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NEURAL NETWORK TECHNOLOGIES FOR RECOGNITION CHARACTERS

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***Abstract*—*The process of neural networks modeling for pattern recognized problem of printed characters considered in this paper. Learning for pattern recognition preparing for a limited set of synthetic characters. It assumes the two-layer neural network training. The convergence of three learning algorithms is studied. They are packet-based adjustment of weights and biases, the gradient, the algorithm based on the computation of the Jacobian function weights. The article provides recommendations for the installation of the initial parameters for a set of tools Neural Networks Toolbox software Matlab. Experimental results for different settings customer networks given that confirms these propositions.*

Index Terms—Neural networks; learning; gradient; Levenberg–Marquardt method; synthetic image.

I. INTRODUCTION

Image recognition is one of the most important and interesting practical problems, and this problem recently dedicated a significant number of publications, for example [1] – [7]. On the existing image to need identify the object or to point it relation to a certain class of images. The typical pattern recognition problem involves the analysis of the measurement vectors and its comparison with some reference vectors. This problem most easily decided when the measurement vector attributed to one of two possible classes. The most well developed and practically used this theory in control problems for dynamic objects when there are a couple of control actions, differing in sign. These control actions associated with a system that have control a "full speed" forward or backward. Separation vector measurement performed flat or curved hypersurface passing through the origin, which allow unambiguous identification of control signal or recognized it patterns. The hypersurface determined by a mathematical model of the system. As usually at the first step of recognition error occurs, this situation needs correction recognition control situations by linear or nonlinear learning scheme.

This approach is also applicable to pattern recognized. Images is easy to divide into two classes, if we have feature "good-bad", "there is – there is no" object at the pattern that we see. In this case, sufficient merely implemented pattern recognition system with learning, where all outcome situations divided into three types as a recognition signals in control systems [4]. Among them correct recognition – is the expected result of the system, false alarm that immediately revealed that we have received features that are not typical of this system and releases when the error recognition manifested in the operation of the system. If these errors appear in a limited area of low estimated value of measurement vector, that there is a need to introduce the dead zone. The introduction of this region contributes increases performance, and further processing done by ways that are more accurate.

Image recognition needs to increase the number of features on which recognition should be leads. If it is necessary to recognize the image, it may be that more than two classes of known objects should carry out classification.

II. PUBLICATIONS REVIEW

Neural network technology – very popular now, though not fully studied the mechanism of finding the correct solutions. The most widely used network straight propagation signal and backward error propagation. In theory, the main principle works neural networks in detail described in [1], [3] – [5]. The problem of pattern recognition lately rises very sharply. To get an excellent, high-quality image is necessary to apply a considerable amount of effort, as evidenced by the works [2], where the problem solved by the method of filtering composition. However, the use of filtering methods is acceptable for primary image processing. In those cases, when you need an understanding of the figure, for extraction of meaning is necessary to use the more difficult methods of processing. These include methods of

synthesis based on image processing by neural networks. Unfortunately, the single-layer network based on simple perceptron are not able to process a composite signal on that in due time pointed Minsky and Papert [3]. However, with time, this drawback was able to circumvent by use of the multilayer network, wherein between the inlet and outlet used more than one treatment layer.

A number of useful learning algorithms used in neural networks presented in [4], [5]. In these studies, the main emphasis placed on the gradient methods, which requires knowledge and the ability to calculate the derivative to determine the weighting coefficients. The main problem of these methods is the convergence of customizable coefficients to satisfy of certain criteria values. The need for adjustment leads to growth and the possible loss of the reasonable value of the weight vector [6].

It should be note that the search for a weight vector based on a gradient algorithm network training – a long process. We can to increase the speed of convergence of the network if we refused of the gradient of the error signal and replace it with a special replacement Jacobian model, according to the algorithm, which offered K. Levenberg and D. Marquardt [7], [8].

One of the latest investigations published in this area [7], in which presented in terms of the convergence of the asymptotic behavior weights. Unfortunately, this result is of limited use in the media, provides a set of Neural Networks Toolbox software Matlab. Therefore, the main purpose of this paper is to explore the possibilities of algorithms and settings on their basis to make recommendations for the creation of the system for character recognizer.

III. Problem Formulation

Let we have some image consisting of a limited characters set. The image can be natural or synthetic. In the interests of modeling advisable submit a letter as a rectangular matrix of size $M \times N$, where $M > N$. With means of Matlab, for example, the letter B created as a 5×7 matrix form

$$Bucva\_B = \begin{bmatrix} 1\,1\,1\,1\,0 \\ 1\,0\,0\,0\,1 \\ 1\,0\,0\,0\,1 \\ 1\,1\,1\,1\,0 \\ 1\,0\,0\,0\,1 \\ 1\,0\,0\,0\,1 \\ 1\,1\,1\,1\,0 \end{bmatrix}. \qquad (1)$$

The letters that created this way we can see by the function *plotchar* (), which displays it as a graphic symbol in the following code

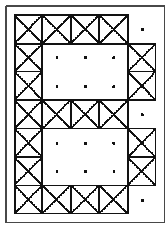

Fig. 1. Image of the letters B that creates a matrix (1)

We pose the problem of correct recognition of letters from the incoming characters set. For solution this problem in the program Matlab we use Neural Network Toolbox that usually applicable for modeling neural networks.

IV. Creation Neural Network by Matlab

Given the complexity of the representation of the input information, we selects a framework for recognition as a two-layer neural network with one hidden layer (Fig. 2). The standard structure of each layer includes a multiplier input vector I, the weight matrix W, and the result of multiplying added to the biases vector b, the result of the summation is arrived to the functional converter 4 that compress input space in a limited area output patterns. Adjustment networks made by change of preset the initial values of the weights W_0 and biases b_0 of neural networks. To correcting functioning networks, the training process applied at the inputs set by adaptation. The comparison of output information and the reference information done for this aim, this operation used for correction of the network errors.

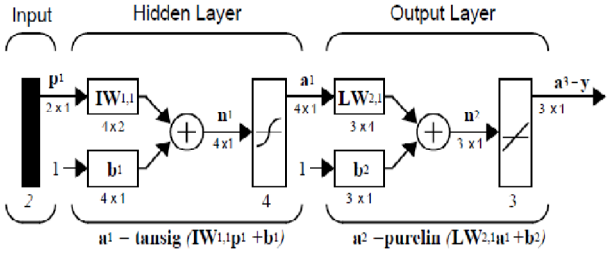

Fig. 2. The structure of the two-layer feedforward neural network

The characters are arrive to the inputs of networks at one, so the number of network inputs is determined by the number of elements in a matrix, and the number of outputs is determined by the number of letters in the set. As a transfer functions are advisable to select the functions that pass through the origin of the space of recognizable characters. This is hyperbolic tangent and the straight line on the plane.

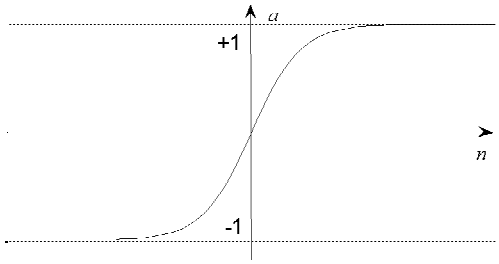

Fig. 3. View of hyperbolic tangent

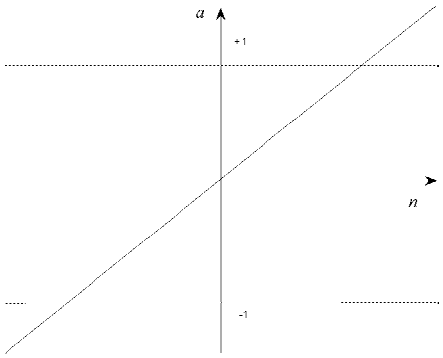

Fig. 4. View of linear dependence

Formulas representation of the transfer function of hyperbolic tangent (tansig) that calculated in Matlab, has the form

$$a(n) = \frac{2}{1+\exp(-2n)} - 1, \qquad (2)$$

and linear function (*purelin*)

$$a(n) = n. \qquad (3)$$

Setting up a network is in accordance with some algorithm that minimizes the selected criteria of quality network performance. Traditionally used as a criterion for error, named – ε. This package have three options for calculating error:

– the average value of the absolute error, the function *"mae"*

$$\varepsilon = \frac{1}{N}\sum_{i=1}^{N} | y_i - I |, \qquad (4)$$

where y_i is the output value in the i-step of setting; I is the a reference vector; N is the number of steps serial corrections;

– mean square error value, the function *"mse"*

$$\varepsilon = \frac{1}{N}\sum_{i=1}^{N} (y_i - I)^2, \qquad (5)$$

– sum of squared errors (*"sse*")

$$\varepsilon = \sum_{i=1}^{N} (y_i - I)^2. \qquad (6)$$

Commonly expression the algorithm of setting the network weighting coefficients formed as

$$w_j = w_{j-1} + \Delta w_{j-1}, \qquad (7)$$

where w_i is the coordinate of the weight vector, and Δw_i its increment to the j-th step of the network settings. Increment Δw_i plays a very important role in adjusting the weight vector: its sign determines the direction and magnitude of the step adjustment. There are several approaches to determining Δw_j. Correcting properties for w is a direct error ε (function *«trainb»)*

$$\Delta w_j = \alpha_j \varepsilon_j, \qquad (8)$$

where α_j – the factor that determines speed learning networks, its gradient (function "*traingd"*)

$$\Delta w_j = -\alpha_j \mathrm{grad}(\varepsilon_j), \qquad (9)$$

and the Jacobian (function "trainlm")

$$\Delta w_j = (\mathbf{H} + \mu\mathbf{I})^{-1} J^{\mathrm{T}} \varepsilon_j, \qquad (10)$$

where **H** – means Hessian and **J** – Jacobian matrixes of weighting coefficients; **I** is the identity matrix; μ is the regularization parameter. The calculation of adjustments to the weights (10) also known as the Levenberg–Marquardt algorithm.

We investigate the effectiveness of algorithms settings (8) – (10) for a two-layer neural network Fig. 2 according to the indexes accuracy (5) and set-up time by means of a software package *Neural Networks Toolbox* software *Matlab* in recognizing synthetic alphabetic characters defined by method (1).

IV. Simulation Neural Networks

As a sequence is selected the set of the first seven letters of the alphabet, namely {*A, B, C, D, E, F, G*}. We will construct a neural network in accordance with the general approach [9] that included steps such as:

– create learning and target data;
– configure the network;
– initialize values of weights and biases;
– train the network;
– validate the network;
– use the network.

It is supposed to build a network of forward propagation with the back-propagation errors. In practice, learning a multilayer neural network input data divided into three subsets: training, validation

and testing. Training subset used to calculate the increment Δw_j and updating weights w and biases b in accordance to the chosen criterion (4) – (6).

Using a validation subset also leads to "re-training" network. If operation of the algorithm is correct, will decrease error signal in tuning. If the error for this subset is increased, that will take place re-training network for input data. Network weight and biases, which found for network training, stored for a minimum specified testing subset.

The test data subset not used for teaching. His goal to check created model neural network. If the error of subset test from previous subsets considerable differs, that will indicate an incorrect division of the set of input data.

We will use function *dividerand* (), which by default divides at random the original set on three subsets with a ratio of 0.7: 0.15: 0.15. In our case, it is a 5: 1: 1.

Created a two-layer neural network of forward propagation by function *feedforwardnet* (*HiddenSizes, trainFcn*) with two arguments. In Fig. 5 shown investigated neural network, it have 35 input elements that corresponds to the number of elements in the matrix and 6 neurons in the hidden layer and 7 in output layer that is determined by the total number of characters in the set and the same network outputs. We investigate the network (Fig. 5) for the algorithm (8) – (10) for the case where $\varepsilon = 0.01$, the maximum number of iterations $N = 25000$. If network not trained, that network after the first iteration provides error detection letters. For example, if necessary, to identify a second set of symbol *"B"*, the network produces a fifth – *"E"*.

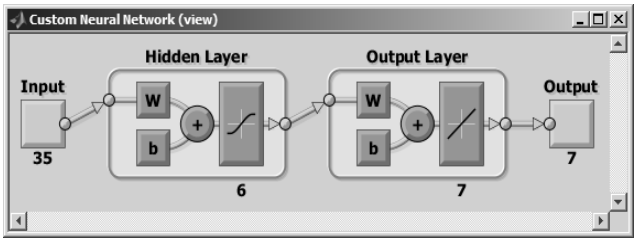

Fig. 5. Neural network for investigations

Results of the study presented in Table I.

TABLE I

INVESTIGATION OF ALGORITHMS SETTINGS WITHOUT NOISE

Algorithm	**trainb**	**traingd**	**trainlm**
Time, *s*	55	134	4
Iterations	9370	21185	6
Error	0 0 1	0.01	0,002

In all cases, the network settings correctly identifies the input characters from a given set. In each case, the use of neural network produces the correct result - number of characters in the set.

Analysis of the study (Table. 1) showed that the fastest method learning the network is algorithm of Levenberg–Marquardt [6], [7], [9]. Gradient and batch algorithms are slow and to get good results require re-training networks. In order to reduce the number of calculations it is advisable to refuse from characteristics that is set default, set their new and to carry out a series of experiments with them.

We will created also version of these characters with noise. We will use the functions *repmat* (*A, N, P*) and *randn* (*N, P*) for this aim. The first function allows you to repeat exactly copy of the original matrix in the newly formed matrix ($N \times$ P), where N is the number of rows and P is the number of columns of the new matrix. The second function defines the matrix size $N \times P$ with elements distributed according to the normal distribution law with the expectation is $\bar{a} = 0$ and standard deviation $\sigma = 1$. Fig. 6 shown 5th symbol of input set that distorted noise and displayed *Matlab* means.

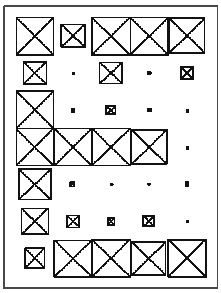

Fig. 6. View symbol of the input sequence with noise

We shall investigate the neural network with the same error parameter, the maximum number of iterations of the adaptation algorithm settings (8) – (10), which in the ideal case without noise. Results of the study network noisy sequence shown in Table II.

TABLE II

THE NOISE INFLUENCE ON THE RECOGNITION PROCESS

Algorithm	**trainb**	**traingd**	**trainlm**
Time, *s*	115	157	4
Iterations	19067	24952	15
Error	0.01	0.01	0.003

In all cases, the configured network is correctly identifies input characters from a given set, it gives the correct result – number of characters in the set. As expected learning outcomes for the signal with the noise longer. Saving time learning for algorithm Levenberg–Marquardt explained by the greater value of a network error.

Positive results obtained on the base of synthetic images and we make forecast the possible use of these networks and to real images.

IV. CONCLUSION

Neural network technology define the mechanism of recognition of characters in a given set. This mechanism is iterative, requiring prior learning network, consisting in setting the initial values of the weighting coefficients. Considered teaching methods based on the criteria of errors and have a different speed of convergence to a positive result. The first two methods are slow; require additional time for setting the weighting coefficients. The latter, based on the Levenberg–Marquardt algorithm, gives significantly better results, which is about 10–100 times better than algorithms batch and gradient. A possible method of increasing the rate of convergence of a neural network may be the refusal of the automatic installation of weighting coefficients by default and setting coefficients close to the optimal regime of recognition. In each case, the use of the network leads to a study based on the variation of parameters such as: the value error, number of layers and iterations allowed. Further studies we will direct to the development of neural network technologies, involving recognition of real characters.

REFERENCES

[1] L. G. Shapiro, and G.C. Stockman, *Computer Vision*. N. J., Prentice Hall, 2001, 752 p.

[2] R. G. Katsalap, D.P. Kucherov, L.V. Zbrozhek "Improving Images Quality by Combination of Filtering Methods". *The International Journal of Engineering and Science* (IJES), vol. 4, no. 7, 2015, pp. 69–77.

[3] M. Minsky, and S. Papert Perceptrons. *An Introduction to Computational Geometry*. MIT Press, 1969, 263 p.

[4] Y. Z. Tsypkin, *Adaptation and learning in automatic systems*. – N.Y.: Academic Press, 1971. – 400 p.

[5] B. Widrow, and S.D. Stearns, *Adaptive signal processing*. N. J., Prentice Hall, 1985, 440 p.

[6] K. Levenberg, "A Method for the Solution of Certain Problems in Last Squares", *Quart. Appl. Math.*, vol. 2, 1944, pp. 164–168.

[7] D. W. Marquardt, "An Algorithm for Least-Squares Estimation of Nonlinear Parameters Read", *Journal of the Society for Industrial and Applied Mathematics*, vol. 11, no. 2, 1963, pp. 431–441.

[8] V. N. Azarskov, D. P. Kucherov, S. A. Nikolaienko, L. S. Zhiteckii, "Asymptotic Behaviour of Gradient Learning Algorithms in Neural Network Models for the Identification of Nonlinear Systems", *American Journal of Neural Networks and Applications*, vol. 1, no. 1, 2015, pp. 1–10.

[9] H. Demuth, and M. Beale.Neural, *Network Toolbox For Use with MATLAB*, The MathWorks, Inc., 2002, 840 p.

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Д. П. Кучеров, І. В. Огірко, О. І. Огірко, Т. І. Голенківська. Нейронні мережеві технології для розпізнавання символів
Розглянуто процес моделювання нейронних мереж для задачі розпізнавання буквених символів. Навчання розпізнаванню проводиться на обмеженому наборі синтетичних символів. Для цього передбачається нейронна мережа, що складається з двох шарів, один їх них прихований, другий вихідний. Вивчено збіжність трьох алгоритмів навчання: алгоритм пакетного коригування ваг і зміщень, градієнтний і алгоритм, заснований на обчисленні матриці Якобі функцій ваг. Надано рекомендації з установки початкових параметрів для набору інструментів нейронної мережі Neural Networks Toolbox програмного забезпечення Matlab для вирішення цього завдання. Експериментальні результати підтверджують висунуті припущення.
Ключові слова: нейронні мережі; навчання; градієнтний підхід; алгоритм Левенберга–Марквардта; синтетичне зображення.

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Д. П. Кучеров, И. В. Огирко, О. И. Огирко, Т. И. Голенковская. Нейронные сетевые технологии для распознавания символов
Рассмотрен процесс моделирования нейронных сетей для задачи распознавания буквенных символов. Обучение распознаванию проводится на ограниченном наборе синтетических символов. Для этого предполагается нейронная сеть, состоящая из двух слоёв, один их них скрытый, второй выходной. Изучена сходимость трёх алгоритмов обучения: алгоритм пакетной корректировки весов и смещений, градиентный и алгоритм, основанный на вычислении матрицы Якоби функций весов. Предложены рекомендации по установке начальных параметров в наборе инструментов Neural Networks Toolbox программного обеспечения Matlab для решения этой задачи. Экспериментальные результаты подтверждают выдвинутые предположения.
Ключевые слова: нейронные сети; обучение; градиентный подход; алгоритм Левенберга–Марквардта; синтетическое изображение.

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Образование: Львовский национальный университет им. И. Франка, Львов, Украина (1999).
Направление научной деятельности: информационные технологии.
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Направление научной деятельности: методы и системы управления.
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