Prediction Of Nitrogen Dioxide & Ozone Concentrations in the Ambient Air using Artificial Neural Networks for Vijayawada Model

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Abstract

This work deals specifically with the use of a neural network for Nitrogen Dioxi de and ozone modeling. The development of a neural network model is presented to predict the Nitrogen Dioxide and ozone concentrations as a function of meteorological conditions and various air quality parameters. The development of the model was based on the realization that the prediction of Nitrogen Dioxide and ozone from a theoretical basis (i.e. detailed atmospheric diffusion model) is difficult. In contrast, neural networks are useful for modeling because of their ability to be trained using historical data and because of their capability for modeling highly non-linear relationships. The network was trained using four years (2009-2013) meteorological and air quality data. The data were collected from an urban atmosphere. The site was selected to represent a typical residential area with high traffic influences. Three architecture models were developed. Architecture – 1 for the prediction of NO_2 by using meteorological parameters as inputs. Architecture –2 for the prediction of O_3 by using meteorological parameters including NO_2 as inputs. Architecture – 3 for the prediction of NO_2 and O_3 by using meteorological parameters as inputs. The generalization ability of the model is confirmed by correlation and regression between measured and predicted concentrations. The results of this study indicate that the artificial neural network (ANN) is a promising method for air pollution modeling.

Keywords - *Air pollution; Artificial Neural-networks; Nitrogen dioxide; Ozone; Prediction.*

I. INTRODUCTION

Nitrogen dioxide and Ozone can have a negative impact on the environment and public health when present in the atmosphere in sufficient quantities. In establishing ambient air quality standards, regulations have been introduced to set limits on the emissions of pollutants in such a way that they cannot exceed prescribed maximum values. To achieve these limits, consideration was given to mathematical and computer modeling of air pollution.

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. Also from power stations, heating plants and industrial processes. Ozone, however, is unique among pollutants because it is not emitted directly into the air. It is a secondary pollutant that results from complex chemical reactions in the atmosphere. It results when the primary pollutants nitrogen oxides (NOx) and sunlight. In addition, these pollutant concentrations are strongly linked to meteorological conditions. To predict pollutant concentrations, it is necessary to apply a model that describes and understands the complex relationships between pollutant concentrations and the many variables that cause or hinder pollutant production. It is expected that they will under-perform when used to model the relationship between pollutants and the other variables that are extremely non-linear.

Therefore, the neural network is a well-suited method for modeling this process since it allows for non-linear relationships between variables. Neural networks, by their unique structure, possess the ability to learn non-linear relationships with limited prior knowledge about the process structure. They are therefore useful for evaluating the pollutant problem at a particular location. In this paper, neural network modeling was used to predict nitrogen dioxide and ozone concentration levels.

II. ARTIFICIAL NEURAL NETWORK CONCEPTS

Artificial neural network (ANN) models are computer programs that are designed to emulate human information processing capabilities such as knowledge processing, speech, prediction, classifications, and control. The ability of ANN systems to spontaneously learn from examples, “reason” over inexact and fuzzy data, and to provide adequate and rapid responses to new information not previously stored in memory has generated increasing acceptance for this technology in various engineering fields and, when applied, has demonstrated remarkable success (Simpson, 1990; Elkamel et al., 2001).

The major building block for any ANN architecture is the processing element or neuron. These neurons are located in one of three types of layers: the input layer, the hidden layer, or the output layer. The input neurons receive data from the outside environment, the hidden neurons receive signals from all of the neurons in the preceding layer, and the output neurons send information back to the external environment. These neurons are connected together by a line of communication called connection. Stanley (1990) indicated that the way in which the neurons are connected to each other in a network typology has a great effect on the operation and performance of the network. ANN models come in a variety of typologies or paradigms. Simpson (1990) provides a coherent description of 27 different popular ANN paradigms and presents comparative analyses, applications, and implementations of these paradigms. Of these, the most frequently used is the back propagation paradigm (Rumelhart and McClelland, 1986). Detailed descriptions on the use of ANNs in environmental modeling can be found in Maier and Dandy (2000).

III. COLLECTION OF DATA

The hourly concentrations of air pollutants like Nitrogen dioxide (NO2) & Ozone (O3) and hourly meteorological parameters like Wind Speed (WS), Wind Direction (WD), Relative Humidity (RH), Solar Radiation (SR), Atmospheric Temperature (AT) & Atmospheric Pressure (AP) were collected simultaneously from Ambient Air Quality Station at Vijayawada from 2009 to 2013.

IV. METHODOLOGY

The proposed ANN models are developed using “Graphical User Interface (GUI)” using NN tool in MATLAB software. This paper presents the development of three architecture models for the prediction of NO_2 and O_3 concentration:
Architecture – 1 for the prediction of NO_2 by using meteorological parameters as inputs. Architecture – 2 for the prediction of O_3 by using meteorological parameters including NO_2 as inputs. Architecture – 3 for the prediction of NO_2 and O_3 by using meteorological parameters as inputs.

A. Selection of data for training and testing neural network model

The whole dataset was divided into three parts: one part i.e., about 60% of data for each study area is for training of models, second part i.e., about 20% of data for each study area is for evaluate the performance of model developed and the remaining 20% of the data is to test the network developed in this study with different combination of no. of neurons and hidden layers. The no. of neurons assumed for three architecture are 5 to 10. It is based on trial and error basis and the number of hidden layers to be taken is based on the authors shown in table 1.

TABLE 1

S.NO	*Author*	*Hidden layer*
1	M Maren et al (1990); Masters (1993); Rojas (1996)	Trial and error method
2	Salchenberger et al., (1992)	75% of Input
3	Berke and Hajela (1991)	(Input+Output)/2
4	Hecht-Nielsen (1990); Caudill (1989)	(2I*+1)
5	Rogers and Dowla (1994)	No.layers<No.training samples
6	Yu (1992)	Error in 1 layer=Error in (I-1)
7	Masters (1993)	(No.of training samples)/No.of layers = 2
		(Max value of tr sample)/No.of layers = 4
8	Hush and Horne (1993)	(Max value of tr sample)/No.of layers = 10
9	Amari et al (1997)	(Max value of tr sample)/No.of layers = 30

B. Development of ANN model with Feed- Forward Back propagation

Normalize the inputs and outputs with respect to their maximum values.
Normalization can be done by using the formula:

X=0.1+0.8(xi / xmax)

where
X = Normalized Value
xi = Input Parameter
xmax = Maximum in Input Parameter

Choose a neural network, configure its architecture and set its parameters. The network will choose randomly the training data and will train the network with the training-set data. The network itself evaluates its performance by using the validation-set data. Repeat steps 2 and 3 with different architectures and training parameters. Select the best network by identifying the smallest error found with validation set.

For each architecture, about 42 networks has been trained for Vijayawada station by taking 5 to 10 neurons and the no. of hidden layers given by various authors as shown in Table 1. The performance of the proposed ANN models for the prediction of NO2 and O3 for the station considered is verified by using statistical performance.

The best neural networks have been proposed among all the trained networks. The best neural network is chosen in such a way that the correlation value of the network should be >0.9. The best network models proposed for prediction of NO2 and O3are given in Table 2. The correlation values of these proposed models are good.

V. RESULTS AND DISCUSSION

The network model is developed by taking Wind Speed, Wind Direction, Relative Humidity, Atmospheric Temperature, and Atmospheric Pressure and Solar radiation as input variables. The regression graphs are drawn between the measured values and the predicted values are shown from Figure 1 to 3. In the following Figures from 1 to 3 all the points are scattered around the fitting line indicating the measured values and predicted values are close to each other and the same is indicated using R2(Regression).). From the Figure 1 it is observed that the overall performance of the network which is developed for the prediction of NO_2 based on meteorological parameters is giving R2 = 0.9362. From the Figure 2 it is observed that the overall performance of the network which is developed for the prediction of O_3 based on meteorological parameters and NO_2 is giving R2 = 0.9425. From the Figure 3 it is observed that the overall performance of the network which is developed for the prediction of NO_2 and O_3 based on meteorological parameters is giving R2 = 0.9063.

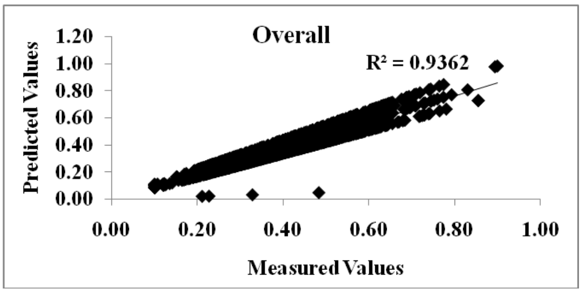

FIGURE 1.OVERALL REGRESSION ANALYSIS OF MEASURED VALUES VS PREDICTED VALUES FOR ARCHITECTURE – 1 (PREDICTION OF NO_2)

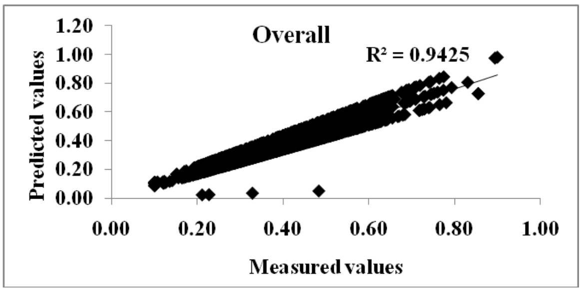

FIGURE 2. OVERALL REGRESSION ANALYSIS OF MEASURED VALUES VS PREDICTED VALUES FOR ARCHITECTURE – 2 (PREDICTION OF O_3)

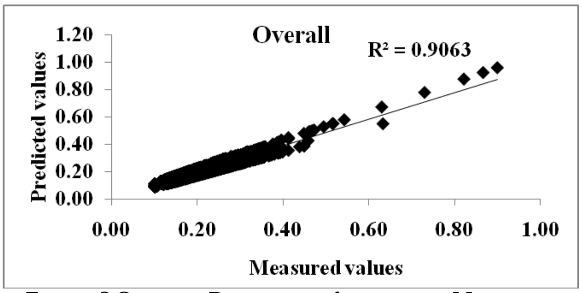

FIGURE 3.OVERALL REGRESSION ANALYSIS OF MEASURED VALUESVS PREDICTED VALUES FOR ARCHITECTURE – 3 (PREDICTION OF NO_2 AND O_3)

TABLE 2.THE BEST NETWORK MODELS PROPOSED FOR PREDICTION OF NO_2 AND O_3

*Network 6-10-4-1 represents no. of inputs - no.of neurons - no. of hidden layers - no. of outputs.

S.No	*Station Name*	***Architecture***	*Network*	*correlation*			
				Training	*Validation*	*Testing*	*Overall*
1	Vijayawada	Architecture-1	6-10-4-1	0.955	0.969	0.963	0.927
2	Vijayawada	Architecture-2	7-10-15-1	0.965	0.968	0.957	0.940
3	Vijayawada	Architecture-3	6-9-13-2	0.935	0.965	0.953	0.932

VI.CONCLUSIONS

From the data it is observed, there is an indirect relation with respect to pollutant concentration and wind speed and also with other meteorological parameters like Relative Humidity, Solar Radiation, and Temperature.

As wind speed and relative humidity increases the concentration of the pollutant are decreasing and with decrease in the solar radiation and atmospheric temperature the concentration of pollutant are decreasing.

ANN modeling is shown to be a successful method to predict NO_2 and O_3 Concentrations in the ambient air as correlation coefficients and regression values of the three architecture networks are >0.90.

For the prediction of NO_2, Architecture – 1 is most suitable rather than Architecture – 3 because the regression value of Architecture – 1 is 0.936 whereas for Architecture – 3 is 0.906.

For the prediction of O_3, Architecture – 2 is most suitable rather than Architecture – 3 because the regression value of Architecture – 2 is 0.942 whereas for Architecture – 3 is 0.906.

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