Handwriting recognition method in real-time mode based on distributed neural networks

Yuri Vetroff, Dmitry Adzinets

***Abstract*—** During the last 10 years, use of portable devices like smartphones and tabled PCs for educational, bisuness and entertaining purposes has increased dramatically. In this case, the most difficult aspect is the organization of the data entry. AI-methods like artificial neural networks helps to understand user input. The method proposes the recognizer based on neural networks and uses the parallel computing technologies.

***Keywords*—**neural networks, atrificial intelligence, pattern recognition, distributed systems.

I. Introduction

High prospects of the development of patterns recognition systems are obvious. No device or application processing the data from the outer world are unable to operate without the components that would ensure the correct and timely analysis of the received information presenting it in a structured way and in the right format. The most popular pattern recognition systems are the systems interacting with images: the automatic facial recognition on photos, the selection of moving objects in the video, auto focus in digital photography, handwriting recognition, and so on.

Handwriting systems are highly demanded in smartphones and tablets, which do not have a physical keyboard. Using a virtual keyboard is connected with a number of inconveniences, such as the small size of the keys. Currently there is a sufficient amount of applications and devices using handwriting recognition based on neural networks, but they all have a number of common problems. Firstly, when the application functions in an offline mode retraining neural network to a new set of characters may take quite a long time. Second, the neural networks are not always able to provide the necessary recognition accuracy, conflicts between similar symbols outlines are possible.

The paper offers a method for effective solving of the problem of handwriting recognition input into the computer in a real-time mode based on the distributed neural networks.

II. Problem Statement

The proposed method is based on the principle of general neural networks separation. A number of experimental studies shows that the greatest defect density is observed for recognition of similar characters, such as letters I and J. If you divide these characters, placing them in different groups, you can achieve elimination of such mistakes. Let`s consider the following alphabet: A, B, C, D, E, F, G, H, I, J, K, L. The alphabet contains 12 patterns-letters.

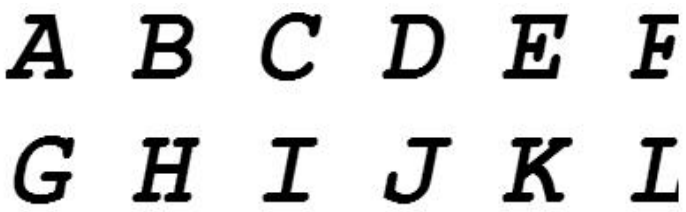

Fig. 1 Outline of the letters.

Y. Vetroff, Belarusian State University of Informatics and Radioelectronics, Minsk, B (e-mail: dea_lucis@ukr.net).
D. Adzinets, Odessa National Polytechnic University, Odessa, Ukraine (e-mail: drozd@ukr.net).

If we analyze the features of the outline of each of them (Fig. 1), we can draw the following conclusion. There is a similarity between the characters I, J, L, symbols B, E, F and the characters A, H, K. Let`s divide the alphabet so that similar characters are in different groups. As a result, we have the following clusters:

1) A, E, I
2) B, C, J
3) F, H, L
4) D, G, K

The proposed method provides for the generation of neural networks corresponding to original character set, training of each of them only characters contained in each particular group. This will enable to avoid conflicts like the IJ or EF. Along with this, the processes of training and recognition will be accelerated in the number proportional to the number of groups.

III. DESCRIPTION

Let`s consider a handwriting recognition method based on distributed neural networks in a real time mode. The functioning of the distributed neural network can be formally divided into two stages: training and recognition.

At the stage of training standard sample is formed containing each character that can be entered to the input of recognizer. A collection of standard characters is delimited to clusters according to degree of similarity, then each cluster is supplied with classifier to be taught. Classifier is a multilayer perceptron with one hidden layer neurons which satisfies the following:

$$n_{input} \geq 2n_{hidden} > 2n_{output}$$

where n is the number of neurons in the respective layer.

Perceptrons training is produced by means of a backpropagation error algorithm. The mathematical formulation of the expression of weights adjustment in the training process is the following:

$$\Delta w_{i,j} = \alpha \Delta w_{i,j} + (1 - \alpha)\eta \delta_j o_{j.}$$

Hyperparameter η which determines the speed of training changes in training process in the following way:

$$\eta = \eta + \frac{d_{n-2}}{d_n}$$

This approach enables to accelerate the sloping area of the training, where the change of output layer mistake decreases uniformly, and to slow down increasing accuracy - in areas where hitting the local minimum is possible.

On completing the training each of neural networks will possess its own repertoire of knowledge corresponding to a certain cluster of characters.

At the stage of recognition the pattern entered by the user is decoded into a binary format and is supplied to the input by each neural network in the recognizer. Neural networks pass the pattern through and on completing the proccess store the result in the corresponding collection.

The format of results is a couple of "key-value", where key is the encoding of the obtained pattern and the value is the degree of "confidence" of the network in its response. The pattern of the network that has the maximal degree of confidence is accepted as final result.

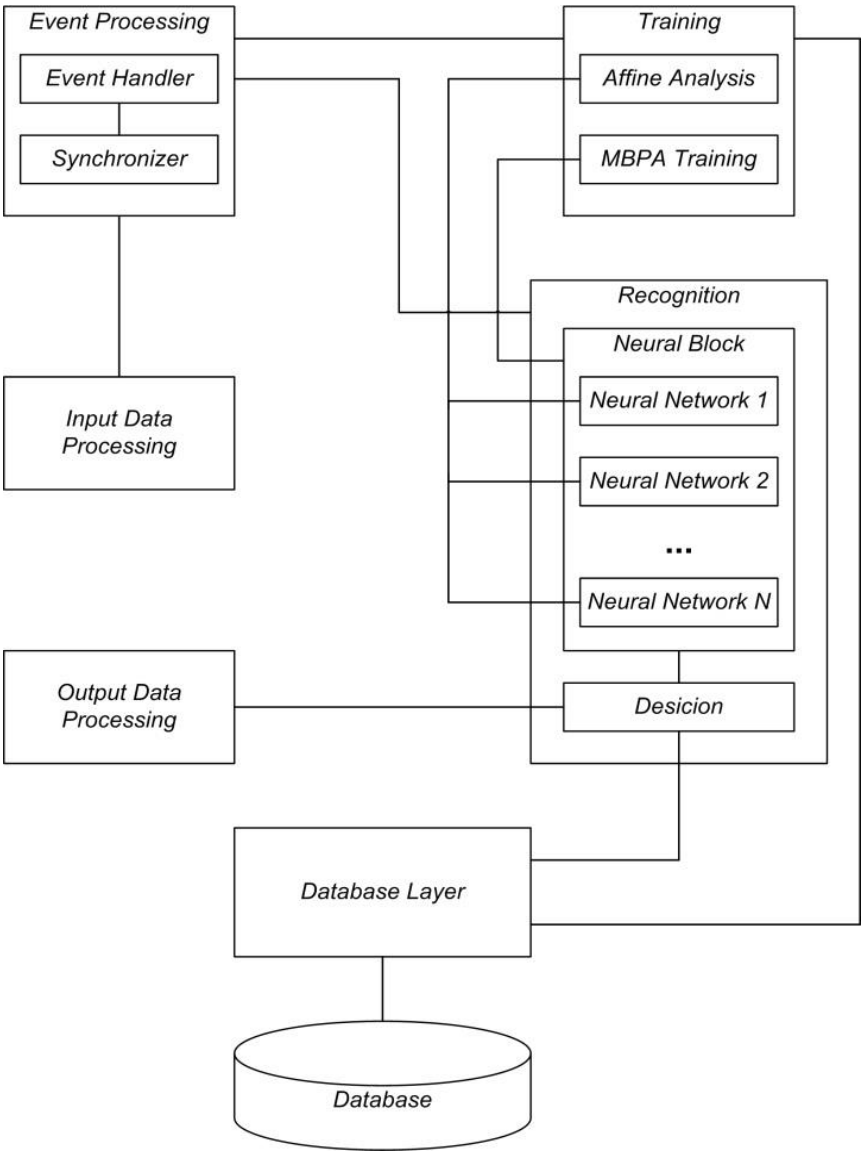

Fig. 2 Schematic diagram.

The specificationof the method is the parallelization of data processing both in the training process and at the stage of recognition. Independence of neural networks from each other allows us to solve a number of problems, such as a significant increase in learning rate due to the impact only on a specific network with a little number of patterns, simple and safe parallelization of calculations using popular technologies (CUDA, MPI), increasing the accuracy of recognition by eliminating conflicts. Individual neural networks training processes and pattern recognition are accelerated in several times due to significant reduction of the working sample.

Handwriting recognition system based on the proposed method consists of the following components (Fig. 2):

1)Event Processing, that provides multitasking and synchronous event processing. The events include: character recognition, structural analysis of the mathematical expression, removing characters, neural network training.

2)Training, that includes a module Affine Analysis (affinity analysis), that analyzes the similarity of images from the training sample and splits it into clusters, and the module MBPA Training, implementing a modified backpropagation error algorithm of neural network training.

3)Recognition, that includes Neural Block module, keeping a collection of neural networks, and Decision module, taking decision about the result.

Database Layer module provides interaction with the database system. The database stores parameters of multilayer perceptrons trained with a modified backpropagation error algorithm that are necessary to the stage of handwriting recognition. Dictionaries defining a set of patterns for each multi-layer perceptron are also stored in the database.

Characters recognition result being corrected by user, corresponding neural network will continue being trained updating the parameters of the classifier in the database. Thus the proposed solution makes it possible to personalize handwriting recognition system, increase its efficiency and to adjust the system to user's handwriting.

IV. Experimental Researches and Test Results

To test the effectiveness of the proposed method experimental researches were conducted that enable to assess the quality of handwriting recognition. For neural network training a sample of 36 patterns and 360 handwritten characters was used (5 different outlines of each pattern). The sample was passed through affine analyzer, which has singled out separate clusters, dividing 36 patterns in 6 groups of 6 patterns. 6 multilayer perceptrons were initialized, a modified backpropagation error algorithm was run for each of them. Thus we found the values of weighting coefficients that are required to initialize the neural network.

Testing was conducted by handwriting characters in a real-time mode into a tablet with a stylus. The total sample for the test is 200 handwritten characters. The average time of recognition of each character is 80 milliseconds (less than one-tenth of a second) for a computer with the following specifications: CPU Intel Core 2 Quad 2.4 GHz, RAM 4 GB.

Overall recognition accuracy: 91.37%.

Accuracy of selecting the "correct" neural network when using a recognizer with parallel neural networks: 96.29%.

Fig. 3 represents the diagram showing each of 6 neural networks "confidence" during the testing.

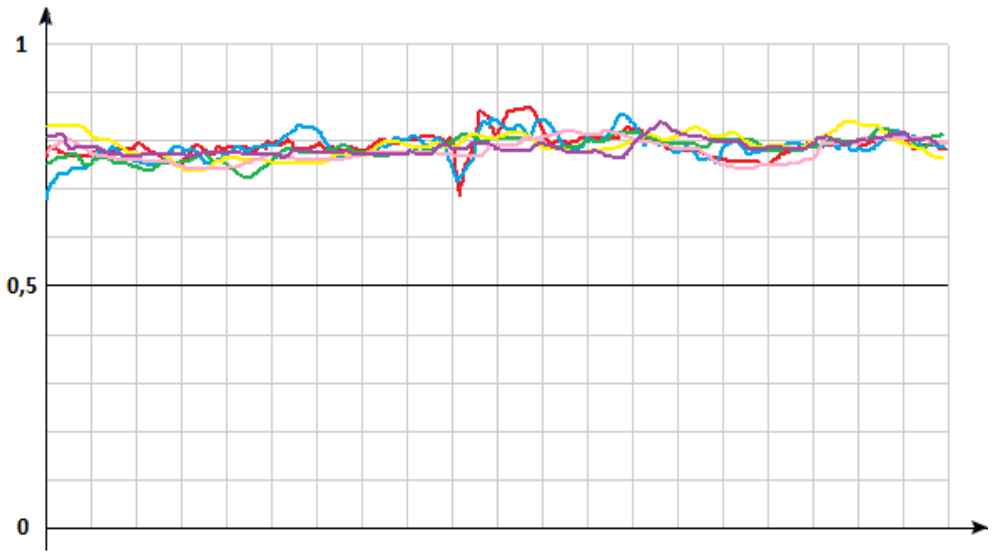

Fig. 3 Recognition diagram.

Accuracy of selecting the right perceptron is higher than the overall accuracy because of the possible classification mistakes in perceptrons. However extremely little difference in overall accuracy and selection accuracy (less than 5%) shows that virtually in all experiments the decision was made in favor of release of the network which showed the correct result. The average recognition time of each character was is 80 milliseconds, which meets the requirements for using the system in a real time mode. Recognition accuracy is 91.37%, the structural analysis accuracy is 71.29%.

V. Conclusion

The article describes a method of handwritten characters recognition input into the computer in a real time mode, which is based on suggested approaches of handwritten characters recognition, interconnected with the idea of parallel data processing. The experimental studies of the proposed method which show a positive result of its operation are described.

Implementation of method corresponds to all the following requirements:

1. Flexibility and capacity for further development.
2. Safety.
3. The minimum response time to the request.
4. Ability to adapt to different handwritings.
5. Convenience and simplicity of the interface.
6. Efficiency.

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