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Application of Artificial Neural Network for Modelling of Traffic Noise on Roads in Delhi

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ABSTRACT: *Pollution is always a matter of concern but when it comes to noise human beings were always ignorant to it. Some of the models developed were UK's CORTN model, USA's FHWA, STACO model in Spain. Most of the models developed have used traffic volume, average speed, vegetation L_{eq}, L_{10} etc as the variables. But none of the model can be applicable as a generalized model due to non-linear (or stochastic) nature of the noise problem. In this paper, an attempt has been made to develop an ANN model for the Metropolitan city Delhi. The structure of the model selected consisted of input variable as 2W, 3W, Car, MCV, Bus, Truck, Average Speed and L_{eq} as output variable. The number of neurons in the hidden layer was selected as 6. The model was selected by varying the number of hidden neurons from 4 to 20. The best model was selected on the basis of Mean Square Error (MSE), which was in present case of 6 hidden neurons. The model selected can be applied for the prediction of L_{eq} level.*

***Keyword**: Noise, ANN, Pollution, sound, Modelling, Road-traffic*

I. INTRODUCTION

Since the time immemorial sound is always present but with the start of industrialization, apart from other parameters of Pollution (air, water and soil), Noise Pollution start gaining consideration. It was becoming a major problem with rapid urbanization, thus in 1972, WHO recognized it as a type of pollution [1, 2]. Although there are several noise sources like industries, trains, planes and automobiles, this thesis is focus on road traffic noise i.e. the noise generated from the automobiles. British Government was the first to introduce legislation to control the noise emitted by motor vehicles in 1929. The decision if a vehicle was too noisy relied on a policeman and a court judgment. UK was also the first country who installed traffic noise barriers since 1960, even if USA started the research in late '50s. [3].

Torija[4], Dhananjay[5], Goswami[6], Mishra[7], Sharma[8] and Kumar[9] used the ANN Techniques for modelling and analysis of traffic noise. Garg[10], Tandel[11] and Chakraborty[12] used the other methods like SPSS to analyze the road traffic noise.

This paper presents the problems areas posed by noise pollution via a thorough study of Delhi region (Delhi and New Delhi regions mainly on the stretches of Mahatma Gandhi Marg (Ring Road)) in the northern part of India. This thesis starts with background cover of noise pollution. The main part of the thesis covers the method of noise prediction for Delhi region. This thesis strives to contribute robust model for measuring noise levels in different situations. The implementation of the model is backed up by a thorough study of Delhi region in north of India. The model can measure noise levels on roads, buildings etc.

1.1 Equivalent Continuous Sound Level

It is the steady state dB(A) level which would produce the same A-weighted sound energy over a stated period of time as a specified time-varying sound.

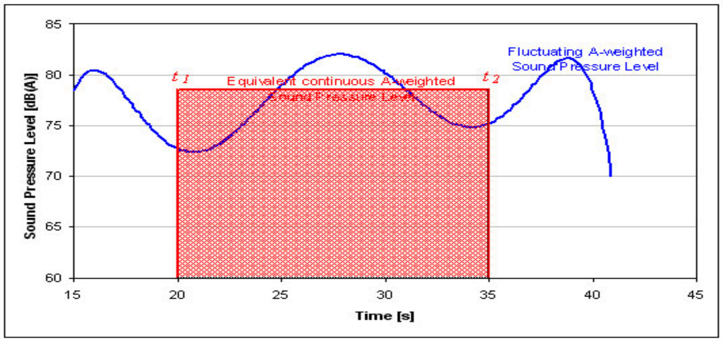

Figure 1: Fluctuation of db(A) with time

Equivalent continuous A-weighted sound pressure level is widely used around the globe as an index for noise. It is defined as "the A-weighted sound pressure level of noise, fluctuating over a period of time T, expressed as the amount of average energy." It is expressed as:

of a number of discrete events such as a train passing then we can use the following equation

$$L_{Aeq} = 10\log\left[\frac{1}{t_2-t_1}\int_{t_1}^{t_2}\frac{p_A^2}{p_0^2}dt\right] \quad (1)$$

where L_{Aeq} = equivalent continuous A-weighted sound pressure level [dB]

p_0 = reference pressure level = 20μPa, p_A= A-weighted pressure [Pa]

t_1 = start time for measurement [s], t_2 = end time for measurement [s]

If we want to calculate the equivalent continuous A-weighted sound pressure level from the sound exposure level of a number of discrete events such as a train passing then we can use the following equation

$$L_{Aeq} = 10\log\left[\frac{1}{10}\left(10^{\frac{L_{AE1}}{10}} + 10^{\frac{L_{AE2}}{10}} + \cdots . + 10^{\frac{L_{AEn}}{10}}\right)\right] \quad (2)$$

II. Error Back Propagation Algorithm

Neural networks are a computing paradigm that came into realization with the fact that human and animal brain works in a way entirely different to that of a computer. There are many types of neural networks but they all have one concept in common: their structure is based somewhat on our understanding of the brain's structure [13]. They are used in an incredibly wide range of applications because of their ability to perform tasks that humans are good at and computers traditionally poor at; those that are unstructured, nonlinear and approximate.

There are two ways the weights can be updated, by online learning or batch-mode learning.

Formally the steps taken during the online training cycle are:

1. Feed a training pattern into the network and let it propagate through to the outputs.

2. Compare the outputs with the target output by calculating the error.

3. Calculate all the derivatives of the error with respect to the weights.

4. Using the derivatives change the weights so as to minimize the error

$$\mathbf{w}(\mathbf{t}+\mathbf{1}) = \mathbf{w}(\mathbf{t}) - \frac{\partial \mathbf{E}}{\partial \mathbf{w}} \quad (3)$$

The online training cycle can be repeated until every single training pattern has been presented exactly once to the network. One complete pass through the training set is known as an epoch. Better training performance is usually achieved if the training patterns are presented in a random order to the network.

But before the data is fed to the network it should be normalized i.e. the data values should be converted into the range [0,1] as it will faster the calculations and thus less iteration are required.

III. Research Methodology

The Problem of traffic noise is very dynamic in nature, so to have the complete scenario in limited time is not possible. Thus, to make the better noise prediction model for the Delhi city, 15 different places were identified out of which reading was taken twice on 8 places. The places were selected on the basis of different kind of traffic flow conditions so that a better and generalized model should be developed. The parameters which were taken for the modelling are number of two-wheelers, three-wheelers, Cars, Medium-commercial Vehicles, Buses and Truck. Also, the average velocity of the vehicles is taken as the seventh parameter. The data was collected for 30 minutes in an hour and then it is integrated to one hour in order to have $L_{(eq, 1h).}$ Other measurements were also integrated to one hour. The Sound Level meter used in the measurement was “Lutron SL 4030” (IEC 651 type 2). The instrument was hold in the hand at the height of 1.2 m above ground level, 0.5 m in front of the observer. The input and output data gathered from all locations is then fed to the MATLAB in the form of target or output matrix ‘T’ (1x129) and input matrix ‘P’ (7x129). A total of 129 hours of reading is taken, which is randomly distributed in three components viz., Training Data (80%, i.e. 104 records), Testing Data (15%, i.e. 19 records) and Validation Data (5%, i.e. 6 records). Before feeding the data in ‘nftool’, it is first normalized by MATLAB commands:

```
a = max(P');
for i = 1:1:7
 P(i,:) = P(i,:)/a(i);
end; % end of loop
T = T/max(T);
```

They are restricted in the range of [0 1], so that the chances of getting trapped of the network itself in local minima has been eliminated. The tool used for the analysis of data is ‘nftool’ of Neural Network Toolbox. The ’nftool’ tool is run 17 times by varying the number of neurons in hidden layer from 4 to 20. Various functions used are given in the table 2.

Table 2: Various default functions used in nftool

Name of Function	Type of function used
Gradient	‘gdefaults’
Initialization	‘initlay’
Performance	‘MSE’
Plot	{‘plotperform’, ’plottrainstat’, ’plotfit’, ’plotregression’}
Training	Trainlm

For Post processing, following MATLAB command were used

```
Pred_Leq = outputs.* max(T);
Meas_Leq = T;
```

IV. Results and Discussions

The best model is selected on the basis of Mean Square Error (MSE), which, in present case, is the Artificial Neural Network with 6 hidden neurons as shown in the table 3 given below.

Table 3: Result obtained from various neural networks

No of Neurons	MSE	R Value	Mu	No of epochs
4	0.000234	0.79993	0.00001	15
5	0.000404	0.80071	0.00001	9
6*	**0.000109-**	**0.81664**	**0.000001**	**17**
7	0.000133	0.80894	0.0001	13
8	0.000129	0.84617	0.0001	14
9	0.000207	0.86073	0.0001	8
10	0.000136	0.82761	0.0001	10
11	0.000174	0.82412	0.00001	11
12	0.000381	0.82093	0.0001	7
13	0.000536	0.85175	0.0001	7
14	0.000272	0.84539	0.0001	9
15	0.000527	0.85649	0.0001	7
16	0.000230	0.87040	0.0001	8
17	0.000189	0.84207	0.0001	9
18	0.000332	0.85664	0.0001	7
19	0.000733	0.78897	0.0001	7
20	0.000225	0.85733	0.0001	7

{Note: **-** * indicates the best neural network chosen on the basis of mse}

Thus, the Regression (R) value for the best model selected was 0.81664. Figure 2 shows the variation of Mean square error with the variation in no of neurons in hidden layer. From the graph, it is clearly shown that the MSE is minimum, i.e. 0.000109, when there are 6 neurons in the hidden layer and it took the peak when number of hidden neuron are 19. All other MSE values were ranges between them.

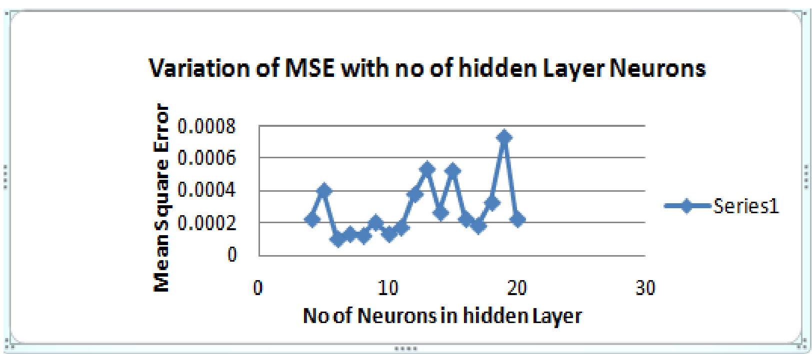

Figure 2: Variation of MSE with no of neurons in hidden layer

By selecting the best performance network i.e. network with number of hidden neurons 6, the graphs of measured L_{eq} with predicted L_{eq} with measured L_{eq} as target value on X axis and Predicted L_{eq} as output value on Y-axis is plotted. It can be clearly seen from the graph that how the output varied with the variation of input value.

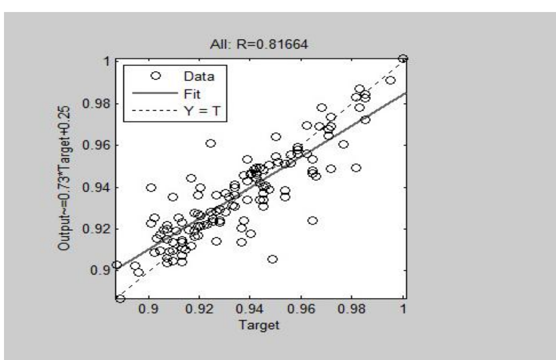

Figure 3: Variation of Measured Leq (Target) Vs Predicted Leq (output)

The equation relating the predicted and measured values is

$$\textbf{Output} = 0.73 * \textbf{Target} + 0.25 \quad (4)$$

Figure 4 shows the variation of MSE for training, testing and validation data with the number of epochs (iterations). The best validation performance was achieved at the epoch 11 where MSE was 0.00027319.

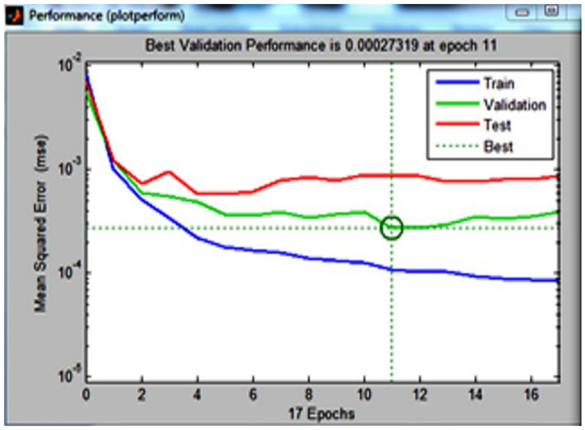

Figure 4: Variation of MSE with the no of epochs

Fig 5 shows the structure of the final model developed with 7 inputs, 6 hidden neurons and one output variable. The training function used for the hidden layer is ‘trainlm’.

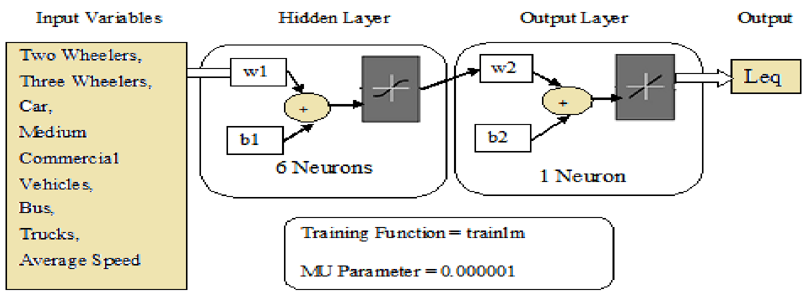

Figure 5: Structure of the Final Model

V. Conclusions

The final structure of the model consists of 7 input variables, 6 neurons in the hidden layer and 1 output variable. The selected training function is “trainlm” (MU parameter value 0.00001) and the chosen transfer-function configuration is “tansig” (layer 1) + “purelin” (layer 2). The model developed can predict (for the test subsets) with an MSE of 0.00019 and Regression value of 0.81664. In light of these results, it can be believed that the model prediction presented constitutes a useful tool to integrate acoustical variables in the context of town planning, so as to ensure that soundscapes are suited to the characteristics and needs of the exposed population. The use of this model provides relevant information for the authorities in urban planning and management. This information, together with that related to the perceptual evaluation of this soundscape, can be used to develop action plans (established in the Indian directive on environmental noise) and for solving possible problems detected, specifically acting on those aspects most harmful to the population.

In addition, this model would be useful in planning and developing new construction areas, helping to design sound spaces adapted to the future resident population.

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