Application of Neural Networks for Calculation of Intensity of Traffic Noise Sources

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Introduction

Definition of types and noise intensity levels of traffic noise sources is a necessary step in noise mapping. The intensities of noise depend on a large number of parameters, such as the number and types of vehicles, speed of the vehicles, number of road lines, quality of road, road inclination, sound absorption and reflection by the surroundings, etc. Besides, some of the parameters cannot be easily quantified. The paper presents a procedure for calculation of intensity of sound sources by application of neural networks that learn on the examples of measurement data acquired in various traffic and environmental conditions. Both numeric data and fuzzy data, which describe characteristics that cannot be numerically expressed, are used in the procedure.

Analitical models for calculation of noise prediction

This paper presents a comparative analysis of analytical models and the designed neural network. There are numerous models for prediction of the contribution of vehicles in the total receipt of noise pollution in urban areas. These mathematical models are used to determine equivalent noise level (Leq) as the most representative physical variable quantifying noise emissions.

Mathematical models for prediction of traffic noise usually extract the functional relationship between the parameter of noise emission, Leq, and measurable parameters of traffic and roads. The classical functional relationships are based on the data measured through semi-empirical models, typically regression analysis [1], [2], [3], [4].

The mathematical models available in literature are:

Burgess

$$Leq = 55.5 + 10.2\log Q + 0.3p - 19.3\log(L/2) \quad dB(A) \quad (1)$$

Josse

$$Leq = 38.8 + 15\log Q - 10\log L \quad dB(A) \quad (2)$$

Fagoti

$$Leq = 10\log(N_c + N_m + 8N_{hv} + 88N_b) + 33.5 \quad dB(A) \quad (3)$$

NAISS

$$Leq = 10\log(N_c + 3.7N_{hv} + 1.9N_b) + 38.2 \quad 55dB(A) < Leq < 65dB(A) \quad dB(A) \quad (4)$$

$$Leq = 10\log(N_c + 11.7N_{hv} + 3.1N_b) + 44.3 \quad 65dB(A) < Leq < 75dB(A)$$

The parameters used in the mathematical models are:

- p - the percentage of heavy vehicles,
- L - the road width,
- Q - the total number of vehicles per hour,
- N_c - the number of light vehicles per hour,
- N_m - the number of motorcycles per hour,
- N_{hv} - the number of heavy vehicles per hour.
- N_b - the number of buses per hour

The total number of vehicles per hour, Q, is expressed as the equivalent number of cars and obtained, as before, under hypothesis that one heavy vehicle is equivalent to 6 light vehicles and one motorcycle to 3 light vehicles. Although these correlations are nonlinear they do not provide very accurate approximation of the trend followed by sound pressure level according to a certain number of physical parameters because any model includes the flow and composition of the road traffic which may be different than examined in urban areas.

Neural network

An artificial neural network is a computational tool inspired by biological neural systems. It is a massively parallel distributed processor with the ability to learn and generalize, i.e. ability to model complex relationships between inputs and outputs or find patterns in data. A neural network consists of an interconnected group of artificial neurons (nodes), organized into multiple layers (one input, one or more hidden and one output layer). These nodes are connected to each other via synapses (called the connections or links). The knowledge of the neural network is contained in the values of the connections weights [5].

Developed neural networks predict equivalent sound level (Leq) according to the input data set which contains a number of light vehicles, a number of heavy vehicles, road width and slope of the road. Three hundred input data sets were used for training, testing and validation of the neural network. Data sets are collected by systematic noise measurement in urban areas of Kraljevo. The training set is used to adjust the values of the connections weights, the validation set to prevent overfitting problem and the test set to evaluate the performance of the developed neural network [6].

Several artificial neural networks were developed using MATLAB computing software and two of them are presented in this paper. The first network contains one hidden layer with ten nodes (Figure 1), and the second network contains two hidden layers with five and two nodes, respectively (Figure 2). Input layers of the networks consist of four nodes and output layers contain one node. Bipolar sigmoid function and linear function are used as transfer functions of the hidden layer and the output layer, respectively. During the neural network training process backpropagation algorithm updates weight and bias values according to Levenberg-Marquardt optimization [7].

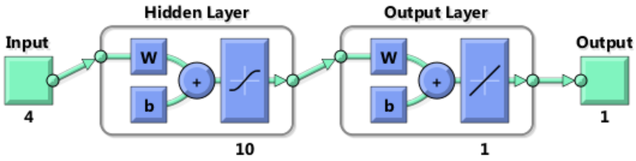

Figure 1: I neural network – Architecture

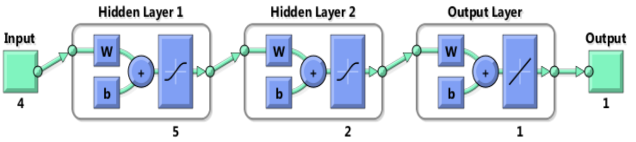

Figure 2: II neural network – Architecture

Results

Figure 3 and figure 4 show the change of the mean squared error (MSE) during the neural networks training process. Minimum MSE of validation set for the first network (value 1.7044) is achieved in the thirteenth epoch, and for the second network (value 2.6369) in the eighteenth epoch.

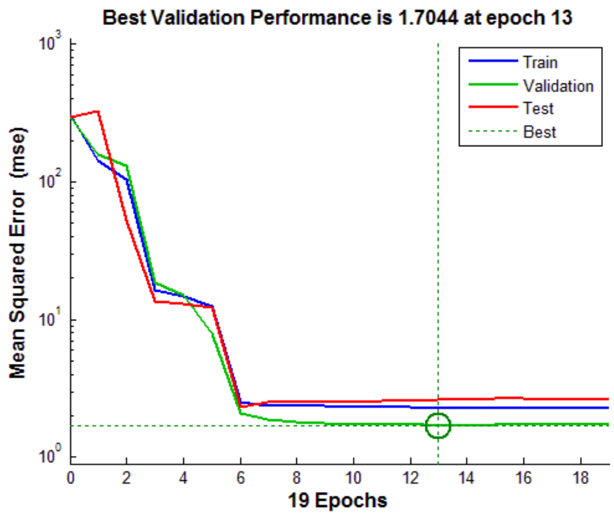

Figure 3: I neural network – Mean squared error

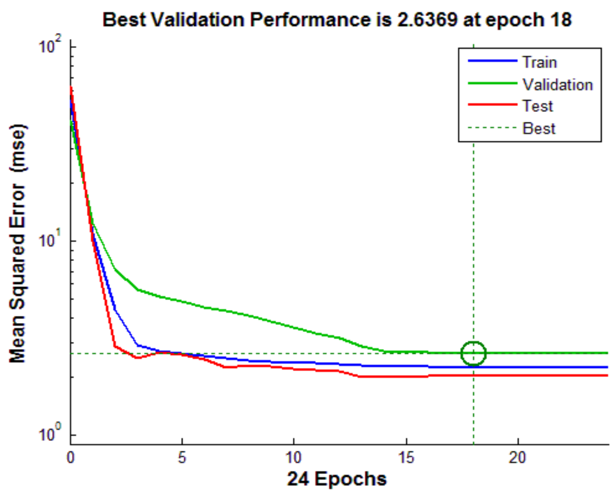

Figure 4: II neural network – Mean squared error

Figure 5 and Figure 6 show the linear regression of targets (measured Leq) relative to the outputs (predicted Leq) for training, testing and validation.

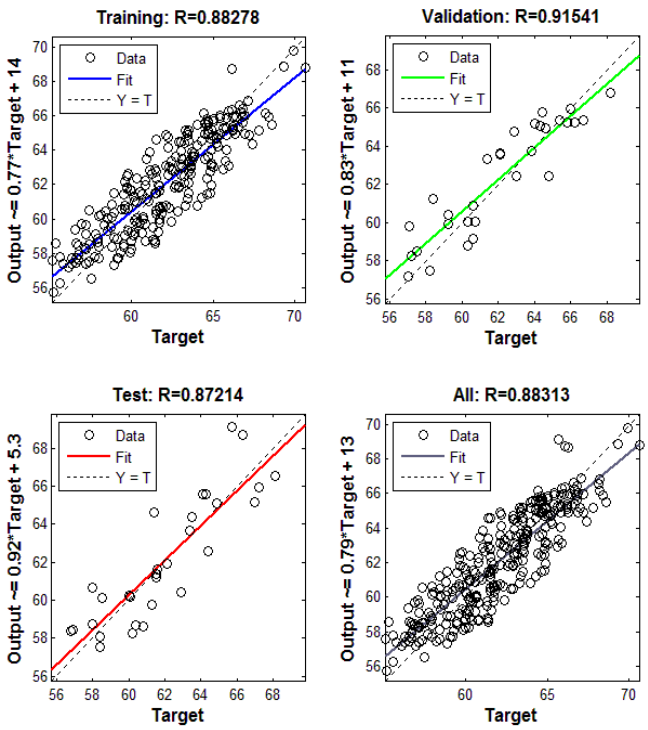

Figure 5: I neural network – Regression

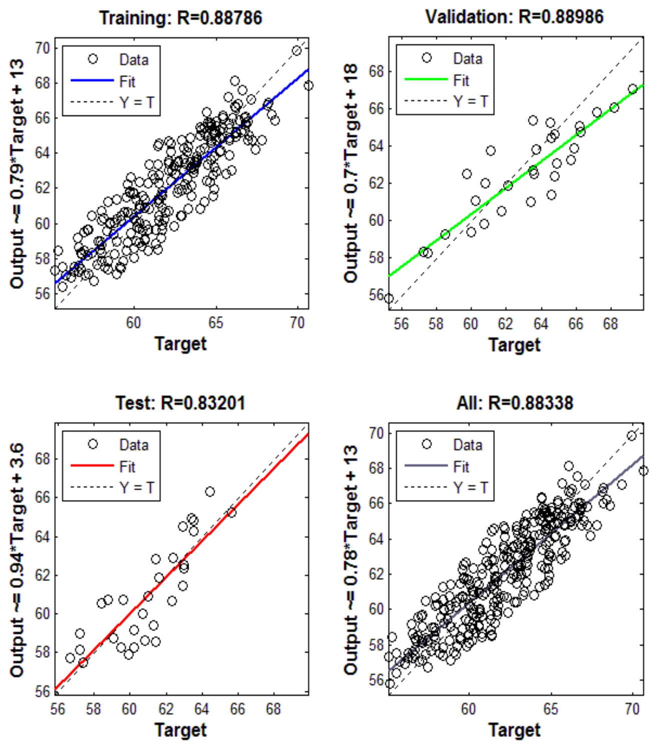

Figure 6: II neural network – Regression

Figure 7 and Figure 8 show comparisons between the errors of traffic noise prediction according to the Fagotti, Naiss, Burgess, Josse mathematical models and created neural networks. These results are shown only for the test and validation set. It can be noted that the created neural networks and the Fagotti and Naiss models give similar results, better than the Burgess and Josse prediction models [8], [9].

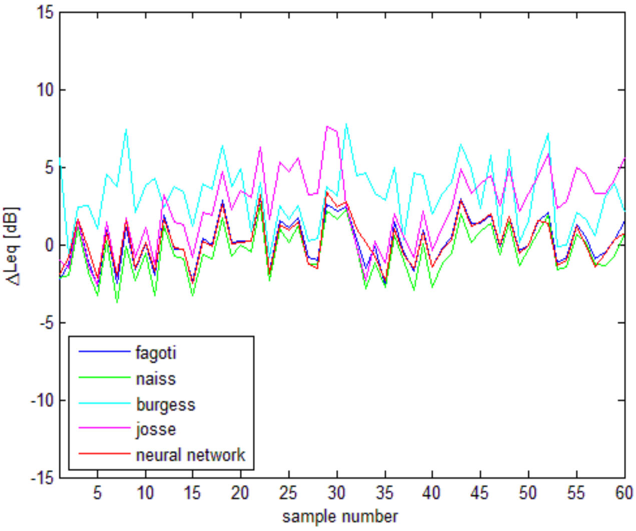

Figure 7: I neural network – Errors of traffic noise prediction

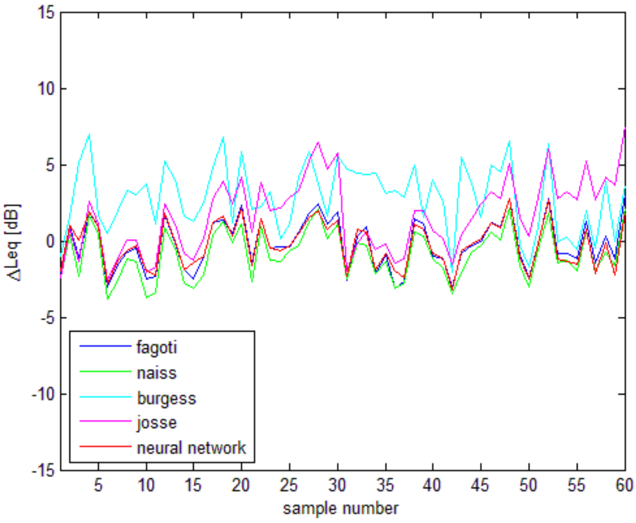

Figure 8: II neural network – Errors of traffic noise prediction

MSE (Mean Square Error), mean values and variances of the errors of traffic noise prediction according to the created neural networks and the Fagotti and Naiss mathematical models are presented in the Table 1 and Table 2. The results of comparative analysis show that the created neural networks enable better noise prediction (the least MSE) than the presented models.

Model	Training set			Validation set			Test set		
	mean	variance	MSE	mean	variance	MSE	mean	variance	MSE
Neural network	0.0112	2.2941	2.2847	0.2709	1.6873	1.7044	0.1066	2.7108	2.6318
Naiss	-0.7122	2.5819	3.0784	-0.3728	2.1213	2.1896	-0.6334	2.9354	3.2388
Fagotti	-0.0439	2.4820	2.4736	0.3165	1.8636	1.9016	0.0474	2.8406	2.7482

Table 1: I neural network – Comparison of the results

Model	Training set			Validation set			Test set		
	mean	variance	MSE	mean	variance	MSE	mean	variance	MSE
Neural network	0.0093	2.2442	2.2350	-0.4910	2.4784	2.6369	-0.0103	2.0949	2.0252
Naiss	-0.6203	2.5430	2.9173	-0.9311	2.2741	3.0653	-0.8099	3.0995	3.6520
Fagotti	0.0545	2.3856	2.3786	-0.3601	2.8620	2.8963	-0.0635	2.5961	2.5136

Table 2: II neural network – Comparison of the results

Conclusion

The obtained results of comparative testing of several well-known models for determination of the intensity noise of traffic in urban areas and neural networks designed for this purpose encourage further research. It is evident that the neural network can recognize the dependence of the intensity noise and the effective parameters, such as traffic intensity, width and slope of the road. Further research would be necessary to study noise levels that depend on various distances from the axis of the road, at different exposures to noise (acoustic shadows), in the presence of absorption and reflection surfaces, variable vehicle speeds and so on. Obtaining good results could be approached by designing a noise mapping system based on neural networks.

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