Smart City Environmental Pollution Prevention and Control Design Based on Internet of Things

He Peng¹, Zheng Bohong*, Kuang Qinpei²
¹ Department of Architecture and Art, Central South University, Changsha 410075, China
² Alibaba Group, Beijing 100000, China

Corresponding author email: hpjzyysxy@csu.edu.cn

Abstract. Due to increasingly serious urban pollution, this paper proposes an environmental pollution prevention and control system in combination with Internet of things. The system transfers data through the Internet, which also utilizes sensor, pH sensor and smoke sensor to obtain environmental data. Besides, combined with the video data acquired through monitoring, the data are transferred to data center to analyze the haze pollution, water pollution and fire disaster in environment. According to the results, multi-purpose vehicles are mobilized to complete the tasks such as spraying water to relieve haze, water source purification and fire fighting in city environment. Experiments show that the environmental pollution prevention and control system designed in this paper can automatically complete the urban environmental pollution detection, prevention and control, which thus reduces human and material resources and improves the efficiency of pollution prevention and control. Therefore, it possesses greatly practical significance to the construction of smart city.

1. Introduction
Among urban environmental pollution prevention and control, most common urban pollution sources include haze, water resource pollution and dramatic fire disaster [1]. At present, environmental pollution prevention and control is one of the prime objectives in smart city construction. Together with the constant development of computer and smart technology, Internet of Things Technology makes favorable advancement. Besides, Internet of Things Technology directly builds the connection among objects throughout the Internet and finishes mutual control with data transfer [2]. Internet of Things could replace sanitation workers and fire fighters, and benefit vehicles and equipment in making environmental construction and settlement of dramatic events, thus greatly saving the waste human resources and materials as well as reducing the efficiency of urban environmental construction.

In this paper, Internet-based smart city pollution prevention and control system adopts advanced computer and network communication technology which also integrates routing technology and video and image recognition technology. Through organically combining all subsystems in urban environmental construction, this paper realizes smart test and control on overall urban environment based on planning management, which also reduces the difficulty in urban environmental maintenance for sanitation workers and fire fighters. In the meanwhile, the proposed system improves air and water resource quality, reduces environment pollution prevention and control costs as well as creates favorable environment for urban life.
2. Management System Framework

Internet of Things-based smart city urban environment pollution prevention and control system is basically composed of four modules, respectively, central server module, sensor and video monitoring module, management scheduling module and multi-function module. These modules deliver information through using wireless network. Figure. I shows the overall framework diagram of the design system.

Wireless network module delivers the signal information received by sensors and video receptors through wireless network to Central Server module for calculation and analysis. Master controller composed of ARM11 has favorable digital signal processing abilities. Targeted at the uploaded signal, the master controller could quickly make processing and illustrate analytic results. Present environment parameters in the monitoring center provide real-time air haze indicators, water resource pollution indicators and regional monitoring information in urban fire disaster region. Throughout regional division, each region is installed with corresponding sensors. When the indicators in certain region exceed given threshold values, sanitation workers could control the multi-functional vehicle to spray water to reduce haze and purify water resources. In case of any fire disaster, the monitoring center delivers fire disaster information through wireless network to fire alarm early-warning system. When the fire disaster reaches certain range, fire fighters could control the multi-functional vehicle to put out the fire through using infrared remote-control device.

3. Data Analysis and Recognition

3.1 Analysis of Sensor Indicators

System sensor module records the temperature and humidity statistics, PM 2.5 statistics, Ph statistics in water resources and heavy metal ion statistics. After the transition of level signals, these statistics are sent to the Central Server. Regarding air haze and water resource pollution test, the first step is to filter the level signal and remove noise introduced by collection and transmission process so as to remove judgment errors. In most cases, denoising uses medium filtering algorithm [3].

The level signal after median filtering removes partial noise introduced by mutation. The denoising level statistics turn more stable and eradicate mutation noise. After filtering, the temperature and humidity + PM2.5 corresponds to haze test while PH+ heavy metal ions corresponds to water resource pollution test. Since air pollution or water pollution is not simply caused at some moment all of sudden, it is necessary to examine the average statistics within certain period during the test process. In this paper, the haze test adopts the average statistics per hour and water resource test adopts the average statistics per week. However, in terms of the selection of two indicators, since PM2.5 is more important to haze test and heavy metal iron test than water resource pollution test while temperature and humidity and PH exert auxiliary functions in the test, this paper finally calculates the judgment indicators in combination
with two indicators in equation (1) and solved average value.

$$\text{Index}_{\text{tot}} = 0.25*\text{Index}_1 + 0.75*\text{Index}_2$$  \hspace{1cm} (1)

As for haze test, $\text{Index}_1$ means temperate and humidity average value, and $\text{Index}_2$ indicates PM2.5 average value. In terms of water resource test, $\text{Index}_1$ means average PH value, and $\text{Index}_2$ refers to heavy metal ion average value.

Compared with present haze and water resource pollution indicator threshold, if the judgment indicator is larger than threshold, then present environment will occur haze and water resource pollution. Otherwise, air and water resource will be in normal state.

3.2 Video Monitoring Image Fire Disaster Test

Under normal conditions, the video monitoring equipment employed in this paper is color equipment which could produce stable colorful images. If fire disasters suddenly occur in images, the most eye-catching point is the color of fire disaster. Therefore, the system designed in this paper uses color image features to detect possible fire disaster from original monitoring scene and takes it as the recognition feature of fire disaster mode. To determine the relationship between fire disaster images and RGB three-primary colors, this paper collects over 500 fire images for analysis, including flames with different illumination and shading degrees. Among over 500 fire images, there are 8828283-pixel points. According to the statistical analysis of each pixel point, the color distribution of flames is usually different from the color distribution of general luminous objects. Besides, the induction and summary results prove that RBG three-primary component in flame images has the restraint relationship, as given in equation (2-5).

$$R(x, y) > R_{\text{mean}}$$  \hspace{1cm} (2)

$$R_{\text{mean}} = \frac{\sum_{i=1}^{K} R(x_i, y_i)}{K}$$  \hspace{1cm} (3)

$$R(x, y) > G(x, y) > B(x, y)$$  \hspace{1cm} (4)

$$R(x, y) > 200, G(x, y) < 200, B(x, y) < 100$$  \hspace{1cm} (5)

Wherein $R(x, y), G(x, y), B(x, y)$ respectively indicates the component corresponding values of red, green and blue colors on $(x, y)$ point in the image. These values have changes in $[0,255]$. K means total number of pixels in the image while $R_{\text{mean}}$ indicates the average value of pixel red color component in the image.

According to above equation, the flame region could be divided from primitive image. After the removal of the background, remaining region will be used as the color features of flame image for fire disaster recognition. During the recognition process, support vector machine (SVM) is used as the classifier [4]. Firstly, the flame region in collected over 500 images is obtained from color features and stored as vectors for the positive samples of SVM training. On the contrary, the background image after division is restored as vectors for negative samples of SVM training. Figure. 2 presents partial positive and negative samples during the training process.
Supposing the training set of flame \( \{x_i, y_i, i = 1, 2, 3, \ldots, n\} \) as a data set, then data \( x \) in the data set is sample data in need of classification and \( y \) is the label corresponding to data. In fact, it indicates proper data classification. When \( y = 1 \), corresponding sample is positive flame sample and when \( y = -1 \), corresponding sample is negative background sample. SVM should find an optimal classification plane \( w^*x + b = 0 \) so that sample data set \( x \) could be possibly separated from others. According to the figure, it is necessary to possibly separate from two types of data, namely, the “optimal classification plane”, as shown in Figure.3.

Through introducing given training positive samples and negative samples into SVM trainer, this paper constantly optimizes \( w \) and \( b \) weight values during the training process and finally obtains the SVM classifier of flames via classification for fire disaster test. The system designed in the thesis trains SVM fire disaster test classifier through central server and timely tests fire disaster on the server after receiving video monitoring images. When it detects the fire disasters, LCD display screen will present a red prompt box and mobilize GSM module to send short messages to fire fighters. Eventually, it assists fire fighters to control the multi-functional vehicle and spray water on fire in fire disaster region.

4. System Test and Experiment
This paper gives the test on the system in experiment context. The test contents contain packet loss test of WSN wireless network in barrier-free condition, and data comparison between sensor calculation results and real experiment results. Meanwhile, it also judges whether the algorithm raised in this thesis could finish haze and water resource pollution test, and whether the fire disaster detection algorithm raised in this thesis could finish real-time fire disaster test according to test recognition rate and test efficiency. Table 1-5 present the comparison conditions of above experiment results.
Table 1 WSN Transmission Packet Loss Results in Barrier-free Condition.

| Distance (m) | Transmission Data Packet Amount | Data Reception Packet Amount | Packet Loss Rate (%) |
|--------------|--------------------------------|-----------------------------|----------------------|
| 20           | 100                            | 100                         | 0                    |
| 40           | 100                            | 100                         | 0                    |
| 60           | 100                            | 100                         | 0                    |
| 80           | 100                            | 98                          | 2%                   |
| 100          | 100                            | 95                          | 5%                   |

Table 2 WSN Transmission Packet Loss Results in Barrier Condition.

| Distance (m) | Transmission Data Packet Amount | Data Reception Packet Amount | Packet Loss Rate (%) |
|--------------|--------------------------------|-----------------------------|----------------------|
| 10           | 100                            | 100                         | 0                    |
| 15           | 100                            | 100                         | 0                    |
| 20           | 100                            | 82                          | 18%                  |
| 25           | 100                            | 24                          | 76%                  |
| 30           | 100                            | 7                           | 93%                  |

Table 3 DTH11 \ SDS018 Data and Real Data Comparison.

| Apparatus     | Exp.1 | Exp.2 | Exp.3 | Exp.4 | Exp.5 | Exp.6 | Exp.7 |
|---------------|-------|-------|-------|-------|-------|-------|-------|
| DTH11 (°C)   | 24.6  | 25.4  | 24.9  | 27.4  | 26.4  | 23.9  | 25.7  |
| Thermometer   | 25.3  | 26.1  | 23.7  | 27.4  | 25.7  | 24.7  | 26.8  |
| DTH11 (%)     | 63.9  | 71.9  | 87.4  | 64.5  | 54.7  | 49.6  | 74.9  |
| Hygrometer    | 64.7  | 73.4  | 88.7  | 69.4  | 57.4  | 49.8  | 75.7  |
| SDS018 (μg/m³) | 69    | 87    | 43    | 97    | 46    | 83    | 49    |
| Particle Meter | 67    | 78    | 45    | 93    | 46    | 89    | 45    |

Table 4 BPH8010 \ PDV6000 and Real Data Comparison.

| Apparatus     | Exp.1 | Exp.2 | Exp.3 | Exp.4 | Exp.5 | Exp.6 | Exp.7 |
|---------------|-------|-------|-------|-------|-------|-------|-------|
| BPH8010       | 5.9   | 4.7   | 7.2   | 6.9   | 8.4   | 6.1   | 6.4   |
| PHtest paper  | 5.7   | 4.3   | 7.0   | 6.4   | 8.2   | 6.1   | 6.7   |
| PDV6000(mg/L) | 0.13  | 0.19  | 0.07  | 0.16  | 0.10  | 0.14  | 0.08  |
| Metal Test    | 0.12  | 0.18  | 0.09  | 0.15  | 0.11  | 0.12  | 0.07  |

Table 5 Fire Disaster Recognition Rate and Test Time.

| Parameter      | Exp.1 | Exp.2 | Exp.3 | Exp.4 | Exp.5 | Exp.6 | Exp.7 |
|----------------|-------|-------|-------|-------|-------|-------|-------|
| Recognition Rate | 82.6% | 83.7% | 84.5% | 84.7% | 81.7% | 83.6% | 82.1% |
| Test Time(ms)  | 127   | 124   | 136   | 175   | 146   | 158   | 170   |

As for WSN transmission test in barrier condition, this paper carries out test with walls in different rooms. However, barrier-free test is conducted in vacant and barrier-free hall. Table 1 proves that stable WSN transmission distance is about 80 meters. Table 2 shows that obstacles have great influences on WSN transmission and complicated environment plays an important role in wireless network transmission. Under barrier condition, stable distance of WSN transmission is about 15 meters.

Based on comparative experiment data in Table 3, the error of PM 2.5 sensor data and real data in temperature and humidity is within 1%. In Table 4, PH error and heavy metal ion test data error are within 5%. The calculation results which judge of haze/water resource pollution in this thesis simply require several simple procedures, including filtering, mean value solution and integration result and threshold value judgment. With small calculation amount, it could realize real-time judgment. Therefore, the algorithm could precisely and timely finish haze test and water resource pollution test.

To test the preciseness and efficiency of fire disaster test algorithm, each test selects over 200 online...
fire disaster images for fire disaster test. Table 5 presents the recognition rate and test time of fire disaster test. From the perspective of recognition rate, fire disaster test system could basically finish 80% test. In addition, within 200ms test time, this system realizes real-time test purpose.

5. Conclusion
Since urban environment pollution prevention and control has attracted wide attention from more and more people, smart city environment pollution prevention and control combined with Internet of Things is future mainstream development direction [5]. This paper designs and realizes the Internet of Things-based smart city environment prevention and control system. Besides, this system uses various sensor and video monitoring interface to test present environment pollution conditions and transmits collected equipment through wireless network to central server for analysis and scheduling. Based on the analytic results, this paper mobilizes relevant staff to finish environment pollution prevention and control with the multi-functional vehicle. Finally, through the experiment on design system in experiment environment, this paper conducts multiple groups of comparative experiments and finds out that the designed system could automatically finish haze, water resource pollution and fire disaster tests. Moreover, this paper also finishes pollution test result control with corresponding strategies, which thus realizes the purpose of pollution prevention and control with stronger practice meanings.

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