A Neural Network Model for Short Term Prediction of Surface Ozone at a Coastal Region

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Abstract

Surface Ozone (O$_3$) level is the potential problem of developing countries. Its role in the atmospheric environment through radiative and chemical processes is very significant. An attempt has been made to predict short term surface ozone levels using the neural network technique. The model can predict the mean surface ozone levels based on the parameters like Nitrogen-di-oxide, temperature and wind speed. The model exhibits a good correlation between the actual and predicted data points.

Keywords: Surface Ozone Concentration, Neural Network, Short Term Prediction.

1 Introduction

Surface Ozone plays a very vital role in atmospheric oxidation processes and hence subsequently in air quality and its increase enhances the greenhouse effect in the free troposphere (IPCC, 2001). Surface Ozone is a secondary pollutant formed by photochemical reaction of primary pollutants like oxides of nitrogen (NO$_x$), carbon monoxide and volatile organic compounds. High concentration of Surface Ozone can cause potential damage to biotic and abiotic factors. (Avol et al., 1998).

Several studies have been conducted aiming to develop tools and methods capable to achieve a short-term forecast of ozone levels (Kovac-Andric et al., 2009, Chaloulakou et al., 1999). The analysis often aims on investigating whether or not a threshold condition is exceeded. However, this means of analysis can often be exploited by environmental and medical authorities in issuing public warnings.

The problems of short term modeling in complex terrain have been discussed in detail by Bonzar et al., 1993. It has been shown that in the case of stable atmosphere and thermal inversions, the dispersion model fails and also this model proves to be inadequate for controlling emissions.

The most common method widely used for developing prediction models is to correlate meteorological and pollution data with the concentration of a certain pollutant. In this aspect, it has been shown that neural network technique can be employed for short term prediction.

Neural network techniques have recently become the focus of much attention as they can handle the complex and non-linear problems much better than the conventional statistical techniques. It is a simple mathematical input-output model which learns the relationship (linear or non-linear) between the input and output during the training period. Neural network model brings out the maximum information available within the data during the training period and reflects these in the independent period.

2 Area and Period of Study

Kariakal, a part of the union territory of Puducherry is a coastal region located along the south eastern side of the Indian Peninsula. Availability of tropospheric Ozone, NO$_2$ concentration, temperature and wind speed...
Table 1: Sensor Head Specifications

<table>
<thead>
<tr>
<th>Sensor Gas</th>
<th>Sensor</th>
<th>Range (ppm)</th>
<th>Lowest Detection Limit (ppm)</th>
<th>Resolution (ppm)</th>
<th>Response Time T90</th>
<th>Operational Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone (O3) 0-0.015 ppm</td>
<td>GSS</td>
<td>0.0-0.150</td>
<td>0.001</td>
<td>0.001</td>
<td>&lt;70 s</td>
<td>5-40 °C</td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO2) 0-0.2 ppm</td>
<td>GSS</td>
<td>0.0-0.200</td>
<td>0.001</td>
<td>0.001</td>
<td>&lt;180 s</td>
<td>0.40 °C</td>
</tr>
</tbody>
</table>

Data’s for a period from October 2013 to September 2014 has prompted us to make an attempt to develop a simple model using neural network technique.

3 Methodology

The O3, NO2 data were continuously monitored from October 2013 to September 2014 at a major traffic thoroughfare in the Karaikal region. Both the gaseous measurements were taken by using a portable sensitive gaseous monitor Aeroqual S500. This instrument is the advanced version of the S200 series utilized by Weisinger et al. (2009) and by K. Elampari et al. (2011) for their studies. The measurement units being either in ppm or µg/m³. Table 1 gives the sensor details used for this study. Surface Ozone, NO2 were measured from 9.30 hrs to 17.30 hrs. The Nine hrs data were averaged to obtain the daily averaged value. The meteorological parameters were obtained from IMD and weather underground Inc.

Neural Network Technique

Neural Networks are a family of statistical learning models inspired by biological neural networks (the central nervous systems of animals, in particular the brain) and are used to estimate or approximate functions that can depend on a large number of inputs and are generally unknown. Artificial neural networks are generally presented as systems of interconnected “neurons” which exchange messages between each other. The connections have numeric weights that can be tuned based on experience, making neural nets adaptive to inputs and capable of learning.

Neural networks is an extended form of regression and has the properties of

1. Adaptivity
2. Robustness
3. Ruggedness
4. Speed (via massive parallelism)
5. Nonlinearity and
6. Optimality with respect to error

For regression, we assume a functional form first, such as linear or exponential and then we find the coefficients that minimize some measure of errors whereas for neural networks, the method itself extracts the functional form from the data.

As input to the model, the meteorological data and NO2 dataset is used, whereas the output, ozone concentration is predicted by the model. The network is trained with the past data. By proper choice of training sets, after the learning process, the trained network is capable of predicting the ozone concentrations as an output according to the inputs and internal structure of the network established during the learning period.

In the present study, for predicting ozone concentration using neural network, Matlab R2014a has been utilized.
4 Results and Discussions

Neural network is one of the vital tools utilized for forecasting or prediction. In this study, Ozone concentration was predicted or forecasted by using the meteorological parameters like temperature and wind speed along with one of the precursors of Ozone namely NO₂ as inputs. The data set is randomly divided into three sets namely training, validation and testing. Training set is the largest set (70%) and the remaining sets are assigned to contain 15% of the samples. The training set is a set of samples used to adjust or train the weights in the neural network to produce desired outcome. The validation set is used to find the best network configuration and testing set is to evaluate the fully trained networks. The most commonly used computational function in air quality modeling is the Log-Sigmoid function \( f(x) = \frac{1}{1+e^{-x}} \) (Seinfeld, 1998).

The model was carried out using Levenberg Marquardt algorithm. The neural network model is trained using all the input parameters. Figure 1 shows the neural network model.

![Neural Network Model](image)

Figure 1: Neural Network Model

The model gives an R of 0.90093 for all the data points. Figure 2 shows the regression of the above model. The model exhibits a good correlation between the actual and predicted data points.

![Scatter plot between actual and predicted data](image)

Figure 2: Scatter plot between actual and predicted data
5 Conclusion

Surface Ozone measurements were taken at Karaikal, a part of the union territory of Puducherry, India for a period from October 2013 to September 2014. This study was an attempt to study the variation of potentially harmful surface ozone concentration level in a site where no previous studies were carried out. Neural network model was performed to predict the Ozone concentration levels using various inputs. The study shows that the model exhibits a good correlation between the actual and predicted data points.

References


