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Air quality prediction using artificial neural network

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Abstract
Over the last few years, the use of artificial neural networks (ANNs) has increased in many areas of engineering. Artificial neural network have been applied to many environmental engineering problems and have demonstrated some degree of success. The aim of study is to develop neural network air quality prediction model for the sensitive area of Ujjain city (MAHAKAL MANDIR) in India. In this study, two prediction models are developed using feed-forward neural network for the air pollutant NOx. Several metrological data such as temperature, relative humidity, air velocity and rainfall are given as input parameters while concentration of NOx was considered as the output variable in this study. The performance of the developed model was assessed through a measure of Mean Square Error (MSE). From the constructed networks, the best prediction performance was observed in a model with network structure 04-07-01 and MSE 0.00223.

Keywords: Air Quality; Artificial Neural Network; Prediction; NOx; MSE; SSE.

1. Introduction
Air pollution is an important issue nowadays, being a factor which influences both human health and activities. Air pollution in urban area are associated with the sudden occurrence of high concentration of vehicular exhaust emission (VEEs). Critical air pollution events frequently occur where the geographical and meteorological conditions do not permit an easy circulation of air and a large part of the population moves frequently between distant places of a city. There are many different chemical substances that contribute to it. Large quantities of any air pollutant can affect the population health. Based on the World Health Organization reports that 2.4 million individuals die annually from causes directly attributable to air pollution, 1.5 million of these from indoor air pollution. Worldwide there are more deaths from poor air quality than from automobile accidents. In order to prevent them, there have been developed regional, national and international air pollution monitoring networks, which inform people about major pollutants concentrations in real time .Air pollutants exert a wide range of impacts on biological, physical, and economic systems .Their effects on human health are of particular concern. The decrease in respiratory efficiency and impaired capability to transport oxygen through the blood caused by a high concentration of air pollutants may be hazardous to those having pre-existing respiratory and coronary artery disease. Consequently, it has become a vital task to accurately keep track of the variation of ambient air pollution levels in urban areas it is important to predict air quality exactly for providing proper actions and controlling strategies so that the adverse effects can be minimized. In response to this concern, several studies on air quality prediction using artificial neural network have been done. Unlike other modeling techniques, artificial neural networks (ANN) make no prior assumptions concerning the data distribution. ANN is capable of modeling highly non-linear relationships and can be trained to accurately generalize when presented with a new dataset.
The strong capability of artificial neural networks in predicting fuzzy data and the successful application of this approach in various fields gives the idea of implementing ANN to predict air quality based on previous data. This research will attempt to use feed-forward neural network modeling in the prediction estimation where historical data collected over the years is used to 'train' the model. This paper is organized as follows: Section 2 provides the materials and methods. Section 3 describes the results of the ANN modeling. The last section concludes the presented works.

2. Materials and Methods

2.1 Data Sets

The data used in this study are daily ambient air temperature, relative humidity, air velocity and daily concentration of NOx in sensitive area of Ujjain for 4 years period from 2009 to 20013. All of these data were provided by State Pollution Control Board of Ujjain. The data was divided into three sets which is learning set for ANN training, validation and testing set to verify the efficiency and correctness of the developed model.

2.2 ANN Model for Air Quality Prediction

As network architecture, a 3-layer perceptron model as shown in **Figure 2.1** was used. Two independent model with different input variables is developed.

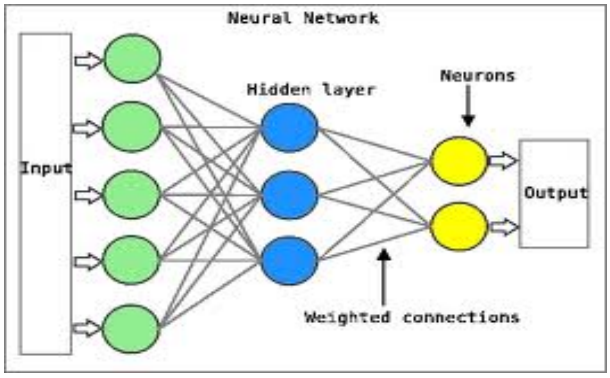

Fig 2.1: A three layer neural network perceptron

Here, in first network there were three neurons in the input layer including temperature, relative humidity and wind velocity .While in second network there were four neurons in the input layer including temperature, relative humidity, wind velocity and rainfall. The number of hidden layers and values of neurons in each hidden layer are the parameters to be chosen in the model. Therefore, one or two hidden layers and different value of neurons were chosen to optimize the ANN performance. The last layer is the output layer, which consists of the target of the prediction model. Here, NOx was used as the output variable. Hyperbolic tangent sigmoid function was used as the transfer function. The database was divided into three sections for early stopping. 50% of the data were used in training the networks, 25% were designated as the validation set, and the remaining 25% were employed in testing the networks. The mean square error (MSE) was chosen as the statistical criteria for measuring the network performance.

3. Results and Discussion

3.1 ANN Modeling

Feed-forward neural network have been applied in this study. The tansig functions were used for the neurons in the hidden layer and output layer respectively. The input and target values were normalized into the range of [0, 1] in the pre-processing phase. The weights and biases were adjusted based on gradient-descent back-propagation in the training phase. The mean square error was chosen as the statistical criteria for measuring of the network performance. The overview of the parameters and their values was shown in **Table 3.1**

Table 3.1: Structure and testing results for the neural network models

Net. No	Net. structure	Learning rate	MSE	SSE
1	03-07-01	0.2	0.00252	0.06289
2	04-07-01	0.2	0.00257	0.06419

During testing, the above figures appeared. It represents the network performance with three variables in input layer including temperature, relative humidity and wind velocity. The performance of the network (3-7-1) is shown in **Fig. 3.1**

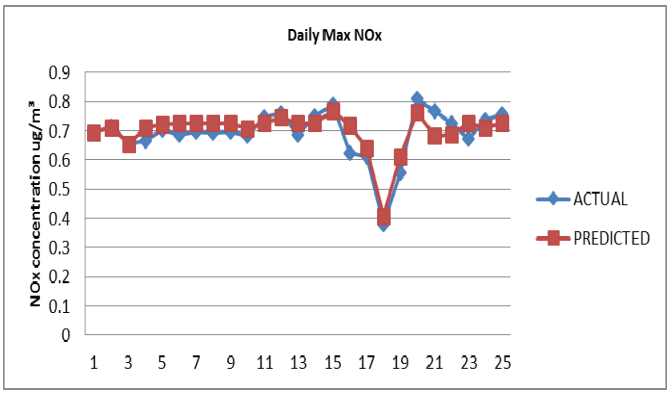

Fig 3.1: model performance for network structure 3-7-1

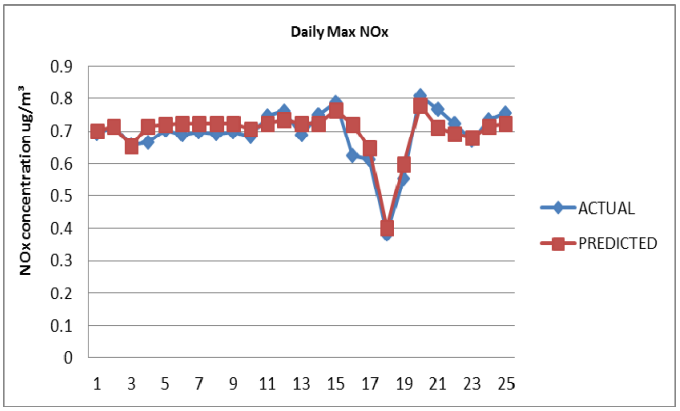

Fig 3.2: model performance for network structure 4-7-1

Fig.3.2 shows the performance of network with four neurons in input layer and the variables includes temperature, relative humidity, wind velocity and rainfall.

4. Conclusion

In this study modeling of air pollutant (NOx) using artificial neural network was developed with two individual network. The study was focused on estimation of mean square error. Of the two networks developed, network with mean square error (MSE) and sum of square error (SSE) as 0.00252 and 0.06289 respectively considered to be best model with minimum percentage error of 0.332.

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