IOT- Based Air Pollution Monitoring and Forecasting System

Chen Xiaojun[1], Liu Xianpeng[2], Xu Peng[3]

[1,2,3]Electro-Mechanical Department, Nantong campus of Jiangsu City Vocational College.
NO.169, zhongyuan road of Chongchuan District, Nantong, Jiangsu Prov, China
[1]948735531@qq.com, [2]31886256@qq.com, [3]34851799@qq.com

Abstract:**Using empirical analysis, conventional air automatic monitoring system has high precision, but large bulk, high cost, and single datum class make it impossible for large-scale installation. Based on intriducing Internet of Things(IOT) into the field of environmental protection, this paper puts forward a kind of real-time air pollution monitoring and forecasting system.By using IOT, this system can reduce the hardware cost into 1/10 as before. The system can be laid out in a large number in monitoring area to form monitoring sensor network. Besides the functions of conventional air automatic monitoring system, it also exhibits the function of forecasting development trend of air pollution within a certain time range by analyzing the data obtained by front-end perception system according to neural network technology.Targeted emergency disposal measures can be taken to minimize losses in practical application.**

Keywords: Neural Network; Air Quality Monitoring; Air Pollution Forecast

I. INTRODUCTION

With the rapid development of economy, chemical industrial park construction and production activity are increasingly frequent, leading to increasing probability of environmental pollution accidents, especially air pollution accident. Affected by meteorological and geographical conditions, air pollution will be highly clustered in a short time after happening, causing great harm or even extreme destruction to both human and environment. So it is particularly important to set up a real-time air pollution monitoring system.

Using laboratory analysis, conventional air automatic monitoring system has relatively complex equipment technology, large bulk, unstable operation and high cost. High cost and large bulk make it impossible for large-scale installation. This system can only be installed in key monitoring locations of some key enterprises, thus system data is unavailable to predict overall pollution situation. To overcome defects of traditional monitoring system and detection methods and reduce test cost, this paper proposes a method combining IOT technology with environment monitoring. By replacing monitoring equipment in traditional empirical analysis with sensor network in IOC technology, through which inexpensive sensors can be laid out flexibly in the whole area to monitor omni-directionally to provide data support for prediction.

II. REALIZATION OF THE SYSTEM

According to IOT architecture, the system is mainly composed of perception layer, network layer and application layer. The system's integral design architecture is shown in figure 1. In practical application, current weather conditions (temperature, humidity, wind direction, wind speed, etc) and geographical conditions have significant effect on air pollution degree and polluting source diffusion. In the process of system implementation, therefore, a full consideration should be taken to the influence of environmental factors on monitoring and prediction effect.

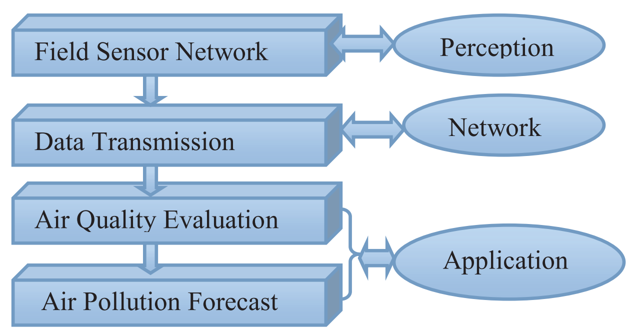

Figure. 1 System's Integral Design Architecture

A. Realization of Perceptual Layer Architecture

Perception layer mainly includes Field Sensor Network which based on front-end acquisition device. The slather of sensors reduces the cost of hardware. In trditional system, we spent more than \$100, 000 for one enviromental parameters in a monitoring point. In this system, we can monitor at least five kinds of enviromental parameters in one monitoring point and the cost under \$10, 000.

Perception layer is realized mainly by establishing a stable and reliable monitoring network system, including monitoring sites selection, environmentsensor deployment and meteorological sensor deployment, etc.

Generally such typically sensitive areas as production area and boundary are selected as monitoring points. Different models are built for the possible leaking ways of different hazards sources (point source, non-point source, instantaneous explosion, continuous type). Monitoring points layout scheme is optimized by considering influence of the region's climate on pollutant diffusion range and intensity, population density, important target areas and key equipment areas comprehensively.

In environmentalsensor deployment, all kinds of environmental sensors are installed in monitoring points, including sulfur dioxide, nitrogen dioxide, smog, inhalable particle, carbon monoxide, chlorine, hydrogen chloride and hydrogen fluoride sensors.

Meteorological sensorsareinstalled in some of the monitoring points in the deployment. Meteorologicalparametersincluding wind direction, wind speed, temperature, humidity and air pressure can be perceived in real time to assist in pollution situation analysis and pollution diffusion forecast.

B. Realization of Network Layer

The primary function of network layer to transmit environmental and meteorological data, connect all the air sensors and meteorological sensors deployed in monitoring area to a central server and transmit the data perceived by sensors to data center in real time.Transmission system is built according to service oriented requirement. By using XML as information exchange language, data is encapsulated based on unified information exchange interface standard and data exchange protocols. By using message passing mechanism, information communication, data exchange between basic data and business data and transfer of control instruction are realized so as to integrate business collaboration and application system. By embedding data validation module and fault-tolerant processing module, error data including empty value, high value, low value and negative value are screened preliminarily and the data within fault tolerance scope is put in data base for operation.

C. Realization of Application Layer

The whole application layer system is mainly to process and analyze air pollutant data, evaluate air quality and then predict the trend air quality develops over a period of time in the future. From a functional point of view, the whole application layer includes air quality evaluation and air pollution forecast. Due to complex relationship between air quality, air pollutants trend and meteorological factors, it is difficult to mine the useful information in historical data to predict accurately with traditional prediction method. In this system, we introduced neural network technology.

Neural network, characterized by nonlinear processing and multivariable input and output, are used to mine mass of data sent back by perception layer and network layer. Model is created based on the study of input data instead of established equation. With the help of strong nonlinear processing ability afforded by neural network, accuracy of air quality assessment and pollution prediction can be improved so as to make up the inadequacy of the traditional method.

In air quality evaluation, by analyzing quality indexes including temperature, harmful gas concentration, particle concentration, taking environmental factors different applications as parameters and using the genetic algorithm and neural network technology, key indicators of air quality are chosen. In addition, quantitative relationship model of atmospheric quality factor and level is established using self-organization modeling and grey system control modeling to realize comprehensive evaluation and analysis of atmospheric quality.

As the core of the whole system, air pollution prediction is a multiple-input-multiple-output forecasting tool based on neural network technology. It has high extensibility and can be used for different applications.Air quality prediction is to predict future trend of air quality based on current situation, pollutant dispersion, current weather conditions and geographical position of monitoring area, so as to provide decision support for emergency disposal and rescue after pollution accident happens. By taking air quality indexes as neural network of training sample, air quality index parameters in the following time node as expected output, and by grasping the inherent law between meteorological factors(such as temperature, wind direction) and air quality, this system can achieve accurate prediction of air quality. Evaluation weight of different quality indexesare studied based on their influence on overall evaluation of air quality .A synthetic method for comprehensive air quality index verified by experiment is established to create a set of accurate and effective air quality evaluation system.

III. DATA PROCESSING OF THE SYSTEM

According to the relationship between current pollutant concentration and the pollutant concentration in the past 24 hours, a 24 hours' prediction network is established. The average pollutant concentration is adopted to train network and then predict the pollutant concentration per hour in next 24 hours.

In network training, inputs are endowed with the same important position to prevent neurons output saturation caused by large absolute value of net input. The scale transformation of data is based on normalization method in this system. We build two matrices, input matrix P and target matrix T. The structure of every matrix is 24*365(i*j), the line 'i'(i=1, 2, 3….24) means some hour of a day, the column 'j'(j=1, 2, 3…365) means some day of a year. The column 'j' of target matrix is the column 'j+1' of input matrix. Parameter setting of pollution forecast networks is shown in table 1.

Due to close relationship between air pollution forecast and meteorological factors, much meteorological data is used in this system including daily mean temperature, average dew point temperature, average sea level pressure, average pressure of monitoring station, visibility, average wind speed, max sustained wind speed, max gust velocity, highest temperature, lowest temperature, total precipitation, snow depth and probability index of extreme weather. This system is used in a chemical industrial park near sea. We build two models for different seasons according to the geography and climate. The system is dived two parts throng competitive network, one includes January, February, November, December, another includes April, May, June, July, August, September, October.

TABLE 1.Parameter setting of pollution prediction network

Project	**Parameter setting**	
Layer number of network	Input layer. Hidden layer. Output layer	
The nodes of each layer	Input layer	24
	Hidden layer	4
	Output layer	1
Transfer function	Hidden layer	Tansig
	Output layer	Logsig
Learning algorithm	Bayesian Regularization	
The max training times and expectation error	5000	
	0.001	
Initialization method of weight	Initial weight of hidden layer *0.1, output layer set positive and negative initial weight equally.	
Division method of samples	Training set: Validation set: Test set=2:1:1	

We add five meteorological factors to the model of air pollution forecast including daily mean temperature, air pressure, visibility, average wind speed and total precipitation, by progressive regression analysis (90% confidence). After adding meteorological factors, the nodes of input increases to 29 and the nodes of hidden layer increases to 6. By comparison of the prediction performance between includes meteorological factors and without meteorological factors(fig 2), it is found that adding meteorological factors can improve the prediction performance greatly.

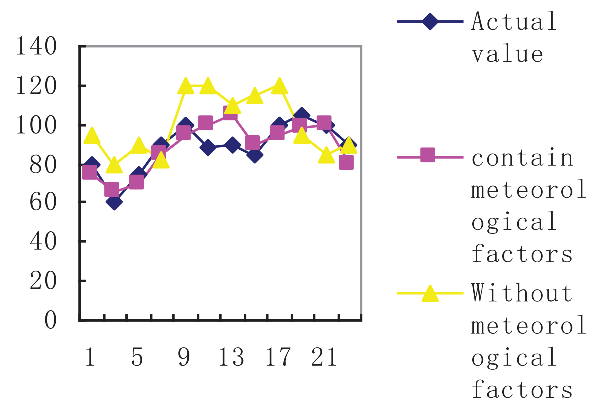

Figure. 2. Comparison of forecast effect of parameters input containing weather factors or not Comparison of forecast effect of parameters input containing weather factors or not

To establish artificial neural network, we need mass data as the input. We show the results of prediction models which are based on recent 5 years' data. The figure 3 shown that enlarge sample data can improve prediction performance, but can't be too large. Using recent 3 years' data as input and following the modeling method, the system can reduce prediction 12%~23%.

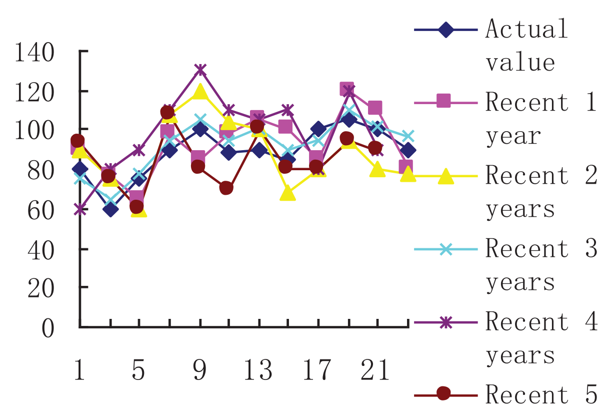

Figure3 Comparison of network's prediction values and true value from different sample set

IV. CONCLUSION

Air pollution monitoring and forecasting system designed in this paper proposed a good solution to the complexity of air pollution. The use of a large number of sensors ensures monitoring accuracy, reduces monitoring cost and makes monitoring data in monitoring area more systematic and perfect. A large number of field data provided by front-end sensor network makes big data analysis in background application layer more direct and effective, providing a real and effective decision-making basis for emergency response afterpollutionaccident happens.

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