Noise Prediction in Urban Traffic by a Neural Approach

G.Cammarata [1],S.Cavalieri [2],A.Fichera [1],L.Marletta [1]

(1) Istituto di Macchine
(2) Istituto di Informatica e Telecomunicazioni
Universita' di Catania
V.le A.Doria, 6 - 95125 Catania, Italy
fax +39 95 338887 - e-mail ad@iit.unict.it

Abstract.

The aim of this paper is to determine functional relationships between the road traffic noise and some physical parameters. Should this goal achieved, it is possible to modify the causes of traffic noise, in order to sensibly reduce it. Correlations are usually derived trough multiple regression analysis. In this paper an alternative solution based on the use of a neural approach is proposed. Its advantage is due to the capability of the neural networks to model non-linear systems such as the one treated in the paper. After an overview about the neural approach, the learning and production phase results are shown and discussed. They point out how good is the approach proposed to model noise pollution in urban areas.

1.Introduction.

The noise pollution in urban areas compromises the quality of life. One of the most important noise source is the road traffic. In recent years a strong need is felt to determine functional relationships linking the noise to some physical parameters, aimed at providing means to reduce the noise pollution.

The meaningful parameters of the traffic noise refer to the number of vehicles and flow velocity (traffic parameters), type of pavement and slope of the road (road parameters), road width and building height (urban parameters).

Many researchers have looked for correlations, linking the noise emissions to the above mentioned parameters. Problems are mainly due to the large number of variables and the suitable choice of the search approach. Whereas correlations are usually derived trough multiple regression analysis, in this paper a neural network will be used. The main advantage of this approach is the possibility to model non-linear systems such as the problem dealt with in this paper.

The model identification is based on acoustic survey of medium and small towns of Sicily [1]. Data were collected in roads with typical features of commercial, residential and industrial areas, and three times for every location point and for every one of the subsequent four time intervals :(7-7:30 am; 10:30-11 am;0:45-1:15 pm; 8-8:30 pm). All the measurements were done in working

days excluding all atypic conditions. The surveys consist of the following parameters :
- number of cars
- number of trucks
- height of buildings in both sides of the road
- width of the road.
- sound pressure level L_{eq} expressed by :

$$L_{eq} = 10 \log \frac{1}{T} \Sigma 10^{\frac{L_i}{10}} \Delta t$$

being T the time of observation and L_i the sound pressure level measured in the time Δ t (in particular Δ t was 10 min.). In order to get a satisfactory identification of the model, data were classified according to the width of the roads. Following this approach the model obtained strictly holds for roads with similar features.

2.The Neural Network Approach.

The particular problem to solve has led to an approach based on a mapping neural network. More specifically, a Back Propagation Network (BPN) [2] was considered, because of the efficiency of the training algorithm in a broad spectrum of applications, as acknowledged in literature.

This network was trained using a set of data mentioned in the previous section, concerning the city of Messina. Then, in the production phase, the correctness of the approach was tested using data measured in some other cities in Sicily.

The neural approach included a preliminary analysis in order to verify if the data were qualitatively significant for the extrapolation of a functional relationship between them. This preliminary analysis was quite difficult because the data concerning Messina were characterized by a certain number of poorly significant values. For example, some measurements were taken at cross-roads, where the noise level was related to the stop at the traffic lights and not to the vehicle flow rate. Discarding the measurements which were not significant to characterize the problem of noise prediction, we obtained a set of examples to be used during the learning phase of the neural network.

2.1. Description of the Neural Network Input/Output Vectors.

The aim of this section is to describe the I/O interfaces used in the neural approach. The training set, obtained from the process of analysis and filtering described in the previous section, is made up of the number of cars, the number of trucks, the height of the buildings on the sides of each road, the width of the latter and the equivalent level of noise pressure. In accordance with the aim, it was necessary to train the neural network so that it was able to determine the level of noise produced by a particular number of cars and trucks in a road of a certain length flanked by buildings of a certain height. The architecture of the neural network was determined on this basis. More specifically, at least in an initial phase it was characterized by 5 inputs and only 1 output. The NN output supplies the value of the equivalent level of noise for a particular value of the four inputs - the number of cars, the number of trucks, the height of the buildings on the sides of the road and the width of the road. The number of neurons in the hidden layer, on the other hand, was varied (together with the set of parameters characterizing the network, such as bias or learning rate) in order to reach full network convergence. Convergence was never reached in any of the tests carried out. This was presumably caused by the excessive number of inputs as compared with the limited number of training examples (the number of measurements available was quite low, on account of the analysis and filtering phase performed on them). It was therefore indispensable to reduce these inputs drastically.

Several examples have been given in leterature [3][4][5] of attempts to model the problem dealt with here, by means of linear regressions in which the level of sound pressure is made to depend, among the other, on equivalent number of vehicles. In order to obtain a neural model directly comparable with most classical approaches, and in order to reduce the number of inputs as far as possible, it was decided to combine the number of cars and trucks into a single parameter: the equivalent number of vehicles. From the results shown in [6], where a equivalence between the number of trucks and the number of cars was stated (on this basis a truck is equivalent to 6 cars as concerning its noise pollution), the total number of vehicles was calculated by summing the number of cars with the number of trucks, previously multiplied by 6. It was then considered appropriate to combine the heights of the buildings on the sides of each road into a single parameter relating to their average value. We believed, in fact, the average height of buildings to be sufficiently significant when the difference in height between the buildings on the two sides of the road is not excessive. This latter condition is plausible in that the modelling presented here was performed with reference to a particular kind of urban architecture characterized by the presence of buildings on both sides of the road.

On the basis of what was said above, it is thus clear that a BPN model characterized by 3 inputs and only 1 output (shown in Fig.1) was considered. The NN inputs were the equivalent number of vehicles, the average height of the buildings and the width of the road. The output was always the equivalent level of sound pressure. The number of neurons in the hidden layer was made to vary along with the other network parameters, until convergence was reached. The number of neurons in the hidden layer finally considered was 30.

2.2 The Learning and Production Phases.

The learning and production phases were carried out by the NN simulator "Explorenet" [7] running on a IBM-pc. After the training phase, which was successfully completed, a production phase was carried out with the with the aim of verifying whether the NN was able to extrapolate the functional relationship between the input and the output variables. With this aim in mind, different measurements taken in the city of Messina and not included in the training set were considered. Such an attempt was unsuccessful. From a subsequent analysis of the data, we ascribed the reason to the presence of a strong dependence of the functional relationship of the data on the characteristics of the road (i.e. the width). In particular we observed similar features in data distribution for roads wider than 30 meters, and for roads narrower than 30 meters. For this reason, we split the training examples into two groups. In the first group only the examples characterized by roads over 30 meters wide were considered. Obviously the second group was made up of the remaining examples.

As a consequence, we considered two different BPNs each of which was characterized by 3 inputs, 1 output and 30 hidden neurons. After the training phase, which was successful for the two NNs, the production phase was carried out.

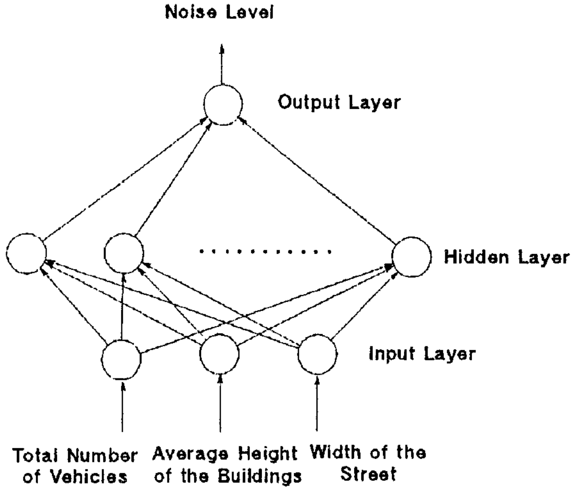

Fig.1 - BPN model.

Tabs.1 and 2 show the data used respectively for the two networks in order to verify the correctness of the generalization. The data refer to the measurements taken in Messina, and not included in the training sets.

Tab.1-Set of data concerning the production phase in the first NN

Number of Total Vehicles per hour (x 10000)	Average Building Height (x 100) meters	Road Width (x 100) meters	Measured Noise (x 100) db	NN Output (x100) db
0.4575	0.085	0.35	0.794	0.7870
0.375	0.085	0.35	0.767	0.7677
0.0525	0.125	0.30	0.714	0.7147
0.2685	0.10	0.30	0.754	0.7646
0.038	0.10	0.30	0.703	0.7025

Tab.2-Set of data concerning the production phase in the second NN

Number of Total Vehicles per hour (x 10000)	Average Building Height (x 100) meters	Road Width (x 100) meters	Measured Noise (x 100) db	NN Output (x 100) db
0.21	0.15	0.28	0.799	0.8068
0.1065	0.15	0.28	0.740	0.7256
0.007	0.10	0.26	0.632	0.6218
0.1375	0.15	0.25	0.763	0.7451
0.121	0.10	0.25	0.745	0.7287
0.008	0.10	0.20	0.599	0.6055

3. The Use of NN for the Noise Prediction.

The goal of this section is to demonstrate the validity of the NN approach shown before. This valuation will be based on the verification of the noise prediction capability offered by the neural networks considered in the previous section. With this aim in mind, a certain number of data concerning the noise pollution in two cities different from Messina were given to the NNs in the production-phase mode. In particular two set of data from the measurements taken in Palermo and Catania were considered. This choice is essentially based on the presence in Palermo and Catania of the same great variety of road width found in Messina. This allows to obtain a validation of the neural approach on a wide spectrum of real scenarios.

According to the methodology described before, the measurements concerning Palermo and Catania were divided into two sub-sets depending on the width of each road. The first group of data was characterized by road larger than 30 meters, while in the second group the road width was under 30 meters. These groups of data were prepared to be given the two NNs respectively in production-phase mode. Fig.2 shows the noise level trend measured in Palermo, in roads larger than 30 meters. It is compared with the noise level provided by the first NN. As can be seen the predicted noise is very close to the real noise. In table 3 the real scenarios concerning the noise levels shown in Fig.2 are represented. As shown in the table a very large spectrum of road width was considered, ranging from 30 meters up to 58 meters. The absolute error between the measurements and the predictions is very low for every scenario considered.

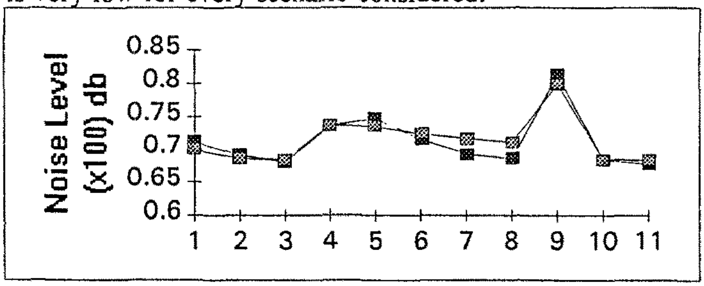

Fig.2 - Real Noise Level Compared with NN Output (Road Width >30 meters)

Table 3 -Set of data obtained by measurements in Palermo and concerning the production phase in the first NN

	Number of Total Vehicles per hour (x10000)	Average Building Height (x 100) meters	Road Width (x 100) meters	Measured Noise (x 100) db	NN Output (x 100) db	Absolute Error
1	0.429	0.125	0.58	0.712	0.699412	0.012588
2	0.3816	0.125	0.58	0.691	0.685386	0.005614
3	0.378	0.125	0.58	0.681	0.684307	0.003307
4	0.2874	0.1425	0.411	0.736	0.737698	0.001698
5	0.2538	0.1485	0.4	0.748	0.735027	0.012974
6	0.1878	0.0660	0.323	0.715	0.723965	0.008965
7	0.162	0.0660	0.323	0.693	0.716785	0.023785
8	0.141	0.0660	0.323	0.686	0.710862	0.024862
9	0.1302	0.38	0.32	0.813	0.799682	0.013318
10	0.0516	0.0495	0.314	0.683	0.683515	0.000515
11	0.0498	0.0495	0.314	0.677	0.682979	0.005979

In a similar way, a certain number of measurements concerning road width under 30 meters were prepared for the second NN in production-phase mode. Fig.3 shows the real noise levels measured in Palermo compared with the one provided by the neural network. In table 4 the set of data are represented. As can be seen, the table contains a larger number of data than the table 3. This is to be ascribed to the presence in Palermo of a much larger number of road whose width is under 30 meters.

The measurements concerning Catania were characterized by road narrower than 30 meters. For this reason, only the second NN was considered in the production phase. Fig. 4 and table 5 show the noise level and the set of data concerning the measuraments taken in Catatnia. Again, the very little differences between real and the predicted noise, point out how suitable is the neural approach considered here.

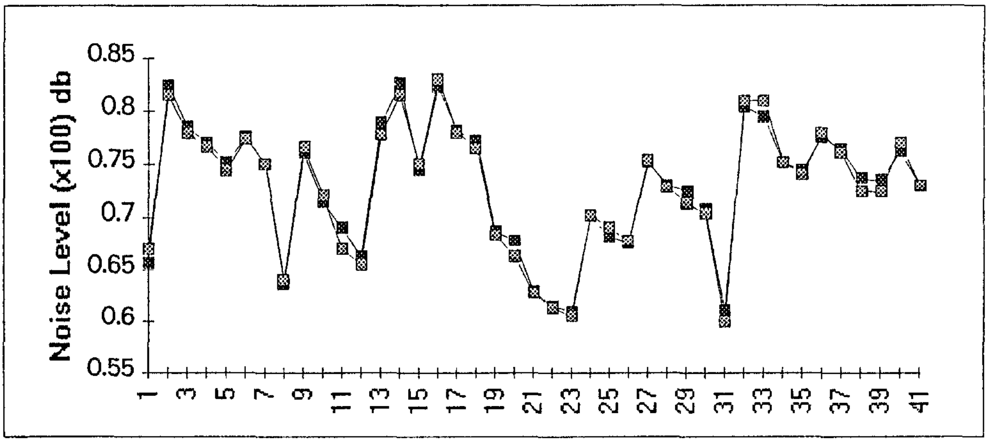

Fig.3 - Real Noise Level Compared with NN Output (Road Width <30 meters)

Table 4 -Set of data obtained by measurements in Palermo and concerning the production phase in the second NN

	Number of Total Vehicles per hour (x10000)	Average Building Height (x 100) meters	Road Width (x 100) meters	Measured Noise (x 100) db	NN Output (x 100) db	Absolute Error
1	0.0534	0.099	0.286	0.657	0.67	0.013
2	0.2172	0.198	0.28	0.824	0.815	0.009
3	0.1806	0.245	0.225	0.785	0.779	0.006
4	0.1668	0.245	0.225	0.77	0.767	0.003
5	0.1392	0.245	0.225	0.752	0.745	0.007
6	0.1764	0.23	0.22	0.775	0.774	0.001
7	0.1482	0.23	0.22	0.75	0.7506	0.0006
8	0.0384	0.205	0.22	0.637	0.64	0.003
9	0.1722	0.1485	0.22	0.76	0.766	0.006
10	0.1194	0.1485	0.22	0.714	0.72	0.006
11	0.0606	0.27	0.2	0.69	0.67	0.02
12	0.0468	0.27	0.2	0.662	0.655	0.007
13	0.1914	0.16	0.2	0.788	0.778	0.01
14	0.2364	0.1485	0.2	0.825	0.815	0.01
15	0.1566	0.1485	0.2	0.745	0.749	0.004
16	0.2808	0.231	0.196	0.823	0.83	0.007
17	0.2022	0.066	0.1915	0.781	0.78	0.001
18	0.1818	0.066	0.1915	0.772	0.765	0.007
19	0.0786	0.25	0.19	0.687	0.683	0.004
20	0.0588	0.24	0.19	0.677	0.663	0.014
21	0.0252	0.215	0.19	0.629	0.627	0.002
22	0.0156	0.2	0.177	0.614	0.613	0.001
23	0.0096	0.25	0.16	0.609	0.604	0.005
24	0.1092	0.245	0.16	0.701	0.702	0.001
25	0.099	0.245	0.16	0.681	0.69	0.009
26	0.0822	0.245	0.16	0.675	0.677	0.002
27	0.171	0.2	0.155	0.751	0.753	0.002
28	0.1428	0.16	0.151	0.73	0.727	0.003
29	0.1266	0.16	0.151	0.723	0.713	0.01
30	0.1134	0.215	0.15	0.707	0.703	0.004
31	0.0108	0.2145	0.15	0.61	0.6	0.01
32	0.261	0.132	0.15	0.804	0.81	0.006
33	0.2532	0.198	0.134	0.795	0.81	0.015
34	0.1818	0.18	0.117	0.751	0.752	0.001
35	0.1674	0.18	0.117	0.744	0.74	0.004
36	0.2178	0.132	0.117	0.776	0.779	0.003
37	0.1938	0.132	0.117	0.764	0.761	0.003
38	0.1488	0.1815	0.1145	0.736	0.724	0.012
39	0.1524	0.0825	0.111	0.734	0.723	0.011
40	0.2148	0.297	0.0722	0.762	0.77	0.008
41	0.1608	0.297	0.0722	0.73	0.729	0.001

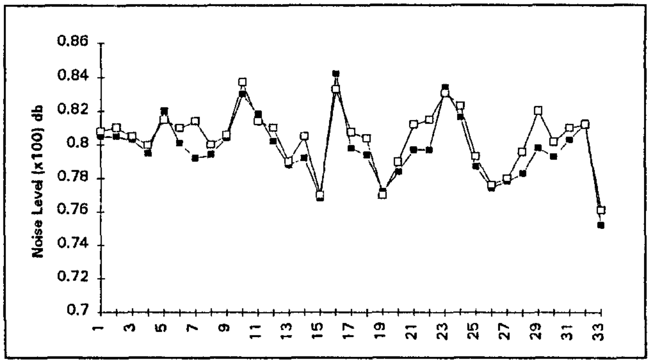

Fig.4 - Real Noise Level Compared with NN Output (Road Width <30 meters)

Table 5 - Set of data obtained by measurements in Catania and concerning the production phase in the second NN

	Number of Total Vehicles per hour (x10000)	Average Building Height (x100) meters	Road Width (x100) meters	Measured Noise (x100)db	NN Output (x100) db	Absolute Error
1	0.2574	0.14	0.2	0.805	0.80816	0.00316
2	0.2676	0.14	0.2	0.805	0.810326	0.005326
3	0.2676	0.14	0.2	0.803	0.805	0.002
4	0.246	0.14	0.2	0.795	0.8	0.005
5	0.2496	0.14	0.2	0.82	0.815	0.005
6	0.3168	0.14	0.2	0.801	0.81	0.009
7	0.285	0.14	0.2	0.792	0.813976	0.021976
8	0.3042	0.14	0.2	0.794	0.8	0.006
9	0.2856	0.105	0.2	0.804	0.805667	0.001667
10	0.2064	0.1575	0.18	0.83	0.837	0.007
11	0.2766	0.12	0.18	0.818	0.813918	0.004082
12	0.2742	0.12	0.18	0.802	0.81	0.008
13	0.2292	0.12	0.18	0.788	0.79	0.002
14	0.291	0.12	0.18	0.792	0.805	0.013
15	0.2466	5.25E-02	0.18	0.768	0.77	0.002
16	0.3222	0.11	0.14	0.842	0.833027	0.008973
17	0.2538	5.25E-02	0.135	0.798	0.80758	0.00958
18	0.237	5.25E-02	0.135	0.794	0.80397	0.00997
19	0.1896	5.25E-02	0.135	0.772	0.77	0.002
20	0.2598	5.25E-02	0.135	0.784	0.79	0.006
21	0.2262	8.75E-02	0.12	0.797	0.812	0.015
22	0.2448	7.00E-02	0.12	0.797	0.814747	0.017747
23	0.2574	0.1225	0.115	0.834	0.830767	0.003233
24	0.2586	0.1225	0.115	0.816	0.823	0.007
25	0.1098	8.75E-02	0.11	0.787	0.793188	0.006188
26	0.114	8.75E-02	0.11	0.774	0.776	0.002
27	0.141	8.75E-02	0.11	0.778	0.78	0.002
28	0.1728	8.75E-02	0.11	0.783	0.796	0.013
29	0.2454	8.75E-02	0.11	0.798	0.82	0.022
30	0.1854	5.50E-02	0.11	0.793	0.801773	0.008773
31	0.2406	5.50E-02	0.11	0.803	0.81	0.007
32	0.1698	0.105	0.105	0.813	0.812264	0.000736
33	2.04E-02	4.00E-02	0.105	0.752	0.760905	0.008905

Conclusion.

The authors have presented a neural approach to the urban traffic noise prediction, based on the use of a BackPropagation Network. The advantage of this solution versus the classic approach, is due to the neural network capability of modelling non-linear functions as the functional relationships in noise prediction seem to be. A methodology of the neural solution has been proposed. In particular a strong dependence from the road width was pointed out. On this basis, two different NNs were trained using a set of data concerning noise measurements in a particular Sicilian city (Messina). After the successful learning phases, a set of data coming from the noise measurements in other Sicilian cities (Palermo and Catania) was presented to the two NNs in production-phase mode. The noise predictions made by the NNs were very close to the real noise level, as shown by the very low absolute error.

References

[1] G.Bisio, G.Cammarata, A.Magrini, L.Marletta, "Acoustic Survey and Statistical Analysis of Messina Noise Levels", Proc. INTER-NOISE 91, Sidney 1991, Vol. II, pp.797-800.

[2] J.L.McClelland, D.E.Rumelhart, "Explorations in Parallel Distributed Processing", The MIT Press, pp.121-159.
[3] C.S.T.B., "L'outil des ètudes acoustiques sur maquettes urbaines", Centre de Maquettes de Grenoble.
[4] M.A. Burgess, "Urban Traffic noise prediction from measurements in the metropolitan area of Sidney", Appl. Acoustics, 10 [1977],1.
[5] R. Josse, "Notions d'Acoustique", Ed. Eyrolles, Paris 1972.
[6] Nelson P., "Transportation Noise", Reference Book, Butterworths, 1987.
[7] ExploreNet, HNC, Release 2.0, User Guide Manual, April 1991.