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Prediction and Optimization of Air Pollution-A Review Paper

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Abstract: ***Traffic and industries are increasing day by day and therefore pollution is increasing rapidly as a result. In world increasing in air pollution is leading to various serious health hazards. Air pollution not only affecting humans, it had a vivid impact on the environment and aquatic life as well. This issue of air pollution has become a global concern due to its effect on nature. Thus the prediction of air pollution can be a useful step to take appropriate measures for the increasing pollution. There various measures had been reviewed in this paper which had been used for the prediction of air pollution pollutants. Some of them are Deep Learning, Machine Learning, Feed Forward Neural Network, and so on.***
Keywords: Air pollution, PSO, NARX, ANN.

I. INTRODUCTION

Air and Water are two inseparable and essential commodities for sustainable human life on earth. Rapid Increase in transportation and industrialization to support a growing population has an adverse effect on the environment. Air pollution has an adverse effect on nature. Air pollution is more common in large cities where the emission from many different sources is concentrated. Sometimes mountains or tall building prevents air pollution from spreading out.

This air pollution often appears as a cloud masking the air musky called smog. Large cities in poor and developing nations tend to possess a lot of pollution than cities in developing nations According to the World Health Organization (WHO), some of the world most polluted countries are Pakistan, India, China, Peru, and Egypt. However, many developed nations also have a pollution problem like Los Angeles, California. Air pollution effected humans as serious health problems. It is widely found that air pollution has increased criminal activities and various unethical activities. Many humans have been seen in a state of anxiety or physiological arousal in reaction to the potential for undesirable outcomes. In many theories it has found that air pollution is increasing anxiety in humans. Therefore, we found a large percentage of pollution is suffering from the stage of depression. Apart from depression, there are many severe diseases such as Asthma, Lung Cancer, Cardio Vascular Problem, etc that are caused by Air pollution. Others, such as Animals, Plants and entire ecosystem can suffer effects from air pollution. Global warming is an environmental phenomenon caused by nature and anthropogenic air pollution. Because of that, many animal or plant species came into an edge of extinction and some animal had extinct from the ecosystem. Hence a system should be designed which can help us to predict the air pollutants so that we are able to take appropriate steps to control it. Thus the prediction system is required to decrease the level of air pollutants from the environment and provide a clean and safe environment for our future generations. There are a number of methodologies were used to predict the air pollutants.

One such method is Neural Network. The 2-NN is an ensemble learning network using back propagation neural network as base learning algorithm in one model. The 2-NN takes the historical time series of pollution index and meteorological data into consideration, which is also a good idea for generic forecasting systems. Another method is wavelet Neural Network (WNN). The Wavelet Neural Network is a combination of artificial neural network [1][2] and wavelet analysis. The network avoids falling into local optimal, and also has the characteristics of time–frequency local analysis. So it is mandatory that we provide such a technique that can overcome the drawbacks of the present technologies and provide solutions to for prediction of air pollutants which will help in providing a safer, cleaner, efficient and more comfortable environment. There many methods used to predict the air pollution. This paper presents a review of prediction of air pollution using various different techniques and their algorithm.

The major pollutants such as ozone (O3), particle matter (PM), sulfur dioxide (SO2), carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), pesticides, and metal contributes to the reason for air pollution. This needs to be controlled in an appropriate manner to control in air pollution. There have found that the Standards of the air pollution particles [3] according to the standards of National Ambient Air Quality Standards (NAAQS). According to that there are two types of standards they are Primary and Secondary Standards. Primary Standards, which protect against sever health problems while Secondary Standard protect against damage to welfare organization that is to crop and vegetation's or to damage in constructed buildings.

Table 1: NAAQS Table Lists For Standard of Air Pollution Standards [3]

Pollutant	Primary/ Secondary	Averaging Time	Level
CO	Primary	8 hours	9 ppm
		1 hour	35 ppm
Lead (Pb)	Primary and Secondary	For 3 Months	0.15 g/m^3
NO_x	Primary	1 hour	100ppb
		1 year	53 ppb
Ozone	Primary and Secondary	8 hours	0.07 ppm

There is another approach called (AQI) Air quality index [3] which is a collection of agencies of government whose main purpose is to exchange information, news, or ideas about the air pollution to the people and create awareness for them how to take preventive measures against increasing air pollution. Different values take between 0 – above 300
Which show air pollutant level of pollution in the society? Different countries have its own index depends upon weather, population, development etc.

Table 2: AQI Index [3]

AQI	Air Pollution Level
0-50	Excellent
51-100	Good
101-150	Low
151-200	Medium
201-300	High
300+	Very High

II. METHOD ANALYSIS

There are various air pollutants such as ozone (O3), particle matter (PM), sulfur dioxide (SO2), carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), pesticides, and metal contributes which is causing many serious health issues to not only to humans but to animals and to our ecosystem is affected adversely therefore there is a need to predict these in advance and take appropriate steps to control these pollutants in right time. To predict air pollution many researchers are doing many research works to get proper and accurate result with the help of which we can be able to take right steps at the right time. According to the Shwetal Raipure [1] in Monitoring and Prediction of Air Quality using Neural Network stated two concepts of predicting the values of air pollutants they are first using the neural network and the other one is using the spatial Prediction of air pollutant particle index in the atmosphere. The main aspect to improve the efficiency and accuracy is to take into account the hidden values and take initial information as input to artificial neural network Surajit Chattopadhya and Goutami Bandyopadhya stated the prediction of mean monthly total ozone concentrations over the calculated period [3], they used the concept of Sigmoid activation function over single hidden layer and two hidden layer perceptron that are they used two neural network model to predict the ozone mean at 0.9 rates of learning.
A paper published by Zhou Kang and Zhiyi Qu used Back propagation neural network [5] for prediction of air pollutants and they used genetic simulated annealing algorithm used for optimizing the result which yields the highest accuracy.
In paper [11] machine learning approach has been used for prediction of air pollutants such as ozone, particulate matter and sulfur dioxide. The prediction has been made for one hour. They proposed a model which can predict hourly prediction of pollutants using a multi task learning (MTL) problem and also used various normalization techniques which helped to achieve better performance and accuracy rate.
Gaganjot Kaur Kang, Jerry Zeyu Gao, Sen Chiao, Shengqiang Lu, and Gang Xie presented a review paper [10] on the big data analytics approaches and machine learning for forecasting the air quality index. According to the paper [4] it has made a research work on predicting PM 2.5 concentrations using RNN (Recurrent Neural Network) with LSTM (Long Short Term Memory) because it has been found that PM 2.5 has been severely effecting the human health and much research has been already proposed

for predicting it so here RNN along with LSTM is used, which is a high level Neural Network API written in python. The data were collected from EPA (Environmental Protection Administration) [4] of Taiwan from 2012 to 2016 for forecasting data of year 2017.Here forecasting has been done for next 4 hours for 66 stations.

According to the paper [8] it showed a method of prediction of air pollutants of eight hours ahead of time in the area of Bilbao. They used different method for the different air pollutants, therefore for the SO2 and CO they used neural network for prediction while NO2 and O3 uses the MLP, GRNN architectures are used. The model has been selected on the basis of pollutants, locations and the number of hours the prediction should be made.

As we increase the time of prediction the rate of negative accuracy rate have been seen due to varying amounts of temperature, dust, humidity, noise which are the key factor for the air pollution prediction. Masoume Asghari Esfandani and Hossein Nematzadeh [6] used ANN-BP (Artificial Neural Network with Back Propagation) hybrid GA(Genetic Algorithm) and BP-PSO (Back Propagation with Particle Swarm Optimization) to evaluate the predictions and concluded that the BP-PSO algorithm provide higher accuracy rate as compared to others.According to the Chao Zhang, Junchi Yan, Yunting Li, Feng Sun, Jinghai Yan, Dawei Zhang, Xiaoguang Rui, Rongfang Bie machine learning [9] can be used to predict the air pollutants particulates which helps to define the multi-channel ensemble learning frameworks which uses the Deep Boltzman Machine as the basic building block of learning system. They used the technique based on data of Beijing China and also used in the web service system as well.

Data mining concept used by Ebrahim Sahafizadeh and Esmail Ahmadi helped to predict air pollutant in dusty days. As a normal dust can severely affect the temperature prediction so that taken in account the pollutants are calculated and predicted by using the decision rule which takes various parameters for prediction such as humidity, air pressure and dusty days.

A. Feed Forward Neural Network

Feed Forward Neural Network [1] has been generally used for prediction in short term the neuron network consists of a single layer of output nodes; the inputs are feed directly to the outputs via a series of weights. The neuron network model has specified in the figure which shows the topology of feed forward neural network.

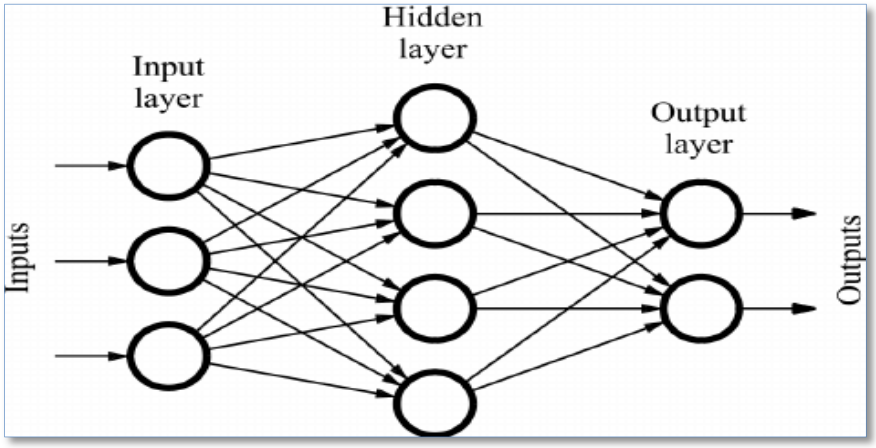

Fig.1 Feed Forward Neural Network [1]

For activation functions of the neurons, there are used hyperbolic tangent in the neurons of the first layer and linear function in the neurons of the second layer. It has various parameters where,

1) C – current value of the pollutant concentration;
2) T – air temperature;
3) W – wind direction;
4) U – wind speed;
5) P – atmospheric pressure;
6) M – unfavorable meteorological conditions mode;
7) Cp – forecasted value of the pollutant concentration

There is another method called nonlinear Auto Regressive model (NARX) [2] based Artificial Neural Network (ANN) [2] used to predict air pollution particles for major two particles such as CO and NOx.

B. Non Linear Auto Regressive Model(NARX)

NARX [2] Non Linear Auto Regressive Model takes exogenous inputs and is a nonlinear autoregressive network, with feedback connection covered various level of the network.

It is also symbolizes as ARX model due to non-linear generalization, which contains tools and techniques to identify black model identifications. These models are widely used in variety of fields of applications. This model is used because they are used in time series; therefore we can predict various values at different time span.

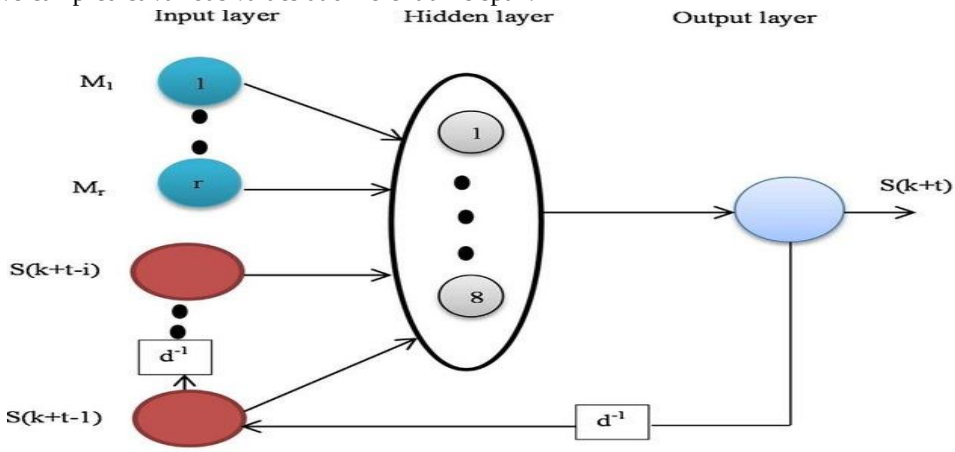

Fig.2 Nonlinear-autoregressive-with-exogenous-input-NARX-model-architecture [2]

Where,

d^{-1}= Delay

M r (t) = Input Vector

S (k + t) = Target Vector

According to the paper [2] shows that the experiment is performed in three set using only pollutants, using meteorological variables and in third process it uses both metrological variables with concentration of air pollutants. Thus conclude that the third process is more efficient way to estimate pollutant concentrations.

Table 3. NARX Parameters [7]

NAME	PARAMETER
Number of network layer	3 layer: input layer, hidden layer, output layer
Number of nodes in input layer	N neurons, where each neuron is feature
Number of nodes in hidden layer	one hidden layer with N/ 2 neurons
Number of nodes in output layer	one output layer, where in the output the next-day concentration is obtained
Learning rate	1
The used activation function	-transfer function in hidden layer: tansig -transfer function in output: purelin
Training set	32
Max training time	epoch=10000
Performance function	Mean Squared Error (MSE) = 0.01
Network training algorithm	Levenberg-Marquardt

1) https://www.google.com/search?q=feed+forward+neural+network&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjuzemTyZXhAhVT6XMBHV8_BLIQ_AUIDigB&biw=1366&bih=657#imgrc=-xBrIbqYy1Pg-M:
2) https://www.researchgate.net/profile/Ditiro_Moalafhi/publication/322177108/figure/fig1/AS:584393957593089@1516341785733/Nonlinear-autoregressive-with-exogenous-input-NARX-model-architecture-showing-the.png

There are various parameters used in NARX which have been shown in the Table 3.

C. Back Propagation Training Algorithm

This algorithm is generally used for long term prediction. It also contains input, hidden and output layer. It basically carried forward with two steps that is with forward and backward pass. As an input to sensory nodes of the back propagation network we pass pattern vector as input, these input will carry forward to each layer to produce an input to next layer that is create an output which is passed to next layer, this process continues until we get a result. In forward pass the weights are constant; it is not variable in forward pass. While during the backward pass due to the error signal the weights cannot be kept constant therefore the these signals are propagated to backward direction opposite of synaptic connections directions.

The diagrammatical representation of back propagation is shown below in Fig 3.

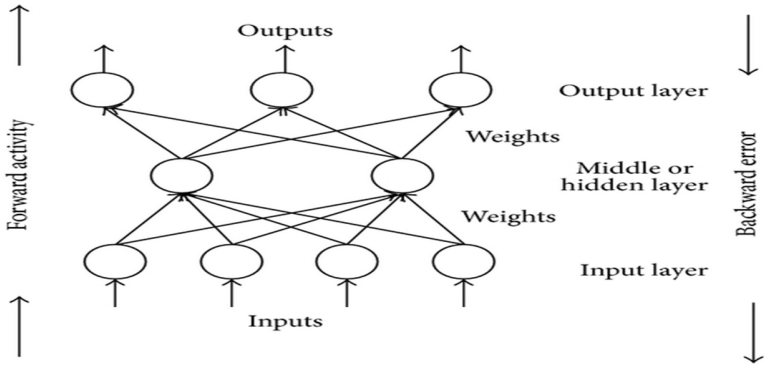

Fig.3 Typical MLP feed-forward artificial neural network structure [3].

With the help of Figure 3 we can conclude there are three layers. According to K.P. Moustris, P.T. Nastos and A.G. Paliatos [13] the first layer consists of training subsets in order to best fit the nonlinear function the networks are trained. Second Layer consists of validation subset where in order to update the best threshold and errors these are verified so that it does not contains any kinds of error. Where last layer is test subset where new or unknown data are evaluated for best approximate results. According to Surajit Chattopadhyay and Goutami Bandyopadhya [3] the algorithm for the multilayer neural network is given in eq. 1

$$W_i(k+1) = w_i(k) + \mu(T_i - O)f\,'(w_i x_i)x_i$$

Where,

1) initial vectors w_o
2) w_i is the weight matrix of nth neuron.
3) X_i is the input i^{th} neuron
4) O_i is the actual output of i^{th} neuron
5) T_i is the Target output
6) μ is the learning rate parameter.

The Mean squared error in Back Propagation
Algorithm it is also called LMS [4] is given by eq. 2

$$E = \tfrac{1}{2}(T_i - O_i)^2 = \tfrac{1}{2}[T_i - f(w_i x_i)]^2$$

D. RNN (Recurrent Neural Network)

RNN mainly deals with input of pieces in any form text, speech, or climate. If we consider of climate then if it is calculating for today then it will requires all data of tomorrow as well therefore we obtain the result in a systematic way with continuous data. With the formula used in RNN [4] we can predict a pattern of sequence of outputs.

$$h_t = \tanh(W_h h_{t-1} + W_x X_t) \quad (1)$$

$$y_t = W_y h_t \quad (2)$$

Where yt is output vector, ht is hidden layer vector, xt is input vector, and Wh is weighting matrix. There are various gradient issues faced by RNN which was solved using the LSTM. According to this paper [4] it has been stated that LSTM is being used as steps to prepare the RNN because of which it is also called as LSTM Network. The information is basically stored in the form of neurons and each neuron has three gates as shown in fig 3.Each gate have their own specifications called input gate, forget gate and output gate which help to solve problems related to long term dependencies of data.

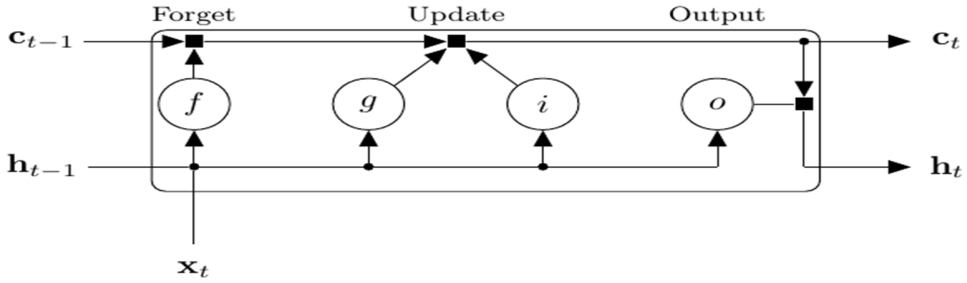

Fig 3. LSTM's Gates [4]

1) *Forget Gate*: The main role of forget gate is to filter the data by remembering it. We pass a data and using Sigmoid functions [4] we can obtain a value of 0 and 1, where 0 means data completely forgotten and 1 means the data is completely remembered.
2) *Input Gate*: It is basically provides more updated data. It decide which data to be remembered and which to not. After that by using sigmoid functions it provides a updated information's to be used for later work.
3) *Output Gate*: By using the sigmoid functions, this gate decides what will be the output of the LSTM cell which needs to be processed further.

For predicting the values have been taken then normalized it to limit the values. Therefore we obtain the results accordingly.
We have undergone through various techniques of ANN now let we compare the entire algorithm in a tabular manner for better understanding.

TABLE 4. Comparisons of ANN method

Ref .No.	Method Used	Data Source	Approach	Strength	Result
1	Use of Neural Network	The Data has been taken from previous year values of air pollutions	Author propose the concept of Elman recurrent neural network with the learning algorithm	The short term model and the spatial model proposed the air monitoring system which is useful for municipal authorities.	To achieve Proper environmental results the neural network model in conjunction should be used.
3	Use of Sigmoid activation function over single hidden layer and two hidden layer perceptron at a at 0.9 rate of learning.	Data taken from Arosa http://www.robhyndman.info/TSDL/monthly/arosa.dat.	Author propose the prediction of mean monthly total ozone concentrations over the calculated period	Here single hidden layer and Two hidden layer are considered with Back propagation, where Two hidden layer perceptron founds to be best for the prediction of Ozone.	Need to predict the value of all months in order to find the best result of the algorithms.
4	Predicting PM 2.5 concentrations using RNN (Recurrent Neural Network) with LSTM (Long Short Term Memory)	The data is collected from EPA (Environmental Protection Administration) of Taiwan Of year 2012-2016.	Author proposes an approach to forecast PM2.5 concentration using Tensor Flow.	Author propose an approach to forecast PM2.5 concentration using RNN (Recurrent Neural Network) with LSTM (Long Short-Term Memory) using Tensor Flow	Need to predict the at local air pollutants areas and at different atmospheric height of airflow data.
5	AQI prediction model using on back propagation (BP) neural network	Data collected from Lanzhou china air quality monitoring and analysis platform from January 1, 2013 to May 31,2017	Author States an approach to Predict and Optimize values using Genetic Algorithm.	Author propose AQI prediction model of BP neural network based on genetic simulated annealing algorithm optimization	The method is complicated and computations are expensive.
6	Artificial Neural Network with Back Propagation and Optimized with PCO	The data of air pollutants and meteorological parameters recorded at Aghdasiyeh Weather Quality Control Station and Mehrabad Weather Station in Tehran	Author used Artificial Neural Network with Back Propagation (BP), its hybrid with GA (BP-GA) and PCO (BP-PCO) were used and Compared.	BP-PCO found to be a data with more accurate data with that of short term predictions as well.	More input data are required in network in order to have better accuracy and can use swarm intelligence algorithms for better accuracy.

There are few Algorithms which is not based on Artificial Neural Network but used in the prediction of air pollutants. So we reviewed such few algorithms which are used in the prediction of air pollution pollutants.

E. Genetic Algorithm

Genetic Algorithm generally used to speed up the process. It will help us to obtain better performance and accuracy of result. The basic objective of Genetic Algorithm is to find the initial weight for using the Artificial Neural network [5].

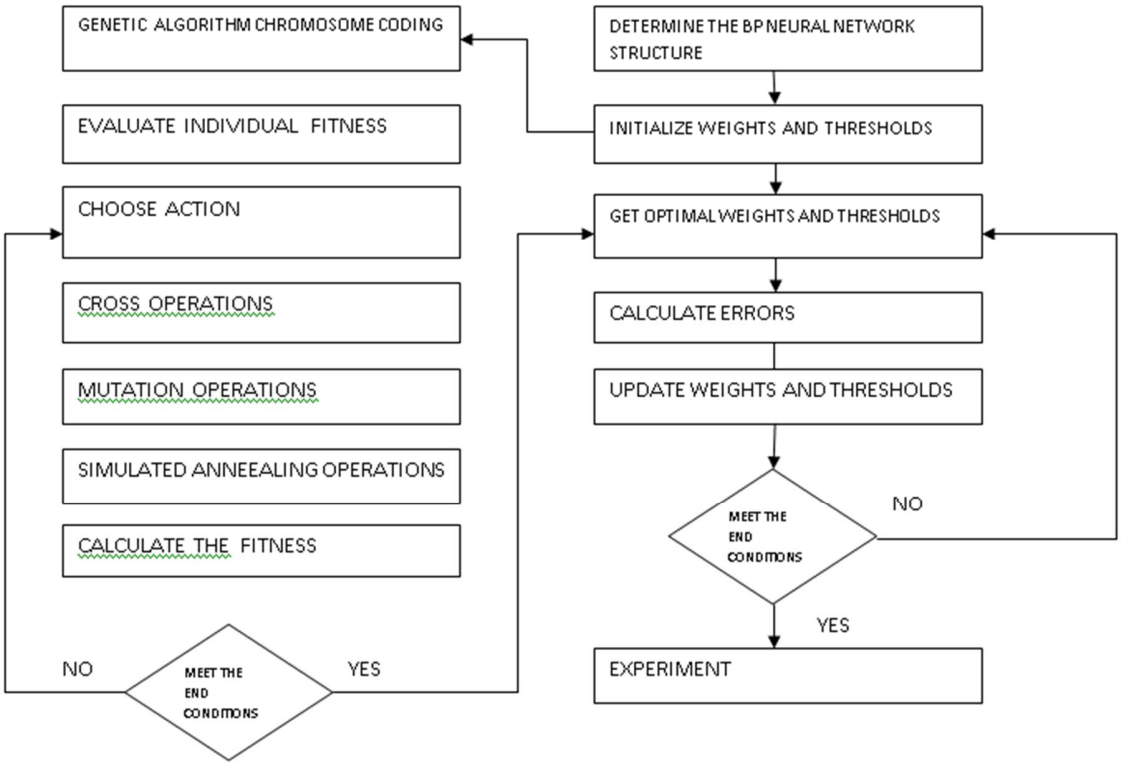

Fig 4. Genetic simulated annealing algorithm Flow [5]

Professor Holland of Michigan University was first person to state the Genetic Algorithm in 1970 [6].It simulate the phenomena of breeding, mating and mutation mainly in natural selection and genetic evolution. The basic idea is to generate a new better and adaptable generation from the previous one using mutation process. With the help of genetic algorithm the *Simulated Annealing* Algorithm [5] was generated to optimize the results.

According to the paper published by Zhou Kang and Zhiyi Qu used Back propagation neural network for prediction of air pollutants and they used genetic simulated annealing algorithm used for optimization the result which yields the highest accuracy. This whole process is depicted in the Fig 4. 3 https://en.wikipedia.org/wiki/Machine_learning

F. Machine Learning Approach

If we consider the Computer Science Branch then without the Machine Learning it is incomplete. There are various algorithms which have been discussed is going to be discussed is a part of Machine Learning such as ANN [1], Genetic Algorithm [5,6] etc. According to the definition of Wikipedia [3] without depending on instructions, patterns and inference to produce effective output is carried out by Machine Learning. Therefore it is considered that to give us an output with best accuracy factor we should consider the Machine Learning Approach. According to the Dixian Zhu, Changjie Cai , Tianbao Yang and Xun Zhou [11] along with Machine Learning they used Model Regularization Techniques to produce the optimized data. According to the Model Regularization [11] it contains two models: Baseline Model, Heavy Model and Light Model.

1) *Baseline Model:* To obtain the prediction value for 24 Hours this model is considered as the base model.
2) *Heavy Model:* To obtain the prediction of every hour with taking in account of previous data this model is taken in account to produce the output.
3) *Light Model:* This model is intermediate of Heavy Model and Baseline Model which calculates output for 24 hours and for next one Hour taking in account of previous day data.

With the help of this model they took regularization values to optimize it [11].

G. Decision Tree Model

Decision Tree Model comes under the Supervised Learning Technique [10]. It is collection of branches and nodes, where each node represents the various choices based on the observations and the output or final decision is represented by the leaf nodes. Since it evaluates result based on decision rules which describes the attributes that helps for the prediction of various parameters one of such parameter is air pollution predictions. It is one of the most important and popular algorithm among the Data mining and Machine Learning. According to the paper by Ebrahim Sahafizadeh and Esmail Ahmadi represented data mining concept using Decision Tree Model is represented by Clementine software [12] to produce the exported decision rules to predict the air pollution pollutants. According to the comparison made in the below TABLE 4t has found that there are various algorithms used in the prediction of air pollutants. Algorithm varied according to the pollutants. And also the time span taken for the prediction is also varied. There are basically two types of prediction made, one is Short-term prediction can be called defined hour prediction and other is Long-term prediction can be defined as monthly predictions. Thus with the help of comparison chart we can easily find different types of algorithms and their strength and result or outcomes ,which helps to find out the new concept to predict the air pollutants with short term prediction with also taking in account of the metrological factors such as noise, humidity etc.

TABLE 5. Comparisons of Other methods except ANN

Ref .No.	Method Used	Data Source	Approach	Strength	Result
9	Multi-channel Ensemble Learning via Supervised Assignment (MELSA) algorithm for air pollution forecasting	Data collected from Beijing	Author Propose multi-channel ensemble learning framework; with a new supervised feature learning and extraction method	Author proposed approach is validated with all evaluations on real-world data	Need to be integrating with web service applications.
11	Multi Task Learning problem used to predict air pollution.	Air pollutant data was from the EPA of Chicago.	Author proposes refined models to predict the hourly air pollution concentration on the basis of meteorological data of previous days by formulating the prediction over 24 hours as a multi-task learning (MTL) problem.	Author proposes a useful regularization by enforcing the prediction models of consecutive hours to be close to each other and compare it with several typical regularizations for MTL.	Needs to commonalities between nearby meteorology stations and combine them in a MTL framework.
12	Data mining technique to predict dusty days.	Boushehr city as a factor of air pollution by using the data of 53 years from 1951 to 2003.	Author extracted the data of 53 years and generated decision rule for the given data by using the air pressure, humidity and dusty days of January, February and March of each year	Using Clementine software and author classified dusty days into 5 classes and then exported decision rules to predict each year classification.	Limited to one city.

III. ISSUES AND NEEDS

Since last year, we have to study various models. Based on literature and experience, we sorted some research issues, challenges, and future needs.

1) *Issues #1: Metrological Data issue* – There have been a lot of research has been done to predict the air pollutants. With Time, there is one more factor which plays an important role is the metrological parameter such as noise, humidity etc, which can adversely affect the prediction.

a) *Need #1: Consider the Metrological Factors* – There is high demand to consider the metrological factor to taken in account to predict the air pollutants values.

2) *Issue #2: Large Duration Timespan* - As the time increases the parameters which are taken in account also changes.

a) Need #2: prediction should be done with minimum value or short period of time span so that at that particular time the parameters which we have taken should be remain the same.

3) *Issue #3: Optimization* Most published research work didn't applied optimization techniques to their algorithm, which does not provide accurate results.

a) Need #3: There are various methods of optimization which should be taken in account to optimize the result and provide best accuracy rate.

IV. CONCLUSIONS

With the main objectives of this paper is to undergo study of various techniques used in prediction of air pollutant particles and optimize it with best PCA algorithm so that we would be able to increase the accuracy level of the prediction values to obtain best result which would help our Government system to take preventive measures to avoid this pollution. Since it is found that the longer the time of prediction the lesser the accuracy rate of result, thus with the many techniques that have been undergone concludes to use shortest time span of time so that we would obtain an adequate result with PCA optimizations to obtain best and precise result.

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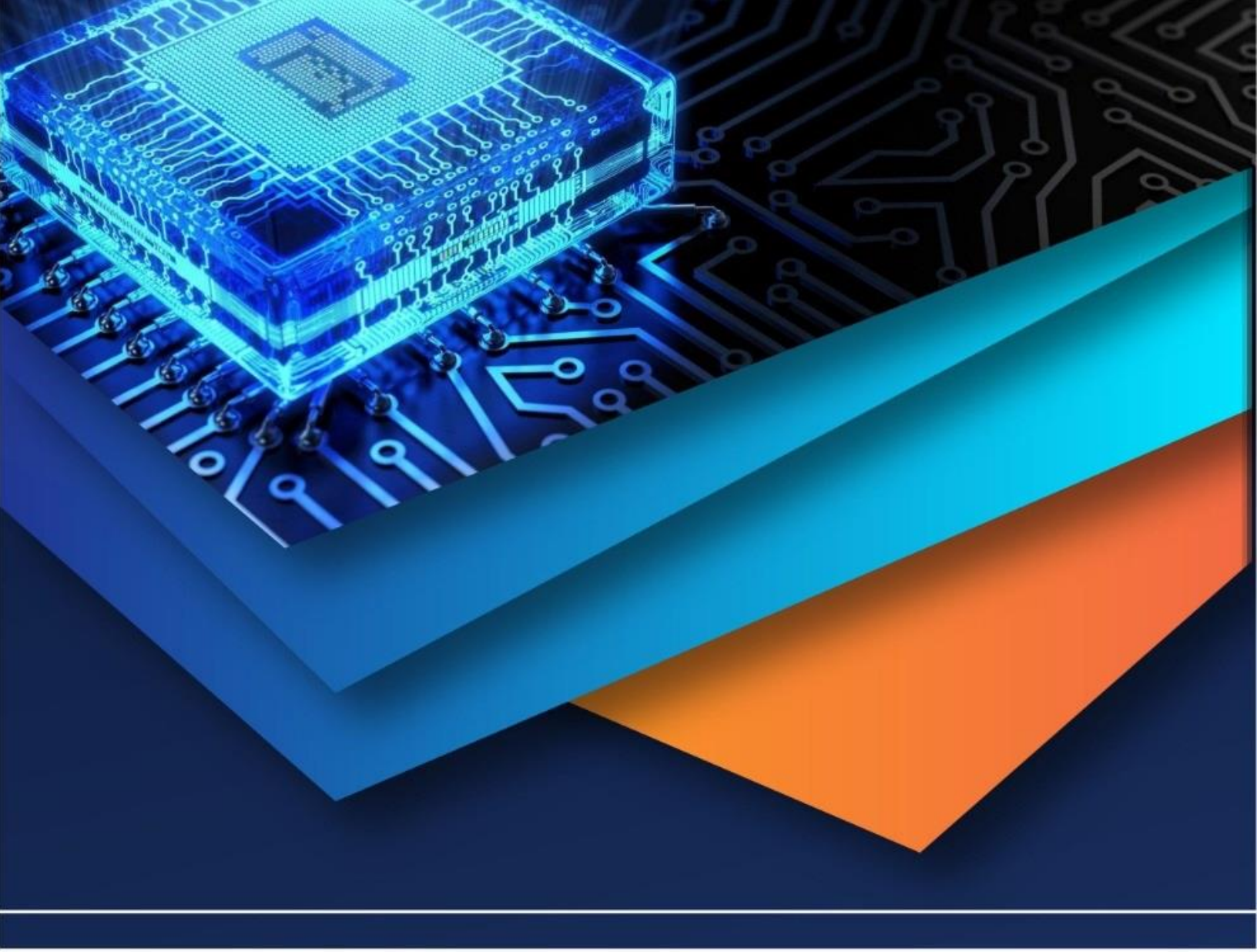

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