Neural Network Model for Transient Ischemic Attacks Diagnostics

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Abstract: *In this paper the neural network model for transient ischemic attacks recognition have been addressed. The proposed approach is based on integration of the NPCA neural network and multilayer perceptron. The dataset from clinic have been used for experiments performing. Combining two different neural networks (NPCA and MLP) it is possible to produce efficient performance in terms of detection and recognition transient ischemic attacks. The main advantages of using neural network techniques are the ability to recognize 'novel" TIA attack instances, quickness and ability to assist the doctor in making decision.*

***Keywords*:** Transient ischemic attacks, multilayer perceptron, Nonlinear PCA neural network, attacks recognition.

1. INTRODUCTION

Nowadays the use of Artificial Intelligence has become broadly applied in medicine. Every year in medical journals are issued over 500 academic publications concerning artificial neural networks in medical applications [1]. In accordance with published literature the artificial neural networks are powerful tool for automatic diagnostics of disease with potential to support clinical decision making. The medical diagnostics is complicated task that needs to be executed accurately and efficiently. It consists on detection of a disease from many factors or symptoms. Unfortunately the medical specialists very often may not enough experience to deal with certain high-risk diseases. Insufficient of medical specialist has increase the mortality of patients suffered from various diseases. So, for instance, the diagnosis of transient ischemic attacks (TIA) by primary care doctors was correct only in 30% cases [2]. Therefore automatic medical decision support system is of great importance for increasing quality of medical diagnostics.

There are different techniques to initial diagnostics TIA: neuropsychological testing, statistical approach, artificial intelligence approach [3-8]. The main disadvantage of neuropsychological testing is correlation on doctor qualification and low accuracy. The statistical approach demands large database. The artificial intelligence techniques use neural networks, genetic algorithm, fuzzy logic or combination abovementioned approaches. Such a technique is characterized high accuracy and demands not too big data set in comparison with statistical approach. Therefore artificial intelligence techniques can be appropriate tool for TIA detection and recognition. In this paper we propose neural network model for TIA detection and recognition. Neural networks technique is used to reduce the diagnostic time and the number of misdiagnosis, as well as to assist the doctor in making decision. The database from the republican scientifically-practical centre of neurology and neurosurgery was used.

The efficiency of the proposed neural network model in detection and recognition transient ischemic attack is illustrated by the experimental results.

The paper is organized as follows. A brief review of related works is given in Section 2. The basic information about transient ischemic attacks is presented in Section 3. Section 4 describes patient's data. The proposed neural network model for TIA recognition is detailed in sections 5, 6 and 7. In Section 8 the experimental results are described. Finally, concluding remarks are made in the last section.

2. RELATED RESEARCHES

At present time there exist different approaches to preliminary diagnostics of TIA. Neuropsychological testing is used for initial evaluation of TIA very often. Subsets of neurologic examination consist of cranial nerve testing, speech testing, somatic sensory testing, cerebellar system etc. [3]. However neuropsychological testing greatly depends on doctor qualification and therefore is very subjective.

The recognition tool for transient ischemic attack is described in [4]. The authors applied multivariate logistic regression using ROC (receiver operating characteristic curves) analysis to develop clinical scoring system. The data base from West Glasgow Stroke Registry was used, which contains approximately 225000 peoples. The nine variables (age, headache, diplopia, LOC/pre-syncope, seizure, speech abnormalities, unilateral limb weakness, facial weakness, history of TIA) with corresponding regression coefficients were obtained after regression analysis. To calculate the total score all coefficients should be summed. Using ROC curves was identified TIA, if total score >6.1. Such a system correctly identified 85% of patients with a cerebrovascular diagnosis and 54% with a non-cerebrovascular diagnosis. However such an approach demands the big database.

The neural networks for Ischemic Stroke are presented in [6]. The proposed models were developed for rapid classification into the following outputs: no event, TIA or stroke in left carotid, right carotid, verterobasilar. The questionnaire from asymptotic carotid atherosclerosis study (ACAS) was used as the input data. The 6 sections of the questionnaire contain the following data: loss or change of speech, loss of vision, double vision, numbness or tingling, paralysis or weakness, spells of dizziness or loss of balance. Each input pattern consists of numbers 0 or 1 from questionnaire. The multilayer perceptron was used for the each section of the questionnaire. As an example, the network for double vision consists of 4 inputs and 5 outputs. Three outputs correspond to case - no event and the other two - to stroke or TIA.

In [7-8] is described the backpropagation neural networks for the prediction of thrombo-embolic stroke. The architecture of neural network consists of 20 input units, 10 hidden and 10 output units. The following parameters were used as the input: hypertensive, diabetes, myocardial, blood cholesterol, left arm and left leg, etc. The output units shows the various categories of stroke diseases: TIA, left hemiplegia, right hemeplegia, dysphasia, monoplegia, left hemianopia, aphasia, right hemianesthesia, dysphasia, and quadriplegia. The prediction accuracy is 78,52% using training set and 90,61% using testing data set.

The mentioned above neural networks approaches are differed each from other used input and output data, as well as database of patients. Therefore is very difficult to compare different approaches.

3. TRANSIENT ISCHEMIC ATTACKS

A transient ischemic attacks (TIA) is a transient episode of neurological dysfunction caused by focal brain, spinal-cord or retinal ischemia without acute infarction [3]. It is result of temporary reduction or cessation of cerebral blood flow in a specific neurovascular distribution due to low flow through a partially occluded vessel, an acute thromboembolic event, or stenosis of a small penetrating vessel. Transient ischemic attacks are named also thrombo-embolic stroke. After TIA are increased the risk of early acute stroke. So, for instance, the early risk of stroke following TIA is approximately 4-5% at 2 days and as high as 11% at 7 days [3]. The patients after TIA should undergo detailed diagnostic at the nearest time (within 24 hours), namely, computed tomography or magnetic resonance imaging evaluation. It can prevent further negative development of disease, which can lead to acute stroke. Therefore the preliminary diagnosis of TIA is of great importance for prevention of acute stroke. However research has shown a high rate of misdiagnosis of TIA. So, for instance, the diagnosis of TIA by primary care doctors was correct only in 30% cases [2]. Improvement of diagnostic accuracy of TIA from primary doctors would reduce the number of acute stroke, clinic waiting times and facilitate rapid assessment.

4. PATIENT DATA

The clinical observations data from the 5-th city hospital (Minsk) have been collected about 114 patients who have symptoms of different TIA diseases. Vector of input data consist of certain amount of signs-predictors which have been selected during long-term studies. As a result 38 signs-predictors are used for each patient. These signs and amount of their gradation are presented in the table 1. The transient ischemic attacks can be classified into 3 classes of subtypes TIA: TIA1 (atherothrombotic subtype), TIA2 (cardioembolic subtype) and TIA3 (hypertensive subtype). The data set contain 28 patterns of TIA1, 25 patterns of TIA2, 27 patterns of TIA3 and 34 patterns of normal state without TIA. It should be noted, that generating of TIA data has been performed by doctors and neurologists of high qualification.

Table1. Structure of the data

№	Parameters	Number of gradations
1	Age	6
2	Sex	2
3	Residence	5
4	Education	4
5	Trade	4
6	Conflicts on job	3
7	Residence change for last 10 years	5
8	Trade change for last 10 year	7
9	Features of night dream	4
10	Sleeplessness	3
11	Heredity on pathology brain vessels	3
12	Heredity on other diseases	3
13	Arterial hypertensia	4
14	Diastolic pressure	3
15	Auscultation hearts	5
16	Heart borders	3
17	Changes on electrocardiogram	3
18	Heart pain	4
19	Cardiac arrhythmia	4
20	Chronic bronchitis	3
21	Chronic hepatocholecystitis	3
22	Chronic gastritis	4
23	Nephrolithiasis	3
24	Osteochondrosis	4
25	Meteodependence	5
26	The alcohol use	3
27	Smoking (amount)	3
28	Smoking (age)	4
29	Working capacity	3
30	Irritability	3
31	Memory decline (degree)	3
32	Memory decline (occurrence time)	3
33	Vision acuity decrease (degree)	3
34	Vision acuity decrease (occurrence time)	4
35	Vision disorders	3
36	Headache (nature)	4
37	Headache (occurrence time)	4
38	Dizziness	4

Collected data from hospital about patients with different TIA diseases create the training data set for neural network model.

5. PROPOSED MODEL

Let's examine the neural network model for detection and recognition transient ischemic attacks. The proposed model is based on two different neural networks. The 38 features mentioned above are used as input vector, which contains information about patient. The main goal of IDS is detection and recognition type of attack. The output data of neural network model represent the 4-dimensional vector, where 4 are number of TIA classes plus normal state. The data processing consists of two stages. The first stage of data processing is feature selection. The important question concerning input data is the following: which input parameters are really useful and contribute significantly to the performance of neural networks? The backward stepwise method or genetic approach for feature selection is used as a rule in papers devoted TIA diagnostics [4,7]. In this work nonlinear principal component analysis (NPCA neural network) for significant information from data extraction and dimensionality reduction is proposed. It transforms 38-dimensional input vectors into 12-dimensional target vectors.

The second stage of data processing is to detect and to recognize transient ischemic attacks. Compressed on the previous step data contain the useful information from input data and are used as inputs on the second stage of data processing. The multilayer perceptron (MLP) is applied for transient ischemic attacks recognition. MLP processes compressed data to define classes of transient ischemic attack or normal state. Output layer includes four units: three for every class of pathology and one for normal state.

Thereby the neural network model consists of two neural networks: NPCA and MLP (Fig. 2).

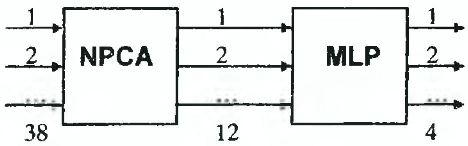

Fig.2 – Architecture of the system

Before entering to NPCA the data should transform by the following way:

$$x_i^k = \frac{x_i^k - \mu(x_i)}{\sigma(x_i^k)}, \quad (1)$$

$$\mu(x_i) = \frac{1}{L}\sum_{k=1}^{L} x_i^k, \quad (2)$$

$$\sigma(x_i^k) = \frac{1}{L}\sum_{k=1}^{L}(x_i^k - \mu(x_i))^2, \quad (3)$$

where L is training data set dimension.

After training the neural network model have ability to transient ischemic attacks recognition.

6. NPCA NEURAL NETWORK

In this section is presented neural network based nonlinear principal component analyses technique, namely, NPCA neural network.

Let's consider an autoencoder, which is also called recirculation or replicator neural network as it is shown in Fig. 3. It is represented by multilayer perceptron, which performs the nonlinear compression of the dataset through a bottleneck in the hidden layer. As we can see the nodes are partitioned in three layers. The bottleneck layer performs the compression of the input dataset.

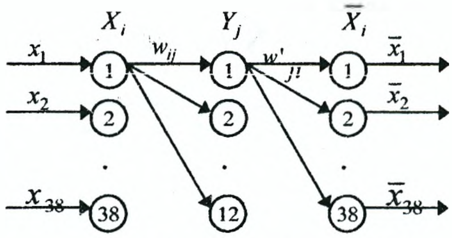

Fig. 3 – NPCA neural network.

The j-th hidden unit output is defined as

$$y_j = F(S_j), \quad (4)$$

$$S_j = \sum_{i=1}^{38} w_{ij} \cdot x_i, \quad (5)$$

where F is activation function; S_j is weighted sum of the j-th neuron; w_{ij} is the weight from the i-th unit to the hidden j-th unit; x_i – i-th unit input.

The i-th output unit is given by

$$\bar{x}_i = F(S_i), \quad (6)$$

$$S_i = \sum_{i=1}^{12} w'_{ji} \cdot y_j. \quad (7)$$

Let's consider the NPCA neural network training. The backpropagation technique for training NPCA is used. The weights are updated iteratively in accordance with the following rule:

$$w_{ij}(t+1) = w_{ij}(t) - \alpha \cdot \gamma_j \cdot F'(S_j) \cdot x_i, \quad (8)$$

$$w'_{ji}(t+1) = w'_{ji}(t) - \alpha \cdot (\bar{x}_i - x_i) \cdot F'(S_i) \cdot y_j \quad (9)$$

where γ_j is error of j-th hidden unit:

$$\gamma_j = \sum_{i=1}^{38} (\bar{x}_i - x_i) \cdot F'(S_i) \cdot w'_{ji}, \quad (10)$$

and $F'(S_j)$ – a derivative of nonlinear activation function on the weighed sum.

The weights data in the hidden layer must be reorthonormalized by using the Gram-Schmidt procedure, as follows:

1) The first vector of the orthonormal frame is chosen as:

$$w'_1 = [\frac{w_{11}}{|w_1|}, \frac{w_{21}}{|w_1|}, \ldots, \frac{w_{n1}}{|w_1|}], \quad (11)$$

where

$$|w_1| = \sqrt{w_{11}^2 + w_{21}^2 + \ldots + w_{n1}^2}. \quad (12)$$

2) The subsequent weight vector is defined by the following recurrent formulas:

$$w_i = w_i - \sum_{j=1}^{i-1}(w_i^T \cdot w'_j) \cdot w'_j, \qquad (13)$$

$$|w_i| = \sqrt{w_{1i}^2 + w_{2i}^2 + \ldots + w_{mi}^2}, \qquad (14)$$

$$w'_i = [\frac{w_{1i}}{|w_i|}, \frac{w_{2i}}{|w_i|}, \ldots, \frac{w_{mi}}{|w_i|}], \qquad (15)$$

where i=2..12.

After training the NPCA neural network can perform orthogonal compression of input data set.

7. MULTILAYER NEURAL NETWORK

As it has been mentioned before the architecture of the neural network for TIA recognition used in this paper is the multilayered feed-forward network with 12 input units, 5 hidden units and 4 output units. The activation function for each unit of hidden and output layers is sigmoid function. The number of hidden layer corresponds to dimension of compressed data and the number of output layer corresponds to number of classes TIA and normal state. The number of hidden layer was defined by experimental way. The backpropagation algorithm is used for training multilayer perceptron. Output value of a neural network is the number in a range from 0 up to 1 which characterizes probability of diagnostics for corresponding class of TIA.

8. RESULTS AND DISCUSSION

For training and testing proposed neural network model the clinical observations of 114 patients with 38 parameters have been used. The clinical data set contain 28 patterns of TIA1, 25 patterns of TIA2, 27 patterns of TIA3 and 34 patterns of normal state without TIA. At the beginning the experiments with NPCA neural network have been performed using backpropagation algorithm together with the Gram-Schmidt procedure.

Let's consider the mapping of input space data for normal state and TIA classes of attack on the plane of two principal components (Fig.4).

As can be seen from the Fig. 4 the data, which belong different types of attacks are located in compact areas.

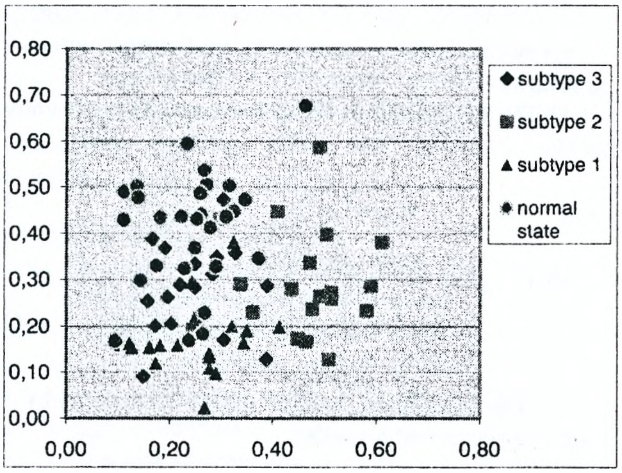

Fig. 4 – Data Visualization on plane of two principal components.

The mapping of input space data for normal state and transient ischemic attacks on the plane of three principal components is shown in the Fig.5.

The all data set have been divided into 2 groups: the training data set and testing data set. The recognition accuracy is 100% using training data set and 78% using testing data set (Table 2).

Table 2. Recognition Accuracy

Number of patterns in training data set	Number of patterns in testing data set	Recognition accuracy on training data set	Recognition accuracy on testing data set
90	24	100%	78%

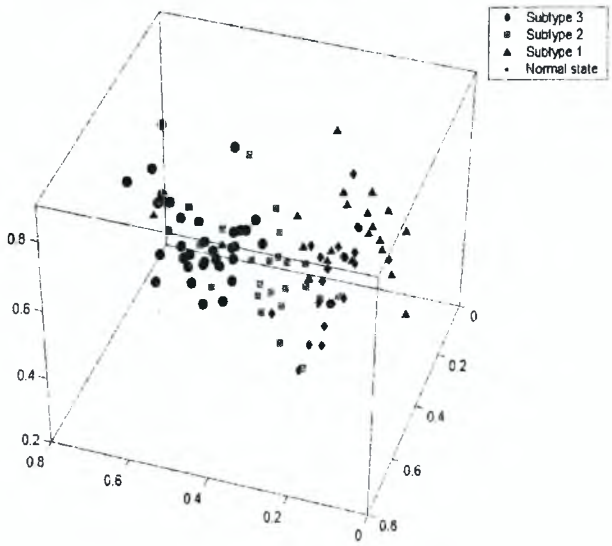

Fig. 5 – Data Visualization on plane of three principal components.

Table 3. Distribution of probability depending on class attacks

Patient	TIA1	TIA2	TIA3	NORMA
1	18.1%	0.1%	13.6%	**68.2%**
2	6.4%	0%	**93.6%**	0%
3	5.1%	12.1%	**64.5%**	18.3%
4	3.6%	**72.6%**	23.8%	0%
5	1.1%	**96.0%**	2.8%	0.1%
6	**94.4%**	0.6%	4.2%	0.8%
7	9.6%	16.8%	0.1%	**73.4%**
8	15.2%	1.6%	1.5%	**81.7%**
9	20.8%	10.0%	0%	**69.2%**
10	8.7%	0.4%	24.1%	**66.7%**

Distribution of probabilities depending on type of attack for 10 patients is presented in table 3.

9. CONCLUSION

In this paper the neural network model for transient ischemic attacks recognition have been addressed. The proposed approach is based on integration of the NPCA neural network and multilayer perceptron. The dataset from clinic have been used for experiments performing. Combining two different neural networks (NPCA and MLP) it is possible to produce efficient performance in terms of detection and recognition transient ischemic attacks. The main advantages of using neural network techniques are the ability to recognize 'novel" TIA attack instances and quickness of work which is especially important in the real time mode. Neural networks technique permits to reduce the diagnostic time and the number of misdiagnosis, as well as to assist the doctor in making decision.

10. REFERENCES

[1] Paulo J. Lisba, Azzam Taktak. The use of artificial neural networks in decision support in cancer: A systematic review, *Neural networks* 19 (2006), p. 408-415.

[2] A. McNeill. How Accurate Are Primary Care Referral Letters For Presumed Acute Stroke? *Scottish Medical Journal*, V. 53, № 4, 2008. p. 11-12.

[3] J. Easton et all. Definition and evaluation of transient ischemic attack. *Stroke (Journal of the American Heart associations)*, 2009.

[4] J. Dawson et all. A recognition tool for transient ischemic attack, *O J Med*, 192, p. 43-49, 2009.

[5] P. Lisba. A review of evidence of health benefit from artificial neural networks in medical intervention, *Neural networks* 15 (2002), p. 11-39.

[6]. R. Barnes, J. Toole, J. Nelson, V, Howard. Neural networks for ischemic stroke, *Journal of stroke and cerebrovascular diseases*, Vol.15, No.5, p. 223-227, 2006.

[7] D. Shanthi, Dr.G. Sahoo, Dr.N. Saravanan. Input feature selection using hybrid neuro-genetic approach in the diagnosis of stroke disease, *IJCSNS International Journal of Computer Science and Network Security*, Vol.8 No.12, December 2008, p.99-107.

[8] D. Shanthi, Dr.G. Sahoo, Dr.N. Saravanan. Designing an artificial neural network model for the prediction of thrombo-embolic stroke, *International journal of biometric and bioinformatics*, Vol.8, No.1,2008, p. 10-18.