРАФИЧЕСКИХ ОБРАЗОВ В СИСТЕМАХ БИОМЕТРИЧЕСКОЙ АУТЕНТИФИКАЦИИ

Аннотация. Статья посвящена проблеме совершенствования технологий применения нейросетевых моделей для распознавания графических образов в системах биометрической аутентификации. Показано, что существенным недостатком современных технологий является недостаточная эффективность обучения нейросетевых моделей, связанная с недостаточным качеством обработки статистических данных. Одной из важных причин этого является отсутствие корреляции между ожидаемым выходным сигналом учебных примеров и близостью эталонов распознаваемых классов. Предложено повысить качество учебных примеров за счет использования процедуры нейросетевого кодирования величины ожидаемого выходного сигнала учебных примеров, которая позволяет учесть в этом сигнале близость эталонов распознаваемых классов. Разработана процедура кодирования ожидаемого выходного сигнала, предусматривающая использование вероятностной нейронной сети. Целесообразность применения вероятностной нейронной сети определена исходя из низкой ресурсоемкости ее обучения. Кроме того, в ее учебных примерах ожидаемый выходной сигнал может быть представлен не числом, а названием ожидаемого класса. Сформирован соответствующий математический аппарат. В результате численных экспериментов показано, что применение разработанной процедуры позволяет на 30-50% уменьшить количество вычислительных итераций, необходимых для достижения заданной ошибки обучения многослойного персептрона, который является базовой нейросетевой моделью для распознавания графических образов в системах биометрической аутентификации. Это указывает на перспективность использования предложенных решений для повышения эффективности нейросетевых технологий, применяемых в системах биометрической аутентификации.

Ключевые слова: нейросетевая модель, обучение, учебный пример, биометрическая аутентификация

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