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Forecasting Criteria Air Pollutants Using Artificial Neural Network

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Abstract: -- **Air pollution is a serious problem all over the world which causes terrific loss to human health and other living beings. Criteria pollutants like Oxides of Sulphur (SO2), Oxides of Nitrogen (NO2) and Respirable Suspended Particulate Matter (RSPM) have either reached or exceeded the acceptable limits specified by Central Pollution Control Board of India for most of the cities like Pune. So, the forecasting of criteria air pollutants is necessary to take precautions from causes due to air pollutants. In present work, the one day ahead forecasting of air pollutants like SO2, NO2 and RSPM are carried out. Feedforward back-propagation (FFBP) and Radial Basis Function Neural Network (RBFNN) tools are used for forecast air pollutants. The univariate time series are used to modeling. The FFBP models for SO2, NO2 and RSPM are modeled.**

Index terms: **- SO2, NO2, RSPM, FFBP, RBFNN, Univariate time series**

I. INTRODUCTION

Air pollution is a presence of toxic particles present in the air which are harmful to living organisms. Due to development of country, number of industries, vehicle increases which leads to a series of problems related to environment such as deforestation, release of toxic materials, solid waste disposals, air pollution and many more [1]. These toxic particles are harmful to human being and living organisms. Now-a-days air pollution is a major problem. The polluted air contains nitrogen, oxygen, carbon dioxide (CO2), helium (He), argon (Ar), krypton (Kr), ozone (O3), nitrous oxide (N2O), xenon (Xe) and oxides of sulphur (SO2) and nitrogen (NO2), as well as very small amount of some other organic and inorganic substances. The amount of air pollutants vary according to place and time. Air pollutants are found in gaseous as well as in particulate form [1].

The degree to which air is pollution free is known as air quality. The air quality is determined by presence of air quality parameters (air pollutants) such as oxides of SO2, NO2, CO2, O3, CO, etc. Air quality forecasts provide the public with air quality information which allows people to take precautionary measures to avoid or limit their exposure to unhealthy levels of air pollution. Hence it is quite essential to predict criteria pollutants [2].

The development of effective forecasting models of AQI for major air pollutants in urban areas is of prime importance. With this end in view, there is a need to have a model that would generate the future AQI. Although many forecasting models exist and some are in use, there is still need for developing more accurate models [1].

Most of the urban air pollution models require information about source inventory, their emissions, types of pollutants, their rate of release, climate of the region and other meteorological parameters. Data collection plays a vital role in air quality modelling and forecasting. Many a times it is difficult to obtain the required data on a continuous basis. Hence model should be robust enough to accommodate such fluctuations in data collection. Traditional forecasting techniques are found to be weak particularly when used to model nonlinear systems. This leaves a scope for data driven approaches which are found to be suitable to model the nonlinear systems [3]. The objective of present study is to forecast the one day ahead concentration of air pollutant criteria like sulphur dioxide (SO2), nitrogen dioxide (NO2), and Respirable suspended particulate matter (RSPM) over the Pune city (Maharashtra). All the values of SO2, NO2 and RSPM are in µg/m3.The feed forward neural network and radial basis neural network models are developed to forecast concentrations of air pollutants. In this paper only feed forward neural network models are modeled.

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II. ARTIFICIAL NEURAL NETWORK

Artificial Neural Networks (ANNs) are biologically inspired parallel computational models. They consist of simple a highly interconnected processing element which processes the input similar to brain [4]. A typical neural network represents (Fig.1) interconnection of computational elements called neurons or nodes, each of which basically carried out the task of combining the input, determining its strength by comparing the combination of bias and firing out the results in proportion to such strength [5].

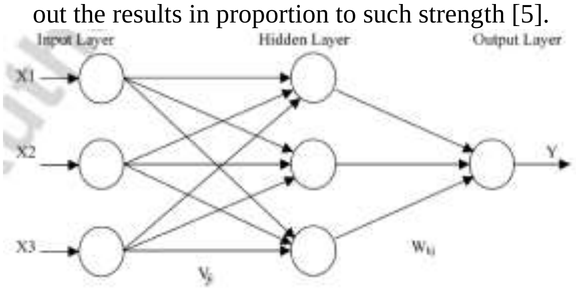

Fig.1 A Typical Neural Network

Mathematically,

$$\text{Output} = \frac{1}{1+e^{-\text{sum}}} \qquad (1)$$

Where,

$$\text{sum} = x_1 w_1 + x_2 w_2 + \cdots \ldots \ldots \ldots + \beta \qquad (2)$$

Where, $x_1, x_2, \ldots$.= input values

$w_1, w_2, \ldots\ldots$.= weights along the linkage connecting two neurons, strength of connection

β= bias value

Before its application, the network is required to be trained and this is done by using a variety of training algorithms, like Standard Back-Propogation, Conjugate Gradient, Quasi-Newton And Levenberg-Marquardt, etc.[2].

There are several types of ANNs like Feed forward back-propogation (FFBP), Radial Basis Function Neural Network (RBFNN), Kohenon network, Hamming's network, etc. For this paper work, FFBP and RBFNN are selected.

III. STUDY AREA AND DATA

Pune is one of the fastest developing metropolitan cities in India which generates about 181.957 tonne of toxic waste daily [2]. It is located on the Deccan Plateau at the confluence of Mula Mutha Rivers and at an elevation of about 560m above mean sea level at Karachi [2]. Under National Ambient Air Monitoring Program (NAMP) and also State Ambient Air Monitoring Program (SAMP), the upper limits set for daily average concentration of SOx, NOx and RSPM by CPCB (Central Pollution Control Board, India) and MPCB (Maharashtra Pollution Control Board) are 80, 80 and 100 µg/m3 respectively [7].

The data used for further study has concentrations of air quality parameters of time period 2005-2008. The data is collected from MPCB, Pune. The data is pre-processed and used as input for model. The concentrations of air pollutants can be recorded using High Volume Sampler, by Improved West and Gaeke Method for SOx , Sodium Arsenite Method for NOx and by Filter paper method for RSPM. The previously recorded values are used to forecast the air quality parameters using data driven techniques like artificial neural network.

IV. MODEL DEVELOPMENT

The feed forward neural network is used to developed models. The models are modeled by trial and error method. As air pollution is the time dependent phenomenon, initially temporal models are developed with air pollutant time series. Pollutant concentrations (SO2, NO2 and RSPM) recorded for January 2005 to December 2008 has been considered for model development.

Univariate one day ahead forecasting models can be written as,

$SO_2\,(t+1) = f\,(SO_2\,(t), SO_2\,(t-1), SO_2\,(t-2), SO_2\,(t-3), SO_2\,(t-4), SO_2\,(t-5))$ (3)

$NO_2\,(t+1) = f\,(NO_2\,(t), NO_2\,(t-1), NO_2\,(t-2), NO_2\,(t-3), NO_2\,(t-4), NO_2\,(t-5))$ (4)

$RSPM\,(t+1) = f\,(RSPM\,(t), RSPM\,(t-1), RSPM\,(t-2), RSPM\,(t-3))$

This univariate models are decided by trial and error method. The trials are taken from one day before concentration upto six day before concentration as an input. Correlation coefficient is taken as a statistical parameter to compare the models. Fig.2 shows the architecture of FFBP-ANN model for NO2.

V. FEED-FORWARD MODELS

ANN architecture consists of number of input neurons as the previous pollutant concentrations and one output neuron corresponding to next day's pollutant in univariate models.

Numbers of hidden neuron are decided by trial and error. For deciding the hidden neurons exercise is carried out by varying the number of hidden neurons from 0 to 35, and selects the hidden neuron which gives maximum value of correlation coefficient(r) and after that the value r is constant or decreases (Fig.3). Each network has 'logsig' and 'pureline' as transfer function and mean squared error as a performance function. Training of the network is continued

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till a very low value of mean squared error was achieved in each case. Network weights were uniformly distributed in the range of -1 to 1. Training algorithm used in each case was Levernberg- Marquardt algorithm. ANN models are developed using NN tool box of the commercial software MATLAB 16.0.

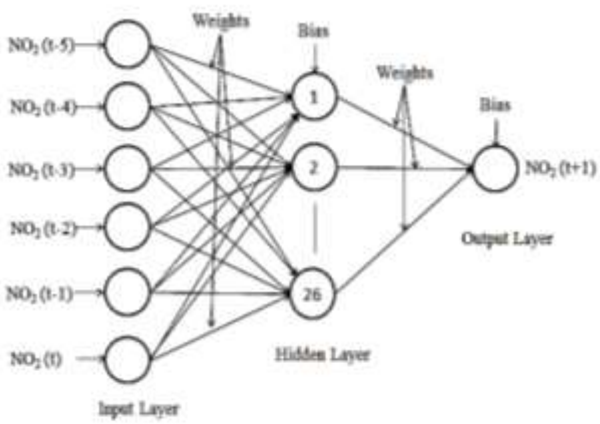

Fig.2 Architecture of ANN-FFBP Model for NO2

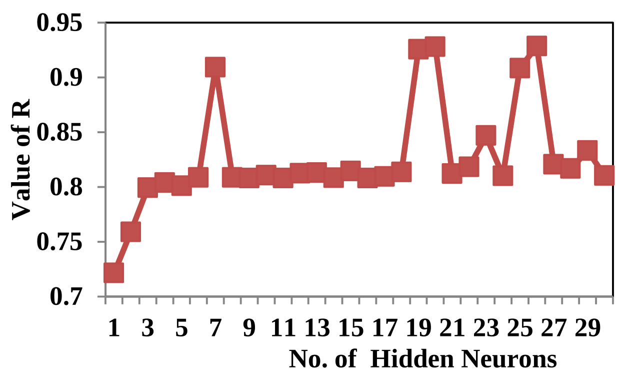

Fig. 3 Selection of Hidden Neuron for NO2 Model

VI. RESULTS AND DISCUSSION

One day ahead forecasting of air quality parameters has been carried out using univariate models with four year data. Performance evaluators like correlation coefficient (r), root mean square error (RMSE), coefficient of efficiency (CE) and mean square relative error (MSRE) are calculated between predicted and observed value listed in table I. For univariate annual SO2, NO2 and RSPM models, the correlation coefficient are 0.66, 0.93 and 0.83 respectively.

Table I: One Day Ahead Univariate Model Results

Performance Evaluator	SO2	NO2	RSPM
r	0.66	0.93	0.83
RMSE	3.54	4.46	26.06
CE	0.41	0.86	0.68
MSRE	0.037	0.022	0.13

The time series plots are also done for observed and predicted criteria air pollutants. Fig.4 shows that the FFBP model works well to predict the one day ahead SO2 conc. The peak prediction also works good for SO2, NO2 and RSPM shown in fig.4, fig. 5 and fig. 6 respectively.

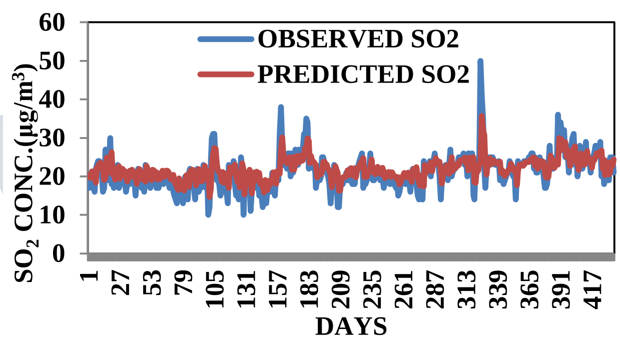

Fig.4 Time Series Plot for SO2

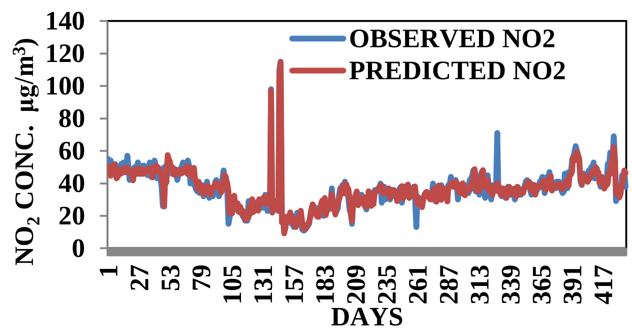

Fig.5 Time Series Plot for NO2

The scatter plots are plotted between observed and predicted values of SO2, NO2 and RSPM shown in fig.7, fig. 8 and fig. 9 respectively. X-axis represents the observed values of criteria air pollutants and Y-axis represents predicted values of respective criteria air pollutants. In fig.7 all points are converge, it seems that there is less correlation between observed and predicted SO2conc. In fig.8 and fig.9 the points are equally spaced along 450 line shows better correlation in NO2 and RSPM conc. than SO2 conc.

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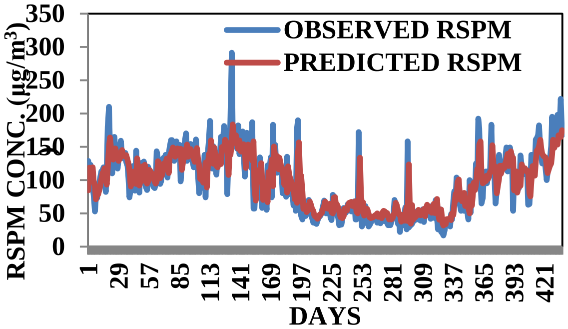

Fig.6 Time Series Plot for RSPM

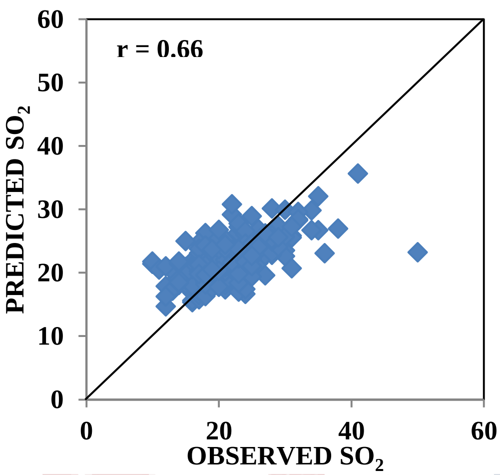

Fig.7 Scatter Plot for SO2

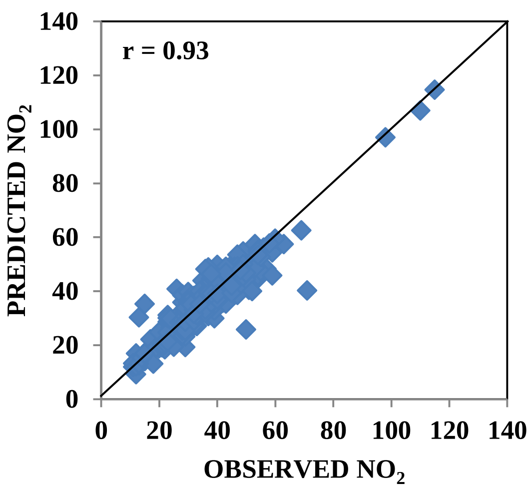

Fig.8 Time Series Plot NO2

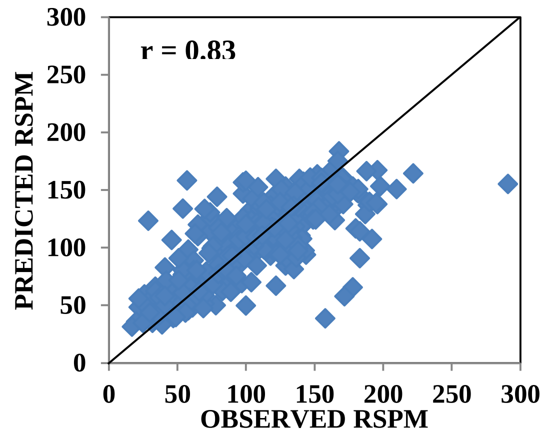

Fig.9 Scatter Plot for RSPM

VII. CONCLUSION AND FUTURE SCOPE

The univariate models are developed for forecasting one day ahead of criteria air pollutant by using Artificial Neural Network. The models worked well in terms of prediction. The peak prediction is also achieved well. The RBF-ANN model will be developed and comparing the results of FFBP and RBF-ANN models.

Appendix

The performance evaluators are calculated as follows:

Correlation Coefficient,

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2 \sum(Y-\bar{Y})^2}} \quad (6)$$

Root Mean Square Error,

$$RMSE = \sqrt{\frac{\sum(X-Y)^2}{n}} \quad (7)$$

Coefficient of efficiency,

$$CE = 1 - \frac{\sum(X-Y)^2}{\sum(X-\bar{X})^2} \quad (8)$$

Mean Square Relative Error,

$$MSRE = \frac{\sum\frac{(X-Y)^2}{X^2}}{n} \quad (9)$$

Where,

X = Observed Value

$\bar{X}$ = Average of Observed Value

Y = Predicted Value

$\bar{Y}$ = Average of Predicted value

n = Number of Observations

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