inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 7.4

CLASSIFICATION ABILITY OF NEURAL NETWORKS IN AUTOMATIC ANALYSIS OF SELECTED VIBROACOUSTIC PROCESSES

R. Tadeusiewicz, W. Wszolek, T. Wszolek

University of Mining and Metallurgy, Al. Mickiewicza 30, 30-059, Krakow, Poland

Tel.: +48 (12) 6172002 / Fax: +48 (12) 6334672 / Email: rtad@biocyb.ia.agh.edu.pl

Keywords:
VIBROACOUSTIC, NEURAL NETWORK, PATTERN RECOGNITION

ABSTRACT
The present work is aimed at the evaluation of neural network's ability of automated analysis and evaluation of vibaroacoustic patterns. The need of using neural networks follows from the fact, that in many technological and biological problems no strict premises are available, which could be used in a fully algorithmic evaluation of a vibroacoustic signal. It is well-known that the artificial intelligence methods, and in particular the neural networks can be useful in such tasks, but up to now none was able to formulate a detailed evaluation of the degree of their utility in the analysis of the vibaroacoustic signal deformation level. The present work deals with this subject and using the examples taken from technological and medical diagnosis it formulates evaluations of the network's classification abilities in tasks related to analysis of selected processes.

1 - INTRODUCTION
It is generally known that the neural network technique can be a favourable alternative for the traditional techniques of pre-processing and analysis of vibracoustic signals. Still substantial evaluations of the degree of network utility in such tasks are still missing. The aim of the present work is to determine the classification abilities of neural networks in tasks related to extraction of information suitable for the diagnostic needs from the acoustic signal. The present work also determines to what degree the neural network technique can be useful in modelling of natural processes of reception and analysis of vibroacoustic signals generated in the course of the analysed technological and biological processes.
An additional purpose of the work is a construction of a unified approach to the solution of problems encountered in the fields of technological and medical diagnosis, including the problems of preliminary signal processing, which in many cases can be also realised using neural networks.

2 - PARAMETRIZATION OF THE VIBROACOUSTIC SIGNAL
Vibroacoustic signal analysed in the present work is usually treated as a residual process taking place in the course of the main technological or biological process (e.g. the noise of a flying plane, vibration and noise of a transmission gear, distorted speech signal etc.), however its proper evaluation and classification can contribute very essential information of diagnostic, prognostic or control nature. In such tasks a fully automated elaboration of recognition better than recognition done by a trained specialist is usually not possible. It follows from the fact that the neural network techniques are still rather poorly developed in comparison with the possibilities of the human brain. Still there is a need for evaluation of what is their actual classification ability.
The basis for a success in the recognition (classification) process is the choice of a proper space of features, which can be used as a method for carrying out a unique classification of the above mentioned groups. Properly defined space of features in necessary for elaboration of a correct network learning process, and what follows for achievement of the expected results (the problem of the preliminary signal processing has been skipped in the present work as it was the subject of papers of other authors [5]).
During the choice of the feature space in the further considerations will take place a very essential problem is a correct construction of the space, i.e. such, which does not lead to contradictions between

the nature of the task and the topology of the selected feature space. The features have to be selected in such a way, which ensures the best characterisation of the interesting diagnostic features, at the same time being least sensitive to the signal variety resulting from its natural structure.
The application of the proposed methodology has been presented in the following examples taken from the field of technological and medical diagnosis. In the present research a triple-layer network has been used, with the feedforward type organisation and elements exhibiting non-linear transfer functions of sigmoidal characteristics, connected according to the rule of full connection between the elements of the input layer and the elements of the next network layer.

3 - TECHNOLOGICAL DIAGNOSIS

One of the presently applied diagnostic methods for evaluation of the transmission line technical condition or the equipment quality is a measurement of the RF interference level. The acoustic signal is usually used as a first syndrome of the line damages detected during routine technical inspections of the line. The correlation of the acoustic signal generated by the line with the intensity of the corona process is sometimes even better than the correlation of the RF interference [1]. The basic difficulty in utilisation of the acoustic signal is the identification of the source for a given signal. The method has been tested in laboratory conditions, by simulating contamination's and various types of the conductor's damages encountered in real conditions, for the two and three conductor groups of the actual size. The studies included also various types of insulator strings. The devices (studied elements) have been supplied with a voltage U from the range between 150 and 325 kV. The studies have been carried out for perfect conductors and for several types of simulated damages and pollution's. During the study an attempt has been made to construct a model of the process based on the function approximation using a limited number of experimental data [2], using neural networks.
For the input layer 98 neurons have been selected, while the output layer contained 2 neurons. The size of the hidden layer has been a subject of the study. Its size affects the quality of realisation of the tasks that the network was expected to perform. As a criterion of correctness of the learning process the root-mean-square error has been selected, given by the following formula:

$$RMS\ Error = \sqrt{\frac{\sum_{i=1}^{N}(y_i - z_i)^2}{N}} \tag{1}$$

Where y the value at the network's output, z the pattern, N number of elements of the learning set.
The learning and test sets have been constructed using the sets of noise spectra containing the curves obtained for the 2×225 mm^2 conductor bundle. Graphical presentation of the typical spectra is shown in Fig. 1.
Typical dependence of the learning process error, for hidden layer containing 15 elements, is presented in Fig. 2.
The results obtained during learning and testing of the network have been listed in Table 1.

No	**NN architecture**	**Epochs**	**RMS error**	**Percent of correct recognition**	
				Learning set	**Test set**
1	$98 \times 12 \times 2$	2070	0,299	91,6	87,1
2	$98 \times 15 \times 2$	2000	0,194	95.1	92,7
3	$98 \times 20 \times 2$	2200	0,256	90,3	85,7

Table 1: Results of classifications.

4 - MEDICAL DIAGNOSIS

Adverse results of some forms of laryngological treatment are sometimes most harmful in the aspect regarding the process of speech signal deformation. By removing [extracting] partially or totally some elements of the patient's glottis the physician saves the patient's life, at the same time destining the patient to a heavy disability connected with a partial or total loss of the communication abilities by means of the speech signal. It often happens that similar therapeutic effect can be achieved using various therapies. The studies undertaken here are aimed at determination, which of the treatments is the best in the aspect of speech pathology.
The research material included the following groups of patients:

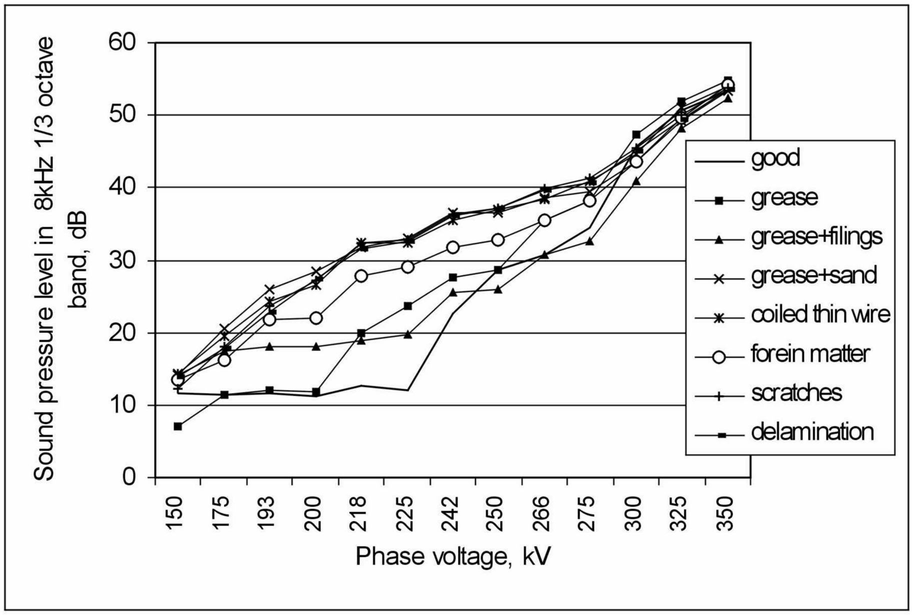

Figure 1: The voltage dependencies of the acoustic pressure in the 2-10 kHz frequency bands.

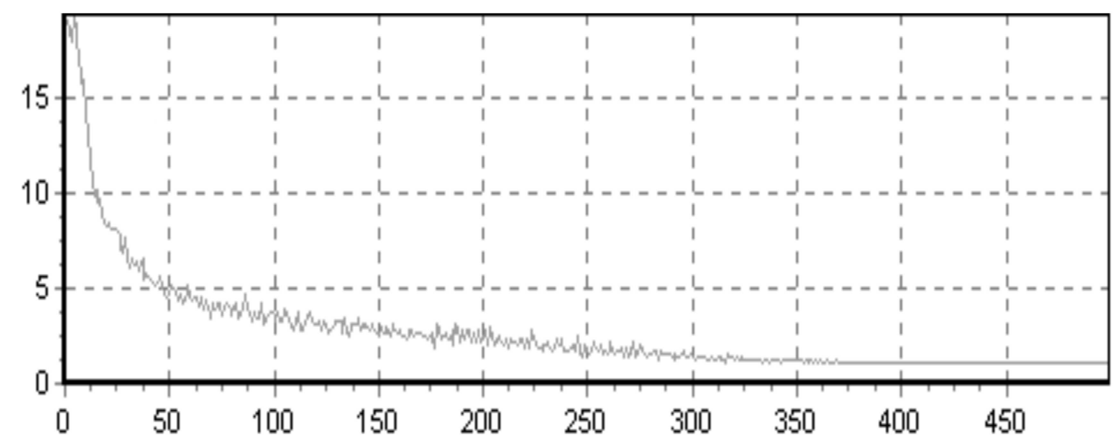

Figure 2: An example of the plot of the RMS error in time dependence (for first 500 epoch).

- I – Cordectomy,
- II – Hemilaryngectomy,
- III – Fronto-lateral laryngectomy
- IV – Subtotal laryngectomy
- V – Control group

Both the patients and the persons in the reference group pronounced three times the same test consisting of vowels (A, E, I, U). For the space of features the spectral moments and the spectrum power coefficients have been selected.

$$X =< M_{0A}, M_{1A}, M_{2A}, WS_{SA}, WS_{1A}, WS_{2A}, WS_{3A}, M_{0E}, M_{1E}, M_{2E}, WS_{SE}, WS_{1E}, WS_{2E}, WS_{3E}, M_{0I}, M_{1I}, M_{2\ I}, WS_{SI}, WS_{1I}, WS_{2I}, WS_{3I}, M_{0U}, M_{1U}, M_{2U}, WS_{SU}, WS_{1U}, WS_{2U}, WS_{3U} > \quad (2)$$

The presented space of features was the basis for construction of the learning and test sets. Also in this part of the study the number of neurons in the hidden layer has been selected during the network's learning process. The initial number of neurons in the hidden layer has been assumed using the equation [4]:

$$N = \frac{N^i + N^o}{2} \tag{3}$$

Where N^i the number of neurons in the input layer, N^o the number of neurons in the output layer.
The best results have been achieved for 17 neurons in the hidden layer (input layer − 28 neurons, output layer − 5 neurons). The course of network's learning process has been presented in Fig. 3 , and the results of the network action are shown in Fig. 4.

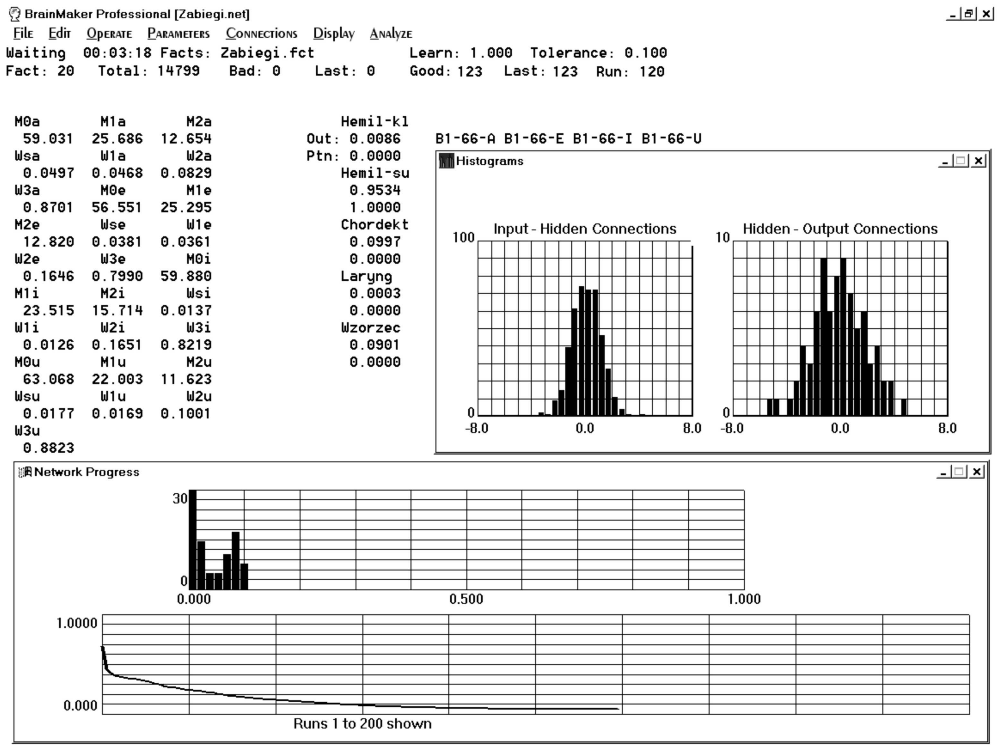

Figure 3: An example of the learning process.

5 - CONCLUSIONS

The presented method of damage recognition for the overhead UHV transmission lines using neural networks shows their ability for signal classification in tasks related to the technological diagnosing. Other research carried out has shown that a neural network is able to perform a patient's classification using their speech signal. In both tasks considered the performance of the selected and trained network was found fully satisfactory. It has been shown that the correctness of classifications obtained by using neural networks in the selected tasks exceeded 80% in the average. However this classification efficiency could not be increased, neither by a long search for an optimal network structure nor by application of very advanced techniques of preliminary signal processing. It means, that for tasks in which the achieved network's quality level can be found satisfactory, the application of a neural network can en a convenient and effective way to solve the analysed problem. However for the cases where the expectation regarding the results reliability is considerably higher further search for better methods seems necessary.
It is worth adding that the described research has also a practical aspect. The suggestions obtained as the result of the research can be useful in construction of the equipment used for automated recognition (diagnosing) in specific technological and medical problems.

REFERENCES

1. **M.G.Comber, R.J.Nigbor, L.E.Zaffanela** , *Transmission Line Reference Book - 345kV and Above*, Second Edition EPRI, pp. 267-272, 1982

2. **Tadeusiewicz R**, *Neural Networks* , Akademicka Oficyna Wydawnicza RM, 1993

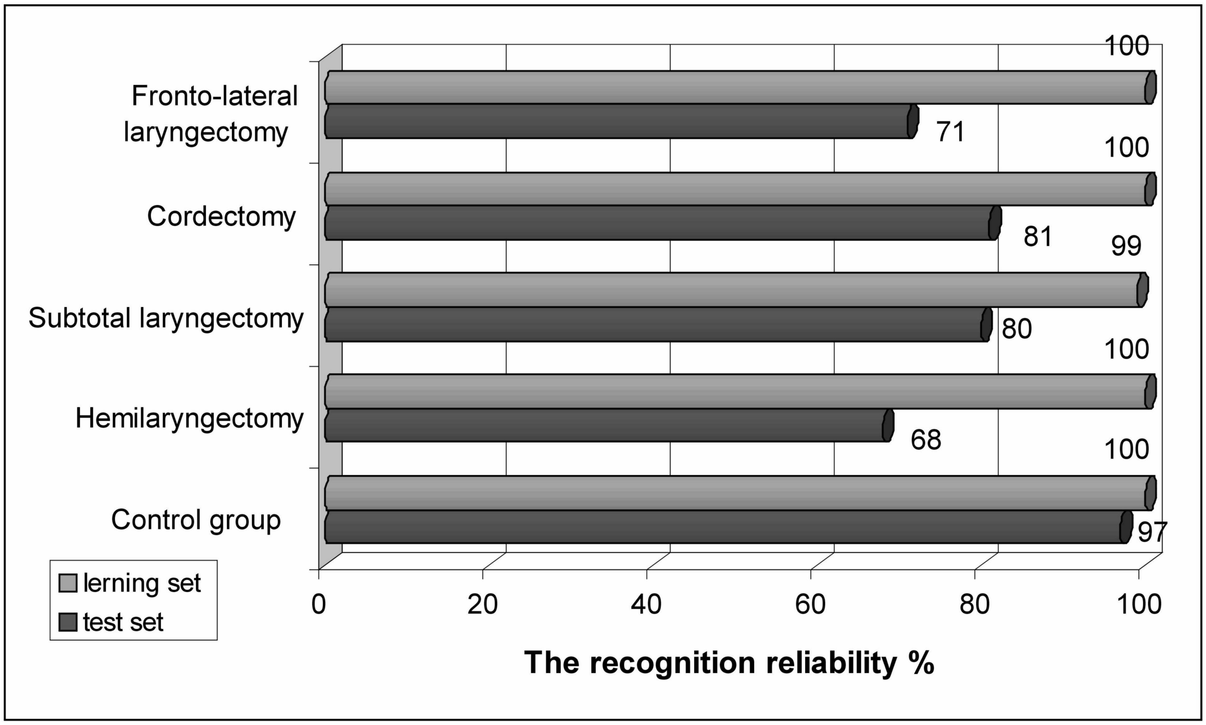

Figure 4: The recognition reliability.

3. **Engel Z., Wszolek T**, Audible Noise of Transmission Lines Caused by the Corona Effect, Analysis, Modelling, Prediction, *Applied Acoustics*, Vol. 47(2), pp. 149-163, 1996

4. **Jeannette Lawrence**, *Neural Networks* , California Scientific Software Press, Nevada City, 1993