

B.Tech Minor Project Report

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on

AIR QUALITY PREDICTION

BY

N SRI HARSHA (11610186)

V SAI SHRAWAN (11610220)

P RAKESH KUMAR (11610222)

**Under the Supervision of
Dr. S.K.JAIN, (Professor, NITK)**



**DEPARTMENT OF COMPUTER ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
KURUKSHETRA – 136119, HARYANA (INDIA)**

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TABLE OF CONTENTS

Section No.	TITLE	Page no.
I	ABSTRACT	
II	INTRODUCTION	
III	MOTIVATION	
IV	LITERATURE SURVEY	
V	PROPOSED APPROACH	
VI	DATA FLOW DIAGRAM	
	VI.1 Level 0 DFD	
	VI.2 Level 1 DFD	
	VI.3 Level 2 DFD	
VII	RESULTS AND OBSERVATIONS	
VIII	CONCLUSION AND FUTURE WORK	
IX	REFERENCES	

ABSTRACT

For the past few decades the contamination in air quality as well as pollution became a major threat. According to World Health Organization report, at least several deaths occur world wide usually because of air pollution. The prediction of quality of air helps people to for see the damage and it keeps the air pollution under control. In this regard , the machine Learning algorithms are proven to be immensely useful. The main focus of this project analyze the data recorded by India air quality. The index of air quality value is on the basis of concentration of some major air pollutants such as nitrogen dioxide, respirable particular matter, sulphur dioxide and suspended particular matter. Eventually, the classification of air quality ranges as good as satisfactory, moderately polluted, very poor and severe.

INTRODUCTION

Air pollutant :

An air pollutant that originates naturally or by artificial means have very harmful impact on humans. The ash formed from the eruption of volcano produces the primary pollutants. The Sulphur dioxide and Carbon dioxide gas is emitted from factories and motor vehicles respectively. The secondary pollutants are produced from the reaction or interaction of the primary pollutants the information about some of the air pollutants which are used in case of estimation of the index of air quality and there by analyze it qualitatively is as follows:

Sulphur Dioxide(SO₂):

Sulphur dioxide is one of the toxic gases which is formed as a by-product of extraction of copper and contamination of fossil fuels with components of SO₂. The processing of various materials that contains sulphur in the industry is the main source of SO₂. It is also implied by the fact that presence of 99% of sulphur dioxide in the air is due to various human sources. SO₂ has sharp and nasty smell. Moreover it is invisible. The reaction of SO₂ with some other substances forms various harmful components such as Sulfurous acid and sulphate particles. The harmful effect of SO₂ are evident swiftly through worse symptoms almost 15 minutes after its intake from respiration. It causes tight feeling around the chest because of shortness of breathe. It also causes coughing, wheezing and irritates the nose.

Nitrogen Dioxide(NO₂):

NO_x is the generic term which refers to Nitrogen oxides. NO₂ is a hazardous gas which causes significant air pollution. It is composed of oxygen and nitrogen. It reacts with ozone and contribute to the particulate pollution in the out door air. It is actually one of the six massively spread air pollutants in accordance with the standards of national air quality. The presence of the No₂ within the indoor air is mainly because of burning fossil fuels like wood or natural gas. NO₂ has several adverse effects on human such as reduction in lung functioning, increased air ways inflammation and asthma effects. Recent research has linked in NO₂ to the cardiovascular attacks and also sometimes results in the premature death of new born babies with lower weight.

Particulate Matter(PM):

PM is the summation of hazardous liquid and solid particles suspension in air . The complex mixture includes dust liquid droplets smoke etc., i.e various inorganic and organic particles. The particles in air are either emitted directly due to burning of fuel and dust i.e carried by wind. It is emitted indirectly because of emission of various gases pollutants to air. The particulate matter is classified into two groups mainly on the basis of size:

1. The inhalable coarse fraction whose size ranges from 2.5 to 10 micrometer and consists of large particles (PM₁₀ to PM_{2.5})
2. The fine fraction whose size is almost 2.5 micrometer and consists of smaller particles. The particles whose size is lesser than 0.1 micrometer can be considered as ultra fine particles.

Most of the air born particulate matter quantity is because of the presence of fine particles. The fine particles are mainly formed from gaseous substances where as the coarse particles are formed from uncovered soil and mining operations, agricultural process and mechanical breakup.

The PM_{2.5} particles possess high risk to human health. The particles that are less than 10 micrometers in diameter can enter deep into lungs and even into blood circulation.

Data Set:

The data set released by the Central Pollution Control Board of India(CPCBI) and Ministry of Environment and forest under the National Data Sharing and Accessibility Policy(NDSAP).It is clear version data of historical daily ambient air quality

Data Description(Features) :

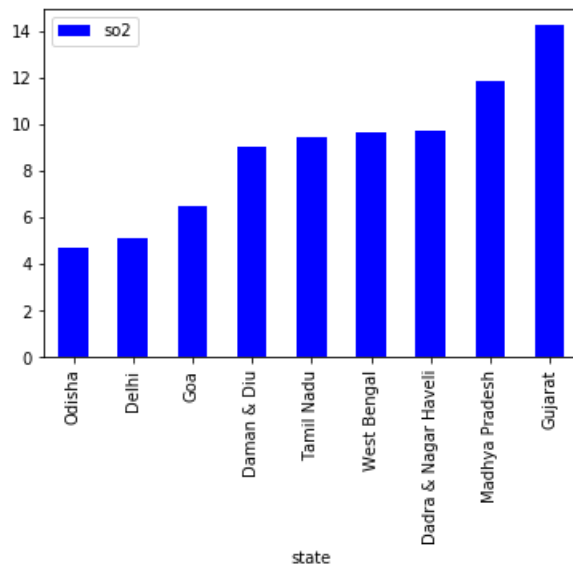
1. Stn_code(the code of corresponding station)
 2. Sampling date(the date of sample collection)
 3. States(The corresponding state in India)
 4. Location (Location where sample collection is done)
 5. Agencies
 6. Type(Area type)
-

7. SO₂ (The concentration of Sulphur dioxide in microgram per meter cube)
8. NO₂ (The concentration of Nitrogen dioxide in microgram per meter cube)
9. RSPM (The concentration of respirable suspended particulate matter which is in the units of micrograms per meter cube).
10. SPM (The concentration of suspended particulate matter which is in the units of microgram per meter cube).
11. Location (Monitoring station)
12. PM_{2.5} (Particulate matter which is in the units of microgram per meter cube).
13. Date

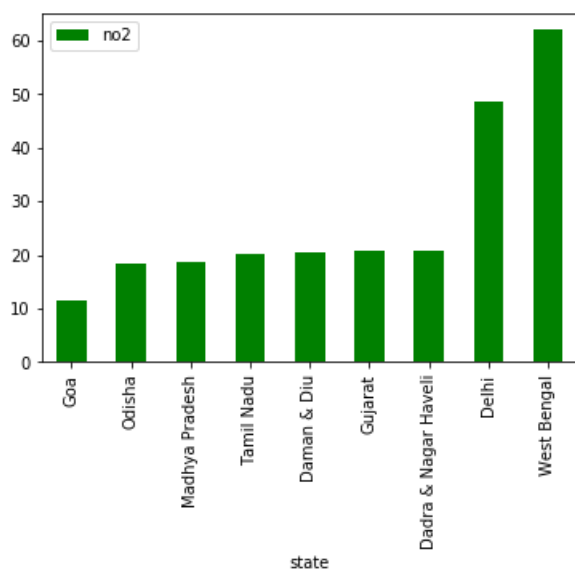
The Data set consists of 30,000 rows and columns.

Visualization of States and individual pollutants:

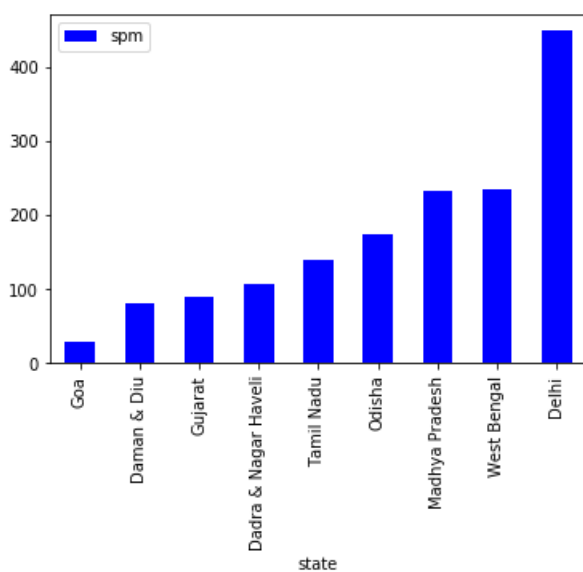
1. Concentration of Sulphur dioxide



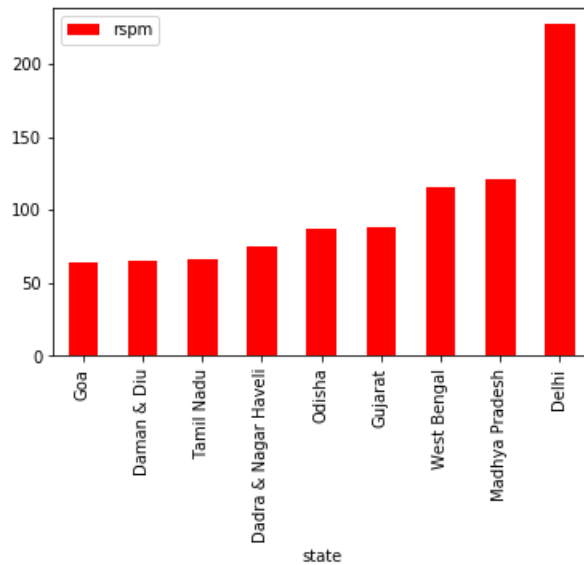
2. Concentration of Nitrogen dioxide



3. Concentration of suspended particulate matter



4. Concentration of Respirable Suspended particulate matter



Machine Learning algorithms used for prediction:

Here is the brief description about various machine learning prediction techniques used.

1. Multiple Linear Regression :

Multiple linear regression method, which is also called as the multiple regression. It can be realized as extension of the ordinary least squares(OLS) regression method which involves one or more explanatory variables. It is basically a statistical approach which uses various variables which are explanatory in order to predict the response variable's outcome.

The formula for the multiple regression is :

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_p x_{ip} + \epsilon$$

Here for n=i number of observations

Yi=the dependent variables

Xi =the explanatory variables

B0=y-interrupt (a term which is constant)

Bp = The coefficient of slope for each

T= The error term in the model (which are also called as residuals).

2. Logistic Regression

The logistic model which is also called logit model is used for probability modelling of an event or class.

Logistic regression is basically a statistical technique which is used for binary dependent variable modelling based on the logistic function. Logit regression is also used for parameter estimation of a logistic model. In a logistic model, the log-odds for the label one values is the linear combination of one or more than one independent variables where each variable can either be continuous or be binary.

3. Random Forest

The Random forest, which is also called as the Random decision forest, corrects the behaviour of decision trees with respect to overfitting to the training set. It is basically an ensemble learning method in order to perform various tasks including classification and regression. At training time, it indulges in the construction of a multitude of decision trees and produces a single class as output which is the mean prediction of the individual trees for regression and the mode of all the classes for the classification.

4. Decision Tree

A decision tree model which is also called as model of decision is a tool which uses an acyclic graph structure. It also leads to possible consequences which include the cost of the resources, event outcomes based on decisions made. In a decision tree, each of the internal nodes notifies the test on some feature and each of the branches depicts the test outcome and each of the leaf nodes represents the label of the class.

5. Support Vector Machine

SVM is basically a supervised machine learning methodology. It is a discriminative classifier which can be depicted by a separating hyper plane. The output produced by the SVM algorithm is an hyper plane which is optimal and used in the classification of the new data points. In the two dimensional space, this hyperplane is the line that bifurcates the plane where either of the sides represents a class.

6. K- Nearest Neighbour

KNN is basically a supervised machine learning methodology, which is a non-parametric method used for regression as well as classification. In the K-nn regression, output produced is object attribute's resultant value. In K-nn classification the output is the membership of an object for a particular class based on the number of votes obtained by observing the classes for which k nearest neighbors belongs. The local approximation of function occurs and the computation is performed only after classification which implies K-nearest neighbour is actually a type of instance based learning, which can also be addressed as lazy learning.

MOTIVATION

A major study carried out in the 650 cities across the globe regarding the urban pollution has confirmed that air pollution has hazardous impact on the health of the human beings in short term. It is linked to the death of the people who frequently suffer from illness and elderly people in a discrete manner. It has been scientifically proven that quality of air massively effects health of the people and pollution free environment greatly signifies paves the way to lead a better quality of life. Because of air pollution, Many bodily functions are tampered such as fatigue, cardiovascular, nervous system and reproductive system damage and so on.

In order to overcome this scenario, various models of machine learning are used such as the linear model, logistic model, model containing decision tree, model containing random forest, knn model and support vector machine model in order to predict index value of air quality. The Indian air quality index uses bands. It is on the basis of the concentration of major air pollutants. The key benefit of using an AQI is that it has the ability to communicate data with public,

conveniently and easily. AQI values are color coded and easily scaled, which exempts one to understand concentrations and units. It is rarely valuable to transform the data into a form that the public can understand. The AQI value can be presented in an understandable and recognizable form for everyone. More over it requires minimum effort and minimum calculation in order to compute the index value of air quality. .

LITERATURE SURVEY

The prominent work has been done in the air quality prediction using machine learning as well as approaches by various researches and scholars. Richard O sinnott and ziyue Gyaan collected air pollution data , especially PM_{2.5} value (Particulate matter less than 2.5 micrometers) from various web based resources and predicted air pollution using various models such as Artificial neural networks(ANN), the Long short term memory(LSTM) recurrent neural networks. Ying Zhang , Yanhao Wang , Minghe Gad proposed an improved version of air quality prediction method based in light GBM mode for the prediction of the concentration of fine particulate matter, PM_{2.5} in Beijing at 35 stations which monitors the quality of air. Mahanijah Md kamal , Rozita Jailini worked towards the investigation of effectiveness of the Neural network that propagate backwards (BPNN) and the Artificial neural networks(ANN) for the prediction of the ambient air quality for air quality monitoring in Malaysian states. Mohamad Reza Delavar, Amin Gholami used various prediction models to determine air pollution in Tehran city based on concentrations of PM_{2.5} and PM₁₀. The machine learning methods used to include geographically weighted regression, artificial neural network, support vector machine and auto-regressive non linear neural network with latter being the most reliable model. Costandna Veljanovska , Angel Dimoski compared four machine learning algorithms neural network, decision tree model, k-nearest neighbors technique and support vector machines in terms of prediction of air quality index. The database used contain meteorological information of each day of 2017 in the republic of Macedonia capital city. It was proven that these algorithms when implemented predicts AQI value in an efficient manner.

PROPOSED APPROACH

The given data set should be normalized in accordance with the prediction requirements before getting trained with various machine learning models.

Data cleaning:

Drop the unnecessary columns:

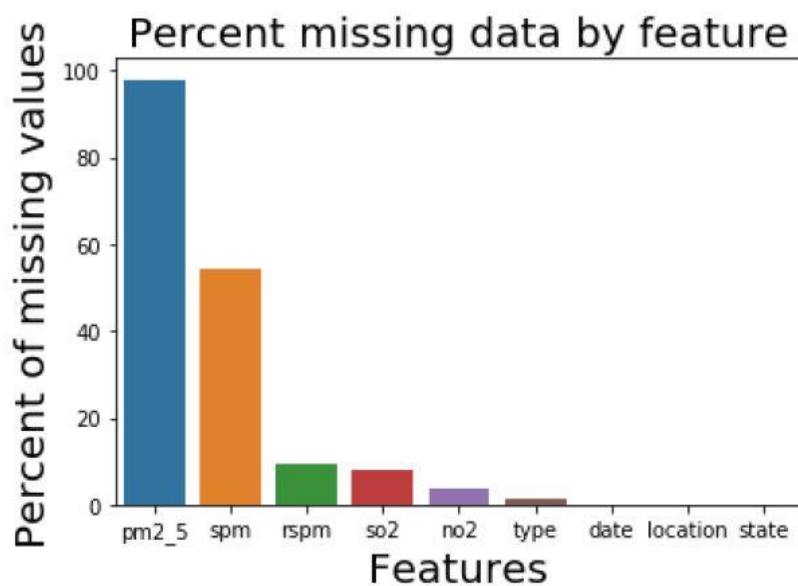
Stn_code

Agency

Sampling_date

Location_monitoring_station

Percent of missing values (Bar plot):



In order to perform the further analysis, missing values in the data set are filled by the mean of each columns grouped by states. This is done through the method of Imputation.

Missing data can create problems for data analysis. Instead of list wise deletion of missing values cases imputation can be realized as a way to avoid this pitfall. This method basically deals with the replacement of missing data with substituted values.

Derivation for individual pollutant index and AQI:

The air quality index transforms complex air quality data that consists of various air pollutants into a single value which represents air index. Color and nomenclature also act as a tool for air quality status communication to the people in easily understandable and highly effective form.

On the basis of the ambient concentration levels of the major pollutants of air and their affect on human health which is also called as health breakpoints. The AQI categories are named as severe,very poor,moderately polluted,satisfactory and good. As the AQI arises, the risk of human health intensifies.

The national air monitoring program(NAMP) has been conducted on more than 342 monitoring stations over 240 cities. This programme was operated by both state and central control boards. According to the prescription of national ambient air quality standards,the propose AQI consider eight air pollutants.They are SO₂, NO₂, NH₃, PB, PM_{2.5}, PM₁₀, CO, O₃ whose values of AQI along with concentrations and the impacts on health associated to it are represented as follows:

AQI Category, Pollutants and Health Breakpoints								
AQI Category (Range)	PM ₁₀ (24hr)	PM _{2.5} (24hr)	NO ₂ (24hr)	O ₃ (8hr)	CO (8hr)	SO ₂ (24hr)	NH ₃ (24hr)	Pb (24hr)
Good (0–50)	0–50	0–30	0–40	0–50	0–1.0	0–40	0–200	0–0.5
Satisfactory (51–100)	51–100	31–60	41–80	51–100	1.1–2.0	41–80	201–400	0.5–1.0
Moderately polluted (101–200)	101–250	61–90	81–180	101–168	2.1–10	81–380	401–800	1.1–2.0
Poor (201–300)	251–350	91–120	181–280	169–208	10–17	381–800	801–1200	2.1–3.0
Very poor (301–400)	351–430	121–250	281–400	209–748	17–34	801–1600	1200–1800	3.1–3.5
Severe (401–500)	430+	250+	400+	748+	34+	1600+	1800+	3.5+

AQI	Associated Health Impacts
Good (0–50)	Minimal impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease.
Very poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401–500)	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

Computing the AQI:

The AQI i.e index of air quality can be realized as piece wise function of concentration of pollutant. A jump of discontinuity of an unit of AQI occurs at the boundaries between categories of AQI. The conversion of concentration to AQI value can be done through the following equation.

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

Where

C= Pollutant Concentration

I= The index of quality of air

C_{low} = The break point of concentration which is less than C.

C_{high} =The break point of concentration which is greater than C.

I_{low} = The breakpoint of index that corresponds to C_{low}.

I_{high} = The breakpoint of index that corresponds to C_{high}.

The stated formula is used in the calculation of pollution index for SO₂, NO₂, PM2.5, RSPM, SPM.

The calculation of a sub index is calculated for each of the mentioned air pollutants based on the likely health impacts and the ambient concentrations. The overall AQI is reflected by the value of worst sub index. If multiple air pollutants exhibit it at the monitoring location site, the largest AQI value of the pollutant is considered for the corresponding location.

After this step data analysis and visualization is done and as per the required criteria. The data has also been standard dated accordingly. The various machine learning models that used on this modified data to predict the air quality index(AQI) are presented as follows:

Linear regression model 1:

Training Features : SO_i, NO_i, RSPM_i, SPM_i (these are the pollution indices calculated)

Target Feature: AQI (the calculated index of air quality)

The split of data set occurred such that 80% is for training and 20% is for testing purposes.

Linear regression model2 :

Training Features : SO₂, NO₂, RSPM, SPM (the concentration of given pollutants).

Target Feature: AQI (the calculated index of air quality)

The split of data set occurred such that 80% is for training and 20% is for testing purposes.

Classification : For the AQI values a new column that contains corresponding AQI range values was added using a function for the multiclass classification.

Logistic Regression model 1:

Training Features : SO_i, NO_i, RSPM_i, SPM_i (these air pollution indices)

Target Feature: AQI_range(the calculated range of air quality index)

The split of data set occurred such that 80% is for training and 20% is for testing purposes.

Logistic regression model2 :

Training Features : SO₂, NO₂, RSPM, SPM (the concentration of given pollutants).

Target Feature: AQI_range (the calculated range of air quality index)

The split of data set occurred such that 80% is for training and 20% is for testing purposes.

Decision Tree Classifier model :

Training Features : SO₂, NO₂, RSPM, SPM (the concentration of given pollutants).

Target Feature: AQI_range (the calculated range of air quality index)

The split of data set occurred such that 80% is for training and 20% is for testing purposes.

Random Forest Classifier model :

Training Features : SO₂, NO₂, RSPM, SPM (the concentration of given pollutants).

Target Feature: AQI_range (the calculated range of air quality index)

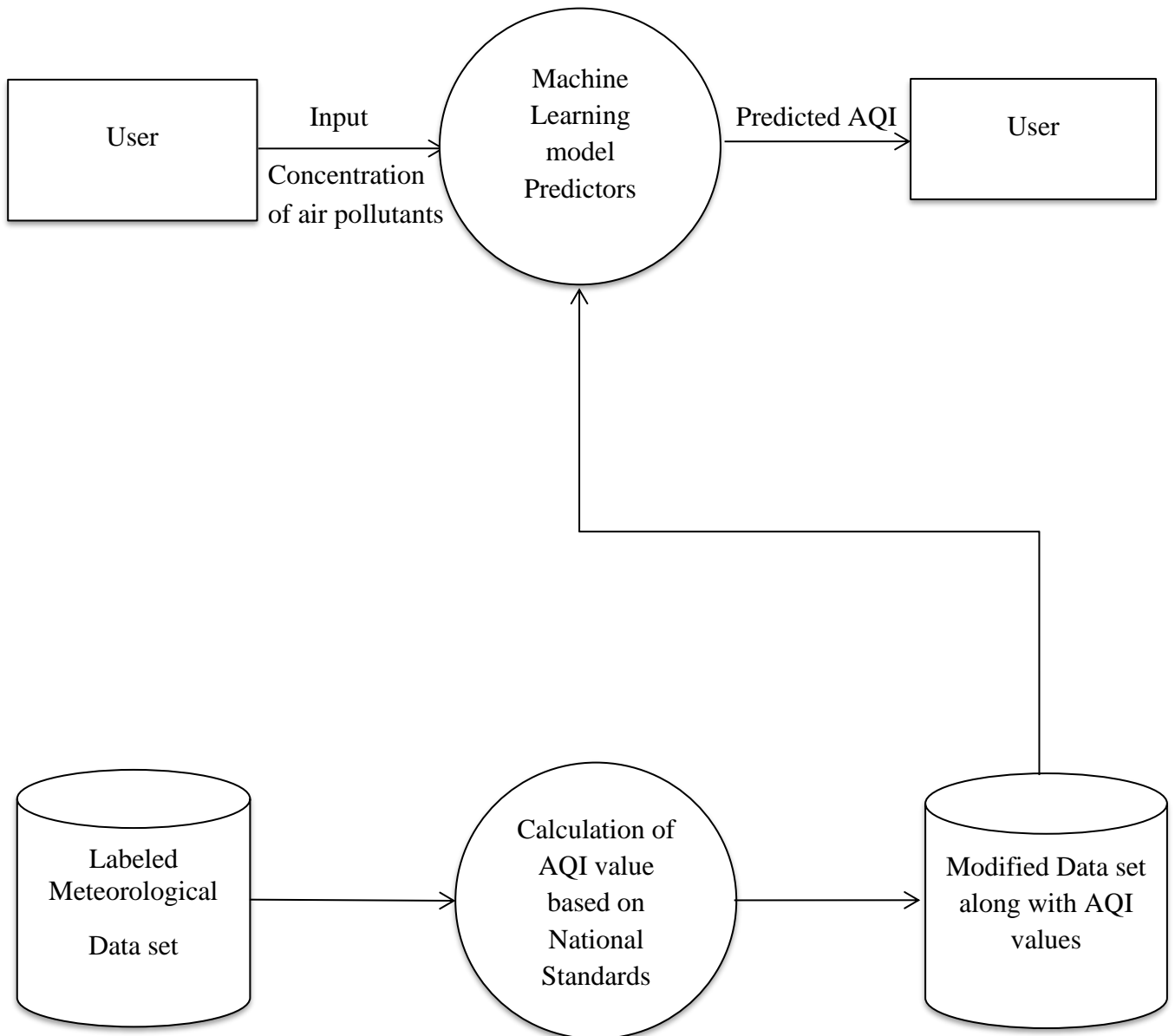
The split of data set occurred such that 80% is for training and 20% is for testing purposes.

DATA FLOW DIAGRAMS (DFD's)

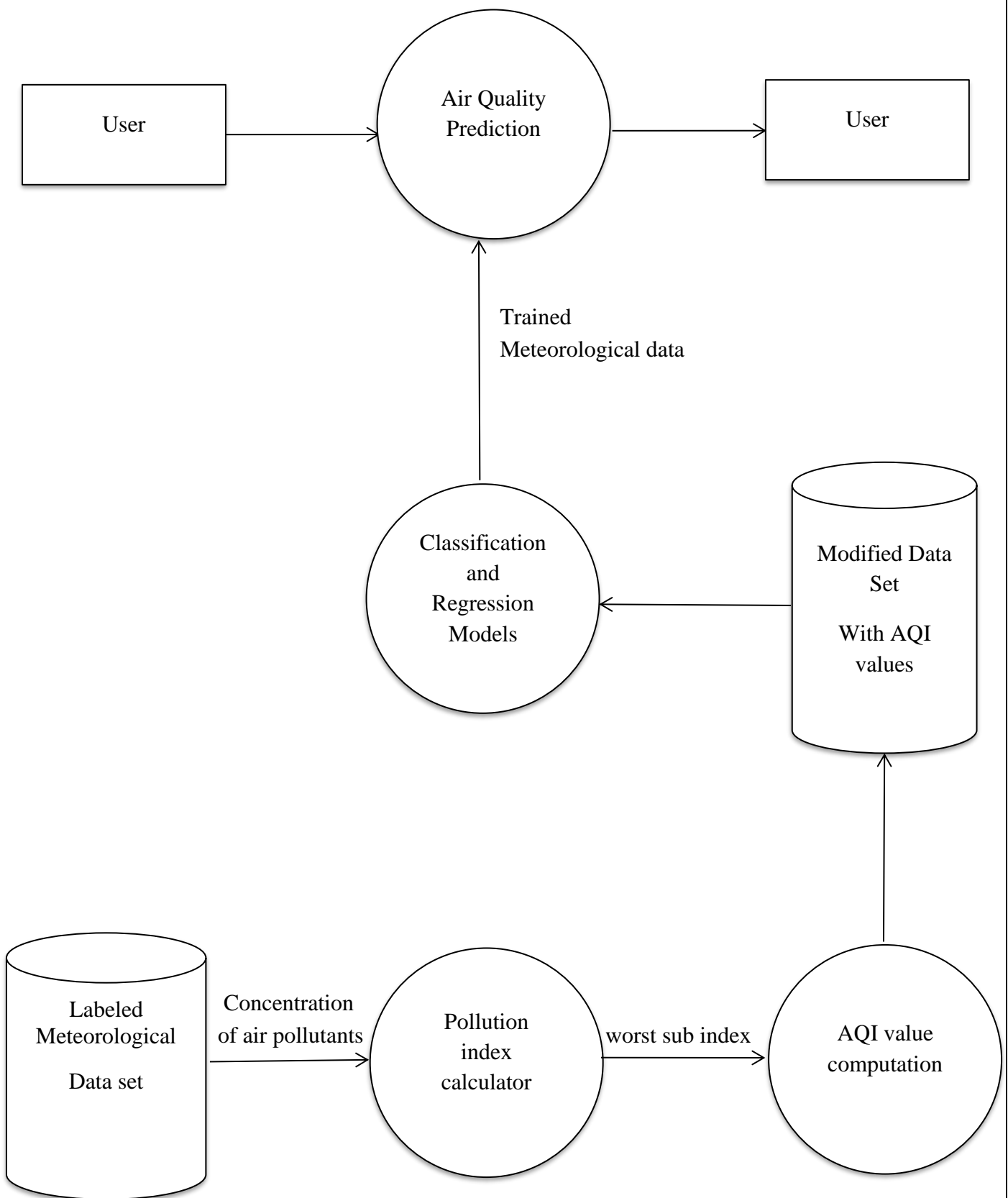
Level 0 DFD:



Level 1 DFD:



Level 2 DFD:



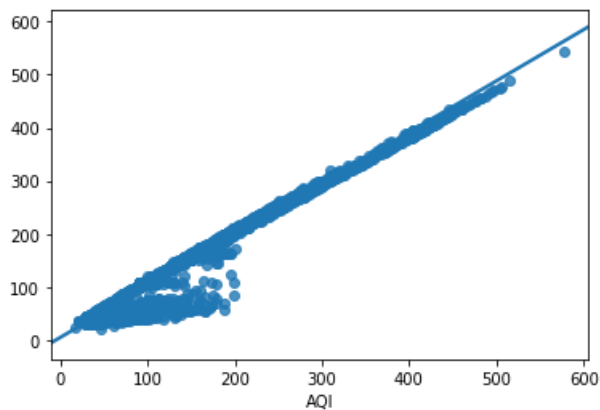
RESULTS AND OBSERVATIONS

The Qualitative assessment of AQI value Prediction using various machine learning models is presented as follows:

Linear Regression model 1:

Intercept	14.6265	
Coefficients	SO _i	0.0164
	NO _i	0.0284
	RSPM _i	0.0554
	SPM _i	0.9083
Accuracy score	0.964 or 96.4%	
R ² value	0.96	
Mean square Error	17.31	

Regression plot of actual values vs predicted values:

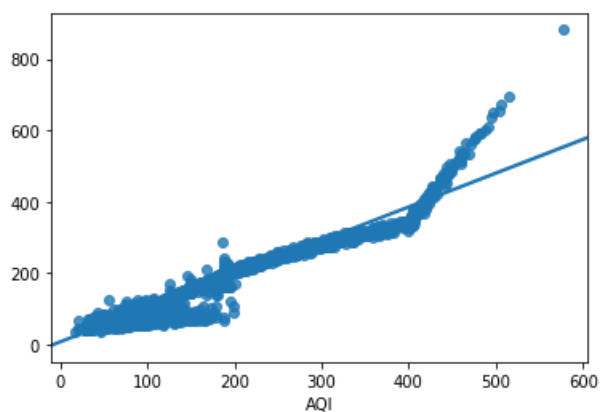


We can see that the model has a high accuracy and it is a good model for AQI prediction given the value of the individual pollution indices

Linear regression model 2:

Intercept	27.8448	
Coefficients	SO2	0.132
	NO2	0.1059
	RSPM	0.1250
	SPM	0.6486
Accuracy score	0.9515 or 95.15%	
R ² value	0.95	
Mean square Error	20.11	

Regression plot of actual values vs predicted values:



We can see that the model has a high accuracy and is a good model for AQI prediction given the value of individual pollution indices, however the Linear Regression Model 1 is much better than the second model

The various other machine learning prediction models used and the corresponding accuracy scores are mentioned as follows:

Model	Accuracy Score
Logistic Regression model 1	0.7572 or 75.72%
Logistic Regression model 2	0.7601 or 76.01%

Random Forest Classifier model	0.9996 or 99.96%
Decision Tree Classifier model	0.9998 or 99.98%

It is clear that model 1 and model 2 of Logistic Regression are not the good models for classification in this case because of the low accuracy score. However, the Random forest classifier model and Decision tree classifier model are very good models (with latter being the best) for classification in this case because of high accuracy score

Model	R ² value	Mean Square Error
K Nearest Neighbour	-49.51	649.24
SVM		

CONCLUSION AND FUTURE WORK

The high degree of correlation between AQI and the pollutants such as SO₂, NO₂, RSPM, SPM has been emphasized significantly. The amount of AQI has been incremented considerably over the years. It is high time to take preventive measures against high AQI and shun the damage it causes on human health. The models used can be extended further to include more pollutants for the comparatively accurate prediction of AQI value. The data set can also be trained using various models of deep learning such as the artificial neural networks (ANN), auto regressive non linear neural network etc., in order to obtain high degree of effectiveness. The proposed system will be useful for meteorological department and common people for the prediction the level pollution in air and take the required action accordingly. This system will also help the people to form a source of data for small localities which are not considered usually compared to larger cities.

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