Air pollution Trend Analysis Using Sen Estimator Method-A Survey

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Abstract: *Environmental data mining gained popularity that helps to identify environment trends and patterns .Air pollution is becoming an environmental problem that is affecting human health. Dispersion of various air pollutants such as SO_2, NO_2, SPM and RSPM from both mobile and stationary sources can effect air quality. This paper presents methods for determining trends of various air pollutants in time series data. Using monthly pollution data from 2010 to 2012 containing pollution parameters called as pollutants like SO_2, NO_2, SPM, RSPM are taken and, time series were plotted and trend analysis is performed using Sen's slope method also called as Sen estimator method. Sen estimator method is a statistical method used to detect increasing or decreasing trend along with their magnitude and sign. This method computes slope between each data pairs and then computes median value as a slope.*

Keywords: Air pollution , pollutants , moving average , Exponential Weighted Smoothing method , Least square method, Linear Regression, MAPE ,MSE, RMSE,Sen's Slope estimator, Mann-kendall..

1. Introduction

Air pollution is one of the major concern nowadays and is increasing at a faster rate. Clean air is one of the most valuable source .Air pollution now reaches to a level that is effecting human health. The monitoring of environmental parameters is one of the highest priorities in the evaluation of environmental status of air quality and in environmental protection policy. The goal of this paper is to propose a method that will identify trends or patterns of various pollutants (NO2, SO2, SPM, and RSPM) in air pollution so that health protective decisions should be taken.This trend analysis help municipal corporations and environmental agencies to plan and deploy of resources so as to prevent from adverse affect of pollution.

1.1 Trend Analysis and Time Series Data

Any decision making process works on past data, present data and analysis. It is comparison of same item over a significantly long period. Trends are often seen on time series data. Trend analysis is a mathematical technique that uses historic results to predict future outcome. It is comparison of same item over a significantly long period. Trends are often seen on time series data. A time series database consist of sequence of values or events that changes with respect to time [25].

In other words a time series is sequence of data points, typically consist of successive measurements made over time. A time series is an ordered set of real values that is defined as $X=[x_1,x_2,\ldots,x_N]$ of N values where X_i denotes the value related to time slot i, i<-T={$t_1,t_2,\ldots,t_N$} where T is domain of time [5]. Various techniques for mining these time series data are used in many applications like measuring sensors ,data center monitoring ,environment monitoring etc

[24].

Time series consist of 4 types of components . First component is called trend. Denoted as T. Trend is long term behavior or pattern of data .Trend analysis is based on the idea that what has happened in the past gives traders an idea of what will happen in the future. Trends in time series data can be obtained by using smoothing methods. Various smoothing methods like simple moving average, weighted etc are proposed [14]. Along with these various hybrid methods in combination with smoothing techniques are also proposed for trend analysis and prediction [21][16].

1.2 Components of Time Series

There are three main types of trends: short-, intermediate- and long-term trend. Although trend analysis is often used to predict future events, it could be used to estimate uncertain events in the past.

The second component of time series is called as seasonal variation denoted as S. Example of seasonal variation is increase in sales of ice-creams and cold drinks in summer as compared to winters.

The third component of time series is cyclic variation denoted as C. These are short term fluctuations. Last component of time series irregular variations denoted as I.
The reason for doing trend analysis on air pollution data are:
- Comparing one time period to another.
- Comparing pollution level of one geographic area to another.
- Comparing level of one pollutant to another and their rate of increasing.
- Making future projections.

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Smoothing

Smoothing help us to see patterns or trends better in time series data. Sometimes term filter is used to describe smoothing.

2. Literature Review

Various methods are given for finding trends. The simplest method of finding trend is called as moving average or simple moving average [14]. A number of moving average methods around 19 are given to smooth the data [14]. The simple moving average technique is further improved by introducing a new method called as Exponential Weighted moving average.

Mustapha.A (2013) does surface water quality trend detection of Jakara basin in Nigeria using non parametric test called as Sen's slope and Mann-Kendall test .Monthly Rainfall data from 2001-2010 are collected .This contains data about water quality parameter such as: dissolved oxygen (DO) , 5 day bio-chemical oxygen demand (BOD_5), chemical oxygen demand (COD) , ammonia-nitrogen (NH_3-NL) , nitrite (NO_3),dissolve solids (DS) and total solids (TS). The paper shows decreasing trend in precipitation and dissolved oxygen (DO) value of Z=-0.72 and -3.58 respectively .There is increasing trend in other parameters like for BOD_5 Z=2.86, for COD Z=3.58 so on.[27] Jain.S (2012) gives methods for trend analysis of rainfall and temperature data for India. According to this paper trend or temporal variation of annual rainfall, rainy days and temperature for basins of India is detected using Mann-Kendall, Regression and sen slope method .In this magnitude of trend is obtained using either regression or sen's slope method .Seasonal analysis shows that in pre-monsoon season rainfall increased over nine river basin, in rainy days six river basin and in post –monsoon season rainfall increased over four river basin. [4] Karim.S , Alwi.S (2013) forecasts electricity load forecasting in UTP in Malaysia using Moving Average and Exponential smoothing method. In this 2 type of load forecasting is taken Semester On (SOn) and Semester Off (SOf) .Result conclude that Exponential Moving average performs better result as compared to Simple Moving average .[16] Olaniyi.S (2011) proposed a method for stock trend prediction using moving average and regression analysis. This paper predicts financial market prices in the banking sector of Nigerian economy using three banks as a case study. Dataset for 3 banks from Nigerian stock exchange (NSE) contains current market price represented by Y and percentage earning (P.E) ratio represented as X on monthly basis. The regression equation represented as Y=aX+b . Coefficients values a and b are computed using by taking mean of X and Y. Then the value of variable X i.e. market price for next month is predicted by calculating 3-months moving average [15]. Rahman.A and Begum.M (2013) uses Mann-Kendall and sen's slope estimator for rainfall trend detection .In this paper data from 1966 to 2011 i.e 46 years data are taken and monthly of rainfall are detected. By using Mann-Kendall and Sen's slope method trend from January to December along with its slope magnitude are found. Slopes are found using both these methods and are compared .It is found that result is quiet significant as the months where Mann-Kendall shows negative trend similar negative slopes are also shown by sen's slope method [26]. Tang.J et.al(2013) develops a hybrid model that combines Double Exponential Smoothing (DES) and Support Vector Machine (SVM) in traffic flow prediction. For prediction purpose 7 week traffic flow data sre used. In this method DES is use for smoothing purpose i.e to fit raw data. Then the residuals between actual traffic flow and DES are fed into SVM. Previous 36 day data is used for training purpose and next 17 day data is used to examine effectiveness of prediction. This hybrid model is then compared with DES and ARIMA method and it is observed that hybrid model gives reduced or less MAPE and MSE errors as compared to DES and ARIMA models.[29] He.Y et.al(2013) analyze the trend of natural illuminance levels in 14 Chinese cities by Mann-Kendall trend analysis method. Data are collected from Meteorological center of China . Data considered for this includes annual total light natural light illuminance or sun shine hours , cloud cover ,Aerosol, solar activity ,water vapour values. Mann-Kendall method is applied on annual light illuminance data and it is found that some cities have a significantly trend. Reason for this decreasing trend is also discussed as due to increase in cloud cover, water vapour, Aerosol and solar activity. [30] Kurt.A et.al (2008) proposed an online neural network based forecasting system. This is a real time based forecasting method that forecasts the level of pollutants for next 3 days. In this a feed forward network is implemented with 7 input layer and 10 hidden layer and uses Levenberg–Marquardt optimization training function to update weights and bias values.[8] Yang.Y, Xia.Y (2012) proposed a trend based similarity calculation approach. The aim of this approach is to extract trend information to characterize a time series. This approach consist of 2 step first is trend based transform i.e. original time series data is transformed to trend based series .In this step value of current node is compared with last node. The second step is similarity calculation by proposed weighted distance. Three types of trends are seen down denoted as(0), smooth denoted as (1) and up denoted as(2).This method will give an accuracy of about 88.9%.[24] Raudys.A et.al (2013) paper gives moving averages methods(simple Moving average, Exponential Hull ,Triple exponential, Ehlers MA, Mesa MA etc) are applied on stock data(ETF, FOREX, Futures) by considering smoothness and lag and taking simple moving average as benchmark. From this it is concluded that Exponential Hull moving average and triple Exponential moving average performs better as compared to others. [14]. Ofoegbu.O et.al (2014) gives an air pollution monitoring system that will analyze and forecast air pollution data by combining neural network and decision tree .The model consist of 3 input layer 4 hidden and 2 output layer uses sigmoid and hyper tan function to update weights and bias. In this paper neural network model is used to learn patterns and forecasting of pollution data for consecutive years are done using decision tree .[12] Rajasekhar.N (2014) developed a method for weather data prediction by analysis huge weather data .They used a hybrid method using K-means clustering and Support Vector Machine (SVM) . On full training data clustering is applied using euclidiean distance. Then SVM is applied on these clusters. [10] Tan.G (2013) proposed a Least square support vector machine algorithm to predict water quality. The LS-SVM algorithm is applied to a section of the river water quality monitoring data to predict the total phosphorus, and with the BP (Back Propagation), RBF (Radial Basis Function) network method for comparative study of prediction [9]. Yu.X et.al(2013)

represents a support vector regression method for forecasting newspaper/ magazines sales . In this paper data are collected from stores related to sales and clustering of sales is done in 3 categories low , medium and high. It is explored how the sales vary according to shoppers demographic characteristics .It is concluded in this paper that demographic characteristics such as age, sex, income ,education, and occupations affects sales of newspaper or magazines[25]. Some other methods are also introduced to predict trend . Clustering techniques are applied to predict trend of crime [9] . In [3] combination of K-means clustering and classification is introduced to predict future prediction of stock market. Vong.C (2014) proposed short term air pollution prediction using support vector machine. Air pollutant data are recorded from meteorological sites and coorelation between different pollutants are calculated for each day are calculated using pearson correlation cofficients .The present day value of pollutant represented as p(d) and previous day as p(d-1) . similarly Correlated pollutant level of current day represented as Corrp(d) and previous day as CorrP(d-1) . All these values are given as input to SVM using 5 different kernel models : linear, polynomial sigmoid, and wavelet and RBF model. From this it is concluded that Linear and RBF kernel model produces superior results with low error rate [22]. Chen.C et al(2011) gives paper about intraday trend retrieval and its influence on traffic prediction .In this paper traffic flow series is collected from same site of consecutive days .The intraday trend is a M-shaped curve .In this 2 peak value of M represents rush hour of morning and evening and shallow dip representing hour of night or noon. This paper also gives prediction models including Auto Regressive Moving Average (ARMA) ,Feed forward Neural Network ,Bayesian Network.[1] Niskaa.H and Hiltunena.T (2013) proposed a neural network method for forecasting air pollution time series. In this Multilayer Perceptron (MLP) is used .It consists of 2 hidden layer. For training hidden layer scaled conjugate backpropogation and sigmoid transfer function is used and linear transfer function for output layer[11].

3. Methods used for Trend Analysis

A number of methods are introduced for trend estimation. The first step to find trend in any data is to smooth the data . Smoothing is considered in statistical data analysis . Smoothing is some kind of regularization in data [14].

3.1 Moving average smoothing method

Moving average is used for reducing fluctuations and obtaining trend values [10]. It is used to show trend. A simple Moving average method assigns equal weight i.e (1/N) to all N data points.

A simple N day moving average is given as follow:

$$Y(n) = \frac{1}{N}\left[\sum_{k=0}^{N-1} x(n-k)\right]$$

This method uses a mean or average of past k observations for one period ahead forecast [16].

3.2 Exponential Weighted Smoothing Method

The exponential smoothing method is used to predict discrete time series data [15]. This method gives larger weights to most recent observations and weights decreases exponentially as observation becomes more distinct . This method is used when there is trend in data but no seasonal pattern.

Let an observed time series be y_1 $y2$, , , yn .   Formally, the simple exponential smoothing equation takes the form of:

$$\overline{y}_{i+1} = \alpha y_i + (1-\alpha)\overline{y}_i \qquad (1)$$

Where,

y_i is actual known series value for time period i.

$\overline{y}_i$ is smoothing value of variable y for time period i.

$\overline{y}_{i+1}$ is smoothing value for time period i+1.

α is smoothing constant.

The forecast $\overline{y}_{i+1}$ is based on weighting most recent observation y_i with a weight α and weighting most recent forecast $\overline{y}_i$ with weight (1-α).

Initially value of $\overline{y}_i$ is not known therefore, Set the first estimate to first observation as $\overline{y}_i$ =y_i .[14]

The value of smoothing constant α is selected between 0 and 1. Therefore, 0<α<1.

When α=1 the original and smoothed version of the series are identical. For α=0 the series is smoothed flat. Smoothing error represented by e_i for time period i and has value

$$e_i = (y_i - \overline{y}_i) \qquad (2)$$

The general form of eqn (1) is as follows

$$\overline{y}_{i+1} = \alpha \sum_{i=1}^{N}(1-\alpha)\overline{y}_i \qquad (3)$$

For measuring various errors such as MAPE (Mean Absolute Percentage error) , MSE (mean square error) and RMSE (Root Mean Square error) are calculated using formula as given below :

$$MAPE = \frac{1}{N}\left(\sum_{i=1}^{N}\frac{|e_i|}{|y_i|}\right).100\% \qquad (4)$$

$$MSE = \frac{1}{N}\sum_{i=1}^{N}|e_i^2| \qquad (5)$$

$$RMSE = \sqrt{MSE} \qquad (6)$$

The Root Mean Square Error (RMSE) is the measure of accuracy in a fitted time series value in a datasets, specifically trending. It usually expresses accuracy as a percentage. [13]

The series of weights used in producing the forecast $\overline{y}_{i+1}$ is α ,α(1-α), α(1-α)^2 ,…….
These weights decline towards zero in exponential manner [13]. Errors are calculated corresponding to different values of smoothing constants. Smoothing constant having less error is considered as best.

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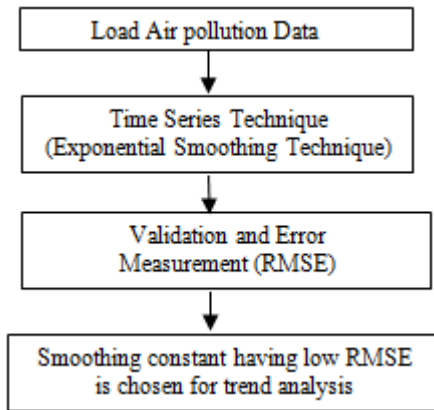
Figure 1: Block diagram for smoothing of pollution data

3.3 Statistical method for trend analysis

In general, the magnitude of trend in a time series is determined either using regression analysis (parametric test) or using Sen's estimator method (non-parametric method).

- **Linear Regression**

Linear regression is a parametric test and it assumes that data has normal distribution and it evaluate existence of linear trend between time variable (X) and desire variable (Y).A linear equation,

$$Y = mX + c \qquad (7)$$

defined by

c (the intercept) and trend m (the slope), can be fitted by regression.The linear trend value represented by the slope of the simple least-square regression line provided the rate of rise/fall in the variable [4].

- **Mann-Kendall Analysis**

This method is used to find trend in time series data along with its magnitude. Mann-Kendall method based on the principle of statistic(S). In this method each pair value is observed for presence of trend.[26][27][28]

Let $X_1, X_2,\ldots., X_N$ represents n data points . let X_i and X_j represents data points at time I and j respectively .
Mann-Kendall statistic (S) is given as:

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^{n} sign(X_j - X_i) \qquad (8)$$

Where

$$sign(X_j - X_i) = \begin{cases} 1 & \text{if } (X_j - X_i) > 0 \\ 0 & \text{if } (X_j - X_i) = 0 \\ -1 & \text{if } (X_i - X_j) < 0 \end{cases} \qquad (9)$$

A positive value for S gives increasing trend negative value of S gives negative trend and zero value of S gives no trend. The normalized test static denoted as Z is then necessary to compute to statistically quantify the significance of trend . It is given as:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases} \qquad (10)$$

The positive value of Z signifies increasing trend and negative value of Z signifies negative trend.Value of VAR(S) is calculated as and is called as variance statistic.

$$VAR(S) = \frac{n(n-1)(2n+5) - \sum_{t=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18} \qquad (11)$$

- *Sen's Estimator Method*

Sen's slope is used to find slope of linear trend. This method calculate the magnitude or slope of existing trend . In this method the slopes (T_i) of all data pairs are first calculated by

$$T_i = \frac{(x_j - x_k)}{(y_j - y_k)} \qquad (12)$$

For i=1,2……,N

Where X_i and X_k are data values at time j and k (j > k) respectively.The median of these N values of T_i is Sen's estimator of slope which is calculated as

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & \text{If N is Odd} \\ \dfrac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & \text{If N is Even} \end{cases} \qquad (13)$$

A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series [4].

4. Conclusion

Different methods such as neural network , support vector machine, Least square method etc are provided for prediction of air pollution as well as other environmental problems.

In this paper Exponential smoothing methodis given to smooth data if there is lot of fluctuations in data. This method also proposed statistical method for trend analysis or we can say prediction of air pollutants.

Statistical method Mann-Kendall only gives sign of trend and sen slope or Sen Estimator method gives slope or magnitude of increasing or decreasing trend. Therefore, combinations of these 2 methods are used for trend analysis that will give both magnitude and sign of trend.

Exponential Smoothing and linear regression methods are used for forecasting .But Linear regression will give a better forecasting with minimum Root Mean Square Error(RMSE).

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