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AN EXAMPLE OF USING SOM NEURAL NETWORK IN IDENTIFYING VIBRATIONS

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Abstract: *The paper describes the application of self-organizing (Self Organizing Maps - SOM) neural networks as models to identify the causes of vibration or vibration type of imbalance. The proposed network model presented in this paper can serve as a template for identification of other types of vibratory imbalance and may be integrated within the CMMS (Computerized Maintenance Management System) as an expert system that serves as a support for decision making.*
Keywords: *vibration, neural network, Self Organizing Maps*

1. INTRODUCTION

The critical task in maintaining complex vibration systems is to make a right diagnosis of a system in a real time. Since a large number of information is concurrently collected from different sources, the human supervision and interpretation of the data collected in that way is rather difficult. The introduction of computerized systems of maintenance, the so called *CMMS* (*Computerized Maintenance Management System*) can solve that problem to a large extent. Yet, one particular problem still persists: the problem of interpreting the collected data and making decisions based on the same, which is still in the scope of human experts with long practical experience, that as a rule are always lacking. Recently, from the sphere of unsolved problems the problem of the lack of practical experience is tried to be solved by the methods of artificial intelligence which main objective is the storage and use of human expert knowledge. The methodology of neural network as one of the methods of artificial intelligence is the closest to that objective. Generally, the operation of neural network is based on the fact that it is not necessary to know the algorithm for solving the problem, by which human thinking is tried to be imitated. And exactly that gave us the motive for writing this paper. Namely, in a vibratory technique there is an experiential problem in interpreting vibratory signals such as harmonics, frequency spectra, vibratory speed, definition of the type of vibratory imbalance etc. (Cyril, 2002; Davis, 1998; Lumme, 1998). The presumption of the authors of the paper is that by use of the so called Self Organizing Neural Maps (*SOM*) the problem of recognizing or identifying the type or kind of vibratory imbalance can successfully be solved in the following way. The data of the frequency characteristics for a known kind of vibratory imbalance (e.g. console) would be experimentally determined and used as samples for learning the *SOM* neural network with the aim of later recognizing or classification as compared to other types of imbalances. The principle of operation of the model is presented in Figure 1. The learned *SOM* – network would comprise the data for the comparison by moving inside the whole frequency spectrum with a certain step. The included data are compared to previously known (learned) data (in Fig.1. shown by shaded rectangle), thus recognizing or classification of the type of vibratory imbalance being automatized. The concept of a Self-Organizing Map - *SOM* was given by Kohonen in 1981 (Kohonen, 1990; Hagan & Demuth, 2002; Sun & Kaveh & Tewfik, 2000). The Self-Organizing Neural Map has M x N neurons, where each neuron or the adjacent group of neurons corresponds to the specific input sample. During the process of learning on a certain site of the hidden layer of SOM network a group of active neurons is formed having a tendency for the different input data sample to become a template, on which basis the SOM network, after finishing the process of learning, would make comparisons i.e. estimate the new input data and samples, respectively. In Fig. 2. the principal scheme of self-organizing neural network operation is presented. Here the neurons (marked with circlets), whose weighted vectors correspond by dimension (number of rows and columns) with the input data vector, are arranged in groups by verticals of a hidden layer. Before starting with the process of learning the algorithm of the *SOM* network is determined by the initial, the so called '*winning neuron*', which has a minimal weighted distance from the input vector. During the learning process the weighted vector of the input data adjusts the *SOM* algorithm in such a way that the data are grouped (mapped) in the closest possible neighbourhood of the winning neuron. When the process of learning the *SOM* network ends, we get the elements of the input data vector which are grouped (mapped) around the different neurons with associated weighted vectors. Most elements of the input vector are always set in the surroundings (neighbourhood) of the winning neuron. In our case, the weighted vector of the winning neuron is represented by a certain type of vibration imbalance.

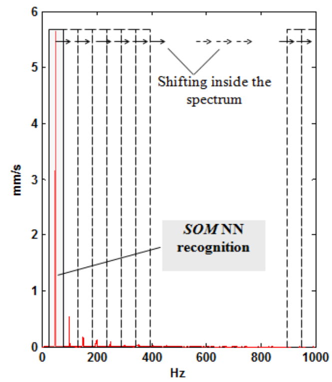

Fig. 1. Operating principle of the SOM neural network for recognizing vibration samples

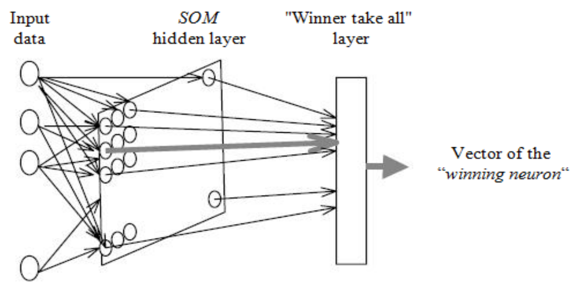

Fig. 2. Operating principle of Self-Organizing (SOM) neural network

2. EXPERIMENTS

As stated in the introduction, the aim of this paper is to find a suitable model of neural network which would be able to recognize the type of vibration imbalance within a given frequency spectrum. Here we deal with a console device loading, which causes certain vibration imbalance. With the relevant equipment (Fig. 3.) two sets of different data on frequency speeds were collected. The first set includes the data on frequency speeds in the case of loading with associated ballast mounted on the simulator (electromotive grinder). The second set of the data was created by mounting the additional mass of some 10 grams to the existing ballast. As shown in the diagram of the frequency domain (Fig. 3.), the total speed of vibrations for the first set is ~6 mm/s, which by ISO 2372 is between the unallowable and the illicit area for the devices from the group K, while for the second set the speed was ~18 mm/s which is a distinctly illicit area. The characteristics of the equipment and devices used during the experiments are the following:

1. Simulator of vibration imbalance: Electromotive grinder "*WALTER SLW 150 R*" (revolution/energy:2950 min^{-1}/150 W; loading: console -ballast).
2. Device for measuring vibrations: portable "*SCHENCK VIBROTEST 60"* (measuring type: Spectrum FFT; Frequency range: 10 Hz to 1 KHz; Sensor: AS - 06x/07x; Unit:mm/s, RMS Window:Hanning; Average: 4; Direction: vertically).
3. Software for data analysis: Xms Software (Brüel & Kjaer); Neural Network Toolbox (Mathworks).

The data on frequency speed collected for further analysis by a portable device *VIBROTEST 60* were sent to the computer by Xms software. As described below, due to its ability of recognising the samples, for identification of the vibration imbalance type the experiments with the model of self-organizing neural (*SOM*) network were carried out. The inputs to the network are the frequency speed and the output is a 10x10 matrix of neural weights (including also the "*winning neuron*") for recognizing i.e. the classification of the input sample. Both sets of collected data on frequency speed were gathered into one, the size of the input vector being 6400 x 1 of elements. Since the aim is to identify the console imbalance, the elements of the input vector are in the frequency range from 45 Hz to 105 Hz, because it is produced by the mentioned simulator. The learning parameter η of the *SOM* network is 0.1.

3. RESULTS

In Fig. 3. the original frequency spectra of initial and additional loading of the simulator are jointly presented. Since the simulator itself is by the mounted ballast already in a console imbalance (initial loading), an additional mass was deliberately added to the ballast (additional loading) to get the frequency sample for learning *SOM* neural network as representative as possible. In Fig. 3.a) it is evident that the simulated console imbalance of the simulator presented in the paper ranges within the limits of frequency speed from ~6 mm/s to ~18 mm and frequency interval from ~45 Hz to ~105 Hz (Fig. 3.b). As a measure for the successfulness of identification by the *SOM* algorithm a coefficient of correlation R was proposed. R is defined on the basis of two vectors: target value – T and estimated value – A. The first vector contains the locations of clusters (neurons) got when the input data are presented to the network on which it learned, and the second vector contains the locations of clusters got as an answer of the learned *SOM* network to old or new input data. R=1 in Fig. 4.a) because the old data on which it learned are presented to the network, and R=0.98323 in Fig. 4.b) because as an input new data on which it did not learn are presented to the network (entered 50% of noise in the data for case a)).

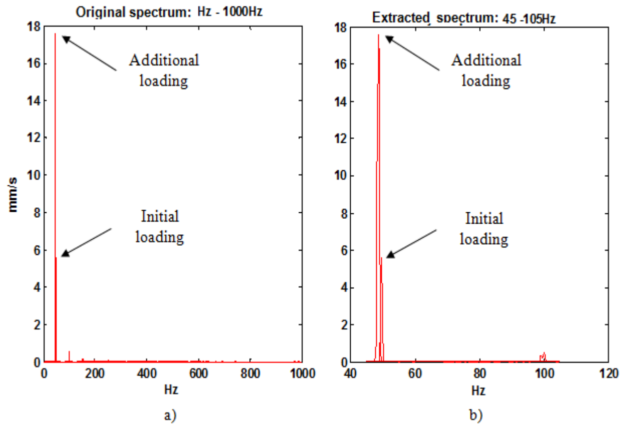

Fig. 3. Frequency characteristics a) 0 Hz to 1000 Hz b) 45Hz to 105Hz

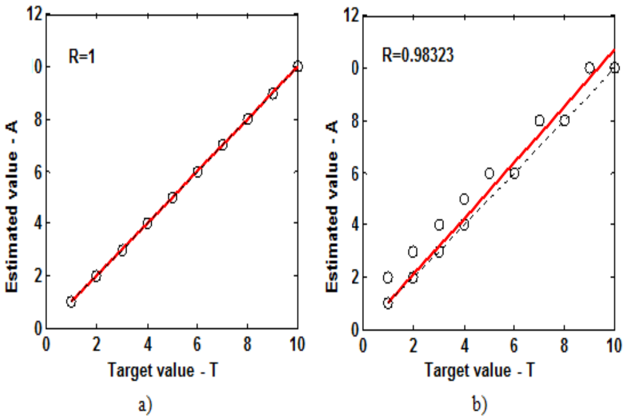

Fig. 4. Correlation of identifying the old a) and the new b) sample *by SOM neural network*

4. CONCLUSION

By comparing the coefficients of correlation R (Fig. 4.) as a measure for successfulness of identification the presumption of recognizing the samples of console vibration imbalance by the *SOM* neural network has been demonstrated. The proposed solution of the problem can be used as a template for identification, i.e. recognition of other types of vibration imbalances, too. In addition, the solution proposed can also be the part of *CMMS* (*Computerized Maintenance Management System*) expert system and used as a support to decision making.

5. REFERENCES

Cyril, M. H. (2002). *Harris' shock and vibration handbook*, 5st Edition, McGraw-Hill, ISBN: 0-07-137081-1, New York

Davis A. (1998). *Handbook of Condition Monitoring - Techniques and Methodology*, Chapman & Hall, 1st Edition, ISBN: 412613204, London

Hagan, M.T., & Demuth, H.B. (2002). *Neural Network Design*, PWS Publishing Company, ISBN: 0971732108, Boston

Kohonen, T. (1995). *The self-organizing maps*, Springer-Verlag, ISBN: 3-540-58600-8, Berlin

Lumme, V. E. (1998). *An online condition monitoring system using neural networks*, The 14th European Conference Euromaintenance '98, Proceedings p. 255-262, ISBN: 953-97615-0-6, October 1998, HDO, Dubrovnik

Sun, H. Kaveh M., & Tewfik, A. (2000). *Self-Organizing Map Neural Network for Transient Signal Classification in Mechanical Diagnostics*, IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP 2000, Vol. 6, p. 3891-3894, Istanbul