# ON LOGICAL CORRECTION OF NEURAL NETWORK ALGORITHMS FOR PATTERN RECOGNITION

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*Abstract: The paper is devoted to the description of hybrid pattern recognition method developed by research groups from Russia, Armenia and Spain. The method is based upon logical correction over the set of conventional neural networks. Output matrices of neural networks are processed according to the potentiality principle which allows increasing of recognition reliability.*

*Keywords: Pattern recognition, forecasting, neural networks, logical correction.*

*ACM Classification Keywords: I.2. Artificial Intelligence, I.5. Pattern Recognition, F.1.1 Models of Computation*

## Introduction

Mathematical recognition theory has long history and the variety of its reality modeling methods is quite wide. Every research group has its own traditions and usually works in specific area of mathematics. There are two basic approaches which are commonly said to be different. They are functional and algorithmic ones. For example, neural networks approximate output function but their parameters has no appropriate interpretation. Algorithmic models as for example algorithms of estimates calculating provide interpretable parameters though may have high calculation difficulty. Integration of scientific schools and small groups of “particular specialists” in the framework of joint projects provide possibilities for revealing potentials of different methods and their combinations. Developing of one such integrated approach is connected to the execution of series of INTAS projects by research groups from Russia, Spain, Armenia and some other countries.

Algebraic theory of pattern recognition based upon discrete analysis and algebra [1] is the basic approach which has been being used for 35 years in the Computing Centre of RAS under the direction of academician Yu.I. Zhuravlev. Research activities of the Institute for Informatics and Automation Problems of NAS Armenia lie in the same area of discrete recognition models. Their specific is the use of optimization structures of discrete isoperimetric tasks, discrete topology and hierarchical class searching [2]. Neural network models especially ones with polynomial output and linear activation functions [3] are the main area of interest of the Spanish group. In particular, they research temporal signal delays in recognition tasks. Good results have been achieved in forecasting of stock exchange and similar problems.

Some hybrid methods and applications for pattern recognition have been developed by these groups in the framework of INTAS projects 96-952, 00-367, 00-636 and 03-55-1969. One of them is based on assembling of neural networks and logical correction schemes. The main cause of this research was the idea of creating such pattern recognition and forecasting application which requires minimal human intervention or no intervention at all. It should be possible for the operator with no specific knowledge in mathematics to use that software. Such NNLC (Neural Networks with Logical Correction) application has been developed in the framework of INTAS projects 03-56-182 inno and 03-55-1969 YSF. Now we are proud to say that it has justified our expectations in a great extent. The method has shown high and stable results in many practical tasks.

## Method description

Further we shall describe general training and recognition scheme for the l-classes task. The notation from [1] will be used. Let the training sample be $S_1, S_2, \dots, S_m$ and the testing one $S'_1, S'_2, \dots, S'_q$:

$$S_{m_{i-1}+1}, S_{m_{i-1}+2}, \dots, S_{m_i} \in K_i, i = 1,2,\dots,l, m_0 = 1, m_l = m \,,$$

$$S'_{q_{i-1}+1}, S'_{q_{i-1}+2}, \dots, S'_{q_i} \in K_i, i = 1,2,\dots,l, q_0 = 1, q_l = q \,.$$

For simplicity sake let us also suppose the task is solved without denials.

Finally, let us have N neural networks $A_j(S) = (\alpha_1^j(S), \alpha_2^j(S), ..., \alpha_l^j(S))$ trained for this task. It will give us the following matrix of recognition results:

$$A_j(S'_t) = (\alpha_1^j(S'_t), \alpha_2^j(S'_t), ..., \alpha_l^j(S'_t)),\ \alpha_i^j(S'_t) \in \{0,1\}, i = 1,2,...,l, \cdot j = 1,2,...,N, \cdot t = 1,2,...,q.$$

Algorithm of recognition by the group of neural networks will be designed according to the principle of potential correction [4]. New object will be assigned to the class of maximum estimation which is calculated according to the following formula:

$$\Gamma_i(S) = \frac{1}{q_j - q_{j-1}} \sum_{t=q_{j-1}+1}^{q_j} \Phi_i(S'_t, S), \cdot i = 1,2,...,l\ .$$

The variable $\Phi_i(S'_t, S)$ is called the potential between $S'_t$ и $S$ and is calculated as follows:

a) $\Phi_i(S'_t, S) = \begin{cases} 1, & \left|\{\alpha_i^j(S) \ge \alpha_i^j(S'_t), j = 1,2,...,N,\}\right| / N \ge \delta, \\ 0, & otherwise. \end{cases}$

b) $\Phi_i(S'_t, S) = \{the\ number\ of\ \ correct\ inequalities\ \ \cdot \alpha_i^j(S) \ge \alpha_i^j(S'_t), \quad j = 1,2,...,N\}.$

A-type potential we will call monotonous, b-type one will be called weekly monotonous with monotony parameter $\delta, \quad 0 < \delta \le 1$.

Thus, training phase consists of training of N neural networks (with no denials) and consequent calculation of binary matrix $\left\|\alpha_i^j(S'_t)\right\|_{l \times N \times q}$. New object $S$ is classified by calculating its binary matrix $\left\|\alpha_i^j(S)\right\|_{l \times N}$ and its estimates for each class according to either a-type or b-type potential. As we have already mentioned software realization of the method has been made by means of NNLC application. By the grant system of INTAS organization the NNLC application has been qualified as innovation software.

## Practical testing

In the current section results of practical experiments will be shown. It represents improvement of NNLC compared to simple neural networks.

The scheme of the first series is very simple. Four practical tasks have been chosen from open UCI repository (http://www.isc.uci.edu/~mlearn/MLRepository.html) and divided into training and testing samples. After that NNLC has been trained and tested. The following tasks have been chosen:

Breast - The task of breast cancer diagnostics was taken from [5]. The training sample consisted of 344 etalons, 218 from class “benign” and 126 from class “malignant”. Nine features, which could take integer values from 1 to 10, were used.

Housing - housing estimation in Boston suburbs [6]. The problem of automatic housing estimation is solved as price interval recognition (very low, low, average, above average, high). As features 13 ecological, social and technical indicators were used: number of rooms, rate of black population in the district, average distance from main supermarkets, air quality, etc. The sample of 242 objects was used for training and 264 objects for testing.

Ionosphere - The following task from radiophysics was considered [7]. There is a system of 16 high-frequency antennas which is used for investigating the properties of ionosphere. The problem is to separate 2 types of signals – “positive” which are reflected by free electrons in ionosphere and carry useful information about ionosphere structure, and “negative” which passed through ionosphere without reflection. The electromagnetic signals are characterized by a set of 17 pulsations each having two attributes. Hence the total number of features is 34.

Credit – credit card confirmation. Credit cards were described by 15 real or k-valued (2/3 of total amount of features) features. 342 objects were used for training.

In the table below there are represented recognition qualities of NNLC and each of basic NNs.

As the table shows results of NNLC are close to best ones of its basic NNs and sometimes are even better.

| *Algorithm* | *Breast* | *Housing* | *Ionosphere* | *Credit* |
|---|---|---|---|---|
| *NN1* | *94.6* | *68.9* | *84.6* | *80.2* |
| *NN2* | *94.6* | *68.9* | *84.6* | *80.2* |
| *NN3* | *94.6* | *68.9* | *84.6* | *80.2* |
| *NN4* | *94.1* | *55.7* | *84.6* | *75.6* |
| *NN5* | *92.1* | *<u>72.7</u>* | *84.8* | *83.6* |
| *NN6* | *92.7* | *67.8* | *89.6* | *76.7* |
| *NN7* | *<u>95.2</u>* | *<u>70.8</u>* | *85.7* | *83.6* |
| *NN8* | *<u>95.5</u>* | *68.6* | *85.7* | *84.8* |
| *NN9* | *91.8* | *57.2* | *85.7* | *79* |
| *NN10* | *92.4* | *65.5* | *77.5* | *79* |
| *NNLC* | *94.6* | *69.7* | *91.8* | *83.6* |

## Acknowledgements

The authors are glad to acknowledge support of the following organizations for execution of the described research: INTAS (projects 03-56-182 inno, 04-77-7076, 03-55-1969 YSF), RFBR (projects 05-07-90333, 06-01-00492, 05-01-00332). The work has been also supported by the project 2.11 of RAS Presidium's program N14, N16 and N17.

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