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Prediction of Air Pollution Due to Traffic by Means of Artificial Neural Network

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Abstract: In this paper a three-layer neural network model with hidden recurrent layer is used to predict pollutant concentration values in site with high traffic flow in Tehran.CO, NO, NO_2, NO_x are chosen for this purpose as air quality parameters. Regression and time series models are used for producing input data of neural networks. A multilayer neural network model is used to simulate air quality parameters. Simulated values of the model compared with measured values. Results show that the simulated values of neural network model are in good agreement with measured values. Also results show the high concentrations of NO in that site comparing to other contaminants. This model is a useful tool for simulating air quality parameters and can be used in such places.

Key words: Air Pollution · Neural Network · Modeling · Contaminant · Teraffic

INTRODUCTION

Geographically Tehran is a deep valley in which air is locked due to wind direction, air flows and surroundings. The flow of traffic is heavy and the concentration of all types of carbon dioxides, nitrogen, sulphur and other harmful gases is more than expected. Studies show that more than 80 percent of the pollution in Tehran is the result of traffic and the rest is made by fixed sources. Everyday 27 people are dying in Tehran because of air pollution and much investment losses for decreasing air pollutants. In the last decade future air condition studied with some researchers. Asha *et al.* [1] worked on prediction of sulfur dioxide. Prez-Roa *et al.* [2] provided a model in which they used diffusion coefficient correlation of air pollution. Meteorological data studied in this field by Slini *et al.* [3]. PM_{10} daily average concentrations in Belgium is investigated by Jef *et al.* [4].Similar studies is done by Grivas and Chaloulakou in recent years [5].Corani [6] used feed-forward neural networks for predicting air quality in Milan. Some researches are based on aerosol transport patterns in cities (Owega *et al.* [7]).Ozone concentrations in recent years studied as an important parameter due to negative impacts of ozone on human life Sousa *et al.* [8]. Diagnosis to prognosis for forecasting air pollution using neural networks is also studied by Ibarra-Berastegi *et al.* [9]. Some online air pollution forecasting systems are investigated by a few researchers Kurt *et al.* [10]. Also NO and NO_2 concentration model by support vector machines and neural network is provided by Juhos *et al.* [11]. Indoor air pollution study on toluene diisocyanate (TDI) and biological assessment of toluene diamine (TDA) in the polyurethane industries is studied by mirmohammadi *et al.* [12]. Also a neural framework for web ranking using combination of content and context features in recent years is considered as a new study by Keyhanipour *et al.* [13]. Many of these researches are based on experimental works and some of them used time series for producing data. In most of them the strong relationship between atmospheric pollution and human health is emphasized.

Model Formulation: Similar to other networks, artificial neural networks are made of neurons. According to the type of relationship among neurons, different types of artificial neural networks are constructed. Multi layer perceptron is mostly used in engineering and technical problems. In this model layers are embraced to each other and neurons are placed in a parallel order. Figure 1 shows the schematic sample of an artificial neuron.

The relation between inputs and outputs of a neuron is shown with:

$$a = f(wp + b) \quad (1)$$

p: The input of neuron
w: The weight of this input
b: A constant for one unit input
f: Transfer function
a: The output of neuron

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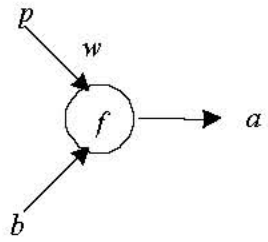

Fig. 1: A schematic model of an artificial neuron

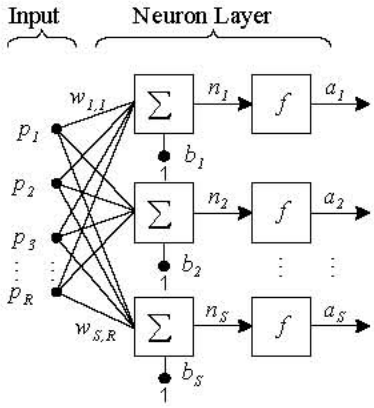

Fig. 2: A schematic model of one layer neural network

Two neurons are connected together with nodes. In a simple one layer network there are some input variables in the nodes of input layer and some output variables on the nodes of output layer. Then the relation between output of each neuron and input is as follow:

$$n_i = \sum_{j=1}^{R} (p_j W_{i,j} + b_j) \quad (2)$$

R: The number of inputs

A schematic model of one layer model network is shown in Fig. 2.

Also networks can have one input layer, one output layer and one or more middle layers is called hidden layer. Inputs are entering to the network via input layer and transmitting to the next layer by multiplying in the weight of the nodes between the layers. A schematic model of a multilayer network is shown in Fig. 3. Input data of the neural network is an important part of these models. Regression and time series models use for providing the input data for input variables of neural network model. A wide range of data is produced in this process and considered as input data for neural network model.

Model Application: For predicting air pollution, CO, NO, NO_2 and NO_x parameters are chosen as air pollution factors in Tehran. Tehran is located in southern region of Alborz Mountains. The Climate in Tehran is steppe and the population is more than 10 million in days. The metropolitan area in Tehran is 2000 km^2 therefore a large volume of transportation and industries collected in this area. An important cause of air pollution is the exhausts from 1.4 million motors, vehicles including 0.5 million motor cycles operating in an extremely congested road space (average speeds below 18km/h) and 70000 industrial units. It is known that between 65 to 70 percent of total

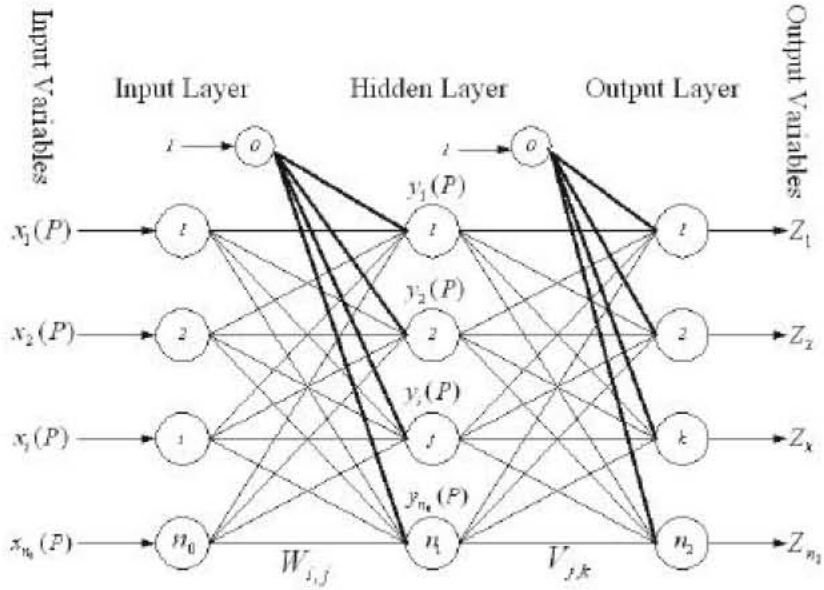

Fig. 3: A schematic model of a multilayer neural network

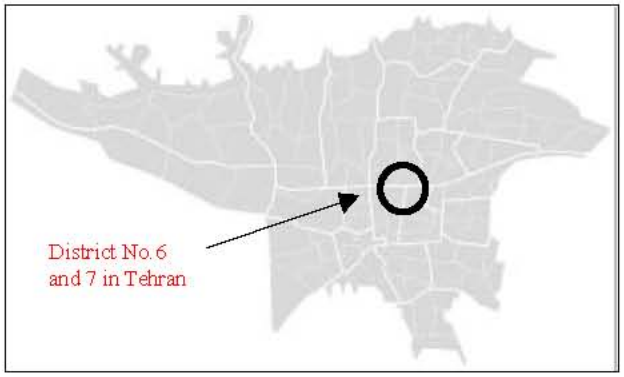

Fig. 4: The location of Measurement stations in Tehran

Table 1: Logical element at the meteorological bureau of Mehrabad International Airport in Tehran

Annual mean temperature	17.5°C
Annual mean humidity	40%
Annual precipitation	229.9 mm
Annual most frequent wind direction	West
Number of clear and partly cloudy days	317 days/year
Number of days with precipitation	more than one mm/day 41.1 days/year
Annual number of days with snow or sleet	13.2 days/year-17.5 days/year
Number of days of thunderstorms	More than 250 days
Inversion occurrence	annually

emissions are related to urban transport operation. High concentrations of CO, NO and NO_2 is caused hazardous diseases for child and old people. Mean daily temperature and mean annual precipitations are 17°C and 229.9 mm respectively. The most frequent wind direction is to west. Table 1 shows the characteristics of Tehran climate.

To determine air pollutant parameters two concentration measuring centers which are measuring CO, NO, NO_2 and NO_x daily is used and the mean value selected for the measured value. These stations are located in the busiest part of the city as shown in Fig. 4. Measured values are compared with calculated values that are simulated by the model. The concentrations Measured for 6 months.

Measured data are used for producing initial inputs of time series and regression models used to create data for input layer of neural network model.

RESULTS AND DISCUSSION

The results of ANN simulations are compared with available field data in order to assess model capability. All the four under consideration parameters were taken under account.

Figure 5 shows measured and calculated concentration values of CO in a six-month period of measurements. As it is observed there is a good agreement between simulation results and real measurements. Fluctuations of this parameter is bounded between 2 and 10 mg/l for both simulation and measurement results and no out standing behavior was observed in both curves.

A time history for measured and calculated concentration values of NO in the similar six-month period of measurements is shown in Fig. 6. Again a fairly good agreement is obtained between simulations and measurements. The Fluctuations of this parameter are bounded between 9 and 90 mg/l for both simulation and measurement results, except a period of twenty days in middle which are between 100 to 140 mg/l. The latter part can be assumed as an out standing behavior which was well estimated by the applied method.

Time variations of measured and simulated NO_2 concentrations during the measuring period are presented in Fig. 7. The agreement between field data and ANN simulated values are reasonable. Fluctuations of this parameter are bounded between 8 and 48 mg/l for measurement results and between 5 and 61 mg/l for

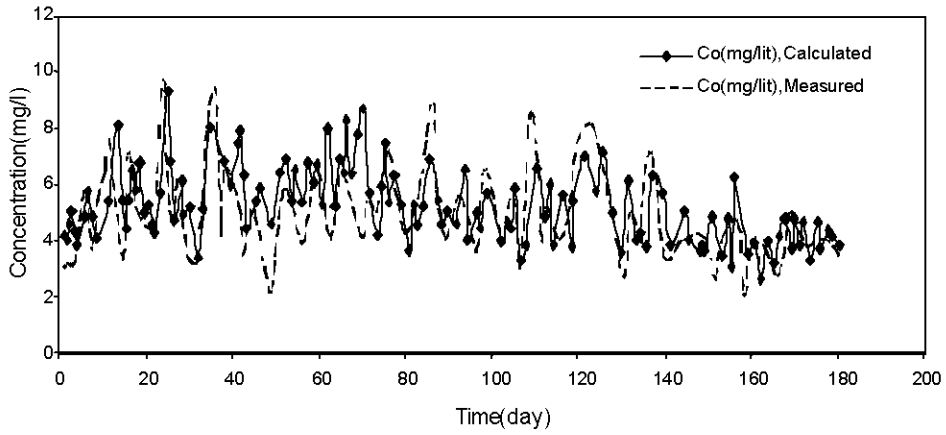

Fig.5: Concentrations of CO in six months

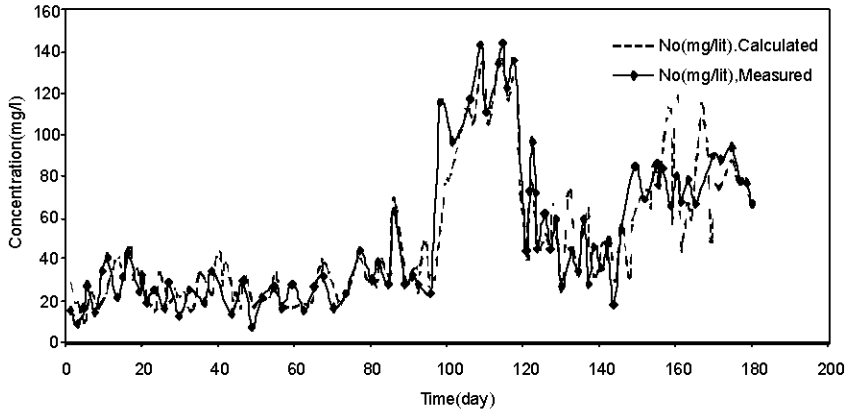

Fig.6: Concentrations of NO in six months

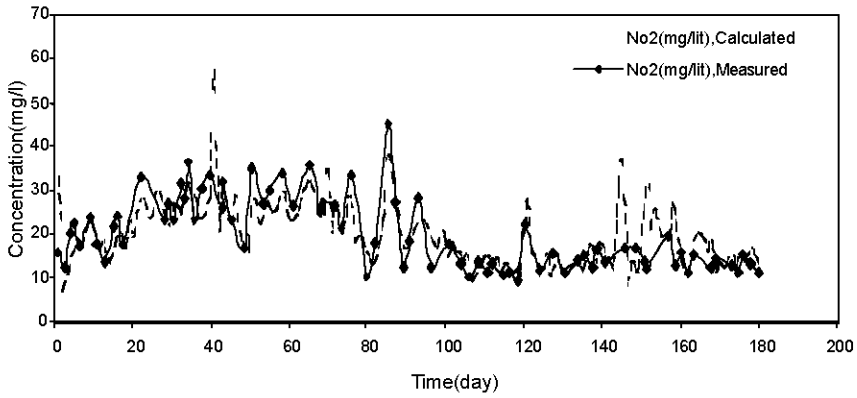

Fig.7: Concentrations of NO_2 in six months

simulation results. Few exceptional cases with short periods are observed as out standing behavior points in ANN curve.

Finally, time histories for simulated and measured concentrations of No_x are shown in Fig. 8. A good agreement is also observed between the presented curves. The concentration values are bounded between 20 and 110 mg/l for both simulation and measurement results. However, there is an exceptional period of about twenty days in the middle of measuring period which are between 120 to 160 mg/l. This period can be assumed as another out standing behavior which was again well estimated by the applied method.

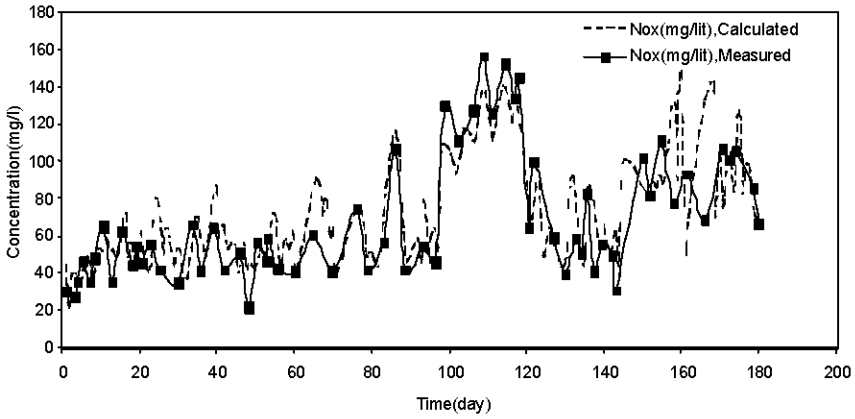

Fig. 8: Concentrations of NO_x in six months

Table 2: Calculated values of MPAE for each parameter

Parameter	CO	NO	NO_2	NO_x
MPAE%	6	12	9	16

SUMMARY AND CONCLUSION

An artificial neural network model is employed to simulate air quality parameters in Tehran. CO, NO, NO_2 and NO_x concentrations are chosen for this purpose. Obtained results show a good agreement between measured values in two stations and simulated values by the model. The most important sources of pollution are vehicles and industrial units. Urban transportation and traffic are producing the large part of this pollution. Starting the winter, industrial activities get increased and acted as a shock for the system and caused high concentrations of NO and NO_x in the air. The fluctuations in all figures are considerable mainly because of daily averaging procedure applied in the measuring process.

A mean percentage absolute error (MPAE) calculated for the parameters are calculated by the model (Table 2). Comparing the MPAE values shows that the model the maximum error for the simulation of NO_x concentrations and the minimum error for CO. It is due to minimum changes in CO concentration and the Traffic flow in most hours of a day as the main source.

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