Distributed intelligent urban environment monitoring system

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Abstract. The current environmental pollution and destruction have developed into a world-wide major social problem that threatens human survival and development. Environmental monitoring is the prerequisite and basis of environmental governance, but overall, the current environmental monitoring system is facing a series of problems. Based on the electrochemical sensor, this paper designs a small, low-cost, easy to layout urban environmental quality monitoring terminal, and multi-terminal constitutes a distributed network. The system has been small-scale demonstration applications and has confirmed that the system is suitable for large-scale promotion.

1. Introduction
The current environmental pollution and destruction have developed into a world-wide major social problem that threatens human survival and development. The United States Environmental Protection Agency pointed out that there is sufficient scientific research results show that inhalable particle can absorb a large number of carcinogenic substances and genotoxic mutagenic substances. To the human health, the pollutants have a negative effect which cannot be ignored. The effects include mortality increases, chronic disease intensifies, respiratory and heart disease have worsened. The pollutants changes in lung function and structure, affect reproductive capacity, alter the body's immune structure[1,2]. Seven million people died as a result of air pollution in 2012, according to the World Health Organization's latest data[3].

In the last century 70's, the United States began to study the geographic information system technology and information sensing technology for environmental management. The real-time environmental information network and analysis system was developed by University of California, Naval Postgraduate School and other research institutions. Since the 1990s, the US air quality monitoring system has been developed and refined in accordance with the relevant air quality laws and regulations. Scientific research institutions put forward the research report on North American air emissions inventories and ambient air monitoring networks in 2009[4]. In the last century 70's, Germany began to build the application platform for national environmental monitoring and environmental management. Canada began the study of environmental information systems in the 1980s, and the environmental information system facilitated the establishment of environmental routine and the management of environmental monitoring program. Australia is carrying out environmental data platform construction which is based on model technology to guide regional resource planning.

In the 1980s, China was in the exploratory stage and initially built a number of research-based environmental information system. In the 1990s, China's environmental information system gradually
matured. In the 21st century, the National Environmental Monitoring Information System which was developed by the Ministry of Environmental Protection, marked the development of China's environmental information system to the market stage[5]. But in general, the environmental monitoring system faces a series of problems. The optical method environmental monitoring system occupies a large space and has high cost. The construction of the distributed grid environment information sensor network lags behind. The system does not have the ability of big data analysis and environmental assessment.

Based on the electrochemical sensor, this paper designs a small, low-cost, easy to layout urban environmental quality monitoring terminal, and multi-terminal constitutes a distributed network. The system is suitable for large-scale promotion in the future.

2. System Functions and System Solutions
Distributed intelligent urban environment monitoring system is a highly integrated use of new generation information technology, such as Internet of Things and large data processing technology. The system is important for improving the efficiency and level of social management and public services.

The functions of the system include:
1. The intelligent urban environment monitoring terminal is equipped with the detection function of air pollution gas, inhalable particle and meteorological parameters;
2. Based on the existing basic conditions of traffic and municipal, the rational distribution of the terminals constitutes a distributed integrated monitoring network;
3. The data platform center monitors and records the real-time dynamic data of each terminal;
4. According to historical records, establish the monitoring system database, analysis the real-time dynamic data and predict the regional environmental pollution situation and development trends, provide a scientific basis to effectively control the environmental conditions.

Distributed intelligent urban environment monitoring system includes: Multiple monitoring terminals and information center. The monitoring terminal belonging to the sensing layer, the transport layer, includes sensors, industrial computer, wireless communication module, power system, etc. Information center belonging to the data layer, the platform layer and the application layer, includes data server, monitoring software, data analysis software, information push, etc. The architecture is shown in Figure 1.

![Figure 1. The architecture of the distributed intelligent urban environment monitoring system](image)

3. The Intelligent Urban Environment Monitoring Terminal
The intelligent urban environment monitoring terminal is the hardware platform support of data
acquisition and the normal operation basis of the system. Terminal equipment using modular design ideas, suitable for large-scale production and custom function configuration. Terminal equipment using modular design ideas is suitable for large-scale production and custom function configuration.

3.1. Gas Detection
Gas detection adopts high sensitivity electrochemical sensors and combines with advanced signal processing technology. It can be used for continuously monitoring the six gases in the atmosphere. The default gas species include SO\textsubscript{2}, NO\textsubscript{2}, O\textsubscript{3}, CO, H\textsubscript{2}S, VOC. The terminal adopts the pump-type circulation system to send the ambient air through the water vapor filter to the sensor air chamber. The signals generated by the sensor are amplified and sampled at first. Then the microprocessor processes the data and calculates the gas concentration.

3.2. Inhalable Particle Detection
Inhalable particle detection is based on light scattering theory. Dust particles in the air produce light scattering effects under high energy laser beam irradiation. The scattered light intensity is proportional to the concentration of dust particles. Highly sensitive photodiode receives scattered light converts the light signal into electrical signal. The electrical signal is amplified and sampled. Then the microprocessor calculates the dust concentrations of pollution sources by specific mathematical model.

3.3. Meteorological Parameters Detection
Meteorological parameters detection can provide six parameters which including wind velocity, wind direction, accumulation precipitation, air pressure, air temperature and relative humidity. The measure principle of air pressure, air temperature and relative humidity is based on a high-level RC oscillator and two reference capacitors. The microprocessor compensates for air pressure and temperature according to temperature dependence.

3.4. Constant Temperature Control
In the environment of constant temperature, it is possible to maintain the detection accuracy of the gas. Constant temperature control system mainly includes PTC heating device, semiconductor refrigeration device. The terminal adopts the pump-type circulation system to send the ambient air through the water vapor filter to the sensor air chamber. When the temperature is below the set temperature, the PTC heating device starts and the gas sample temperature rises. When the temperature is higher than the set temperature, the semiconductor refrigeration device starts, the gas sample temperature decreases. Semiconductor refrigeration device will produce heat. Water transferring heat returns to the external water storage device and cools down through the cooling fan. Then cold water through the pump, re-returns to the semiconductor refrigeration device. Constant temperature control range 0-40 °C with accuracy of ±1 °C.

3.5. Terminal Software
Embedded industrial computer works as the central processing system of the terminal and runs WINDOWS system. Terminal software is a human-computer interaction interface program and provides users with a user-friendly operating platform. The terminal software has the functions of information display, data query and parameter configuration. The information display function provides the detailed information of the terminal equipment such as device initialization, database connection, sensor connection, power supply information, data acquisition information, and so on. The data query function provides detailed data information for the sensor. The user selects the parameter type, sets the start time and end time of the query, and the software provides the user with a visualized data curve. The parameter configuration function is used to set the parameters such as the data update period, the gas unit, the constant temperature, and the equipment calibration. The terminal software guarantees the security of the monitoring system.
4. Information Center
Information Center is the core part of the distributed intelligent urban environment monitoring system and uses GIS technology to build the application software of urban environmental pollution source on the database management system and the graphic library management system. Information center can realize the comprehensive query of pollution source information and analyze the environmental situation synthetically. Therefore, the distributed intelligent urban environment monitoring system provides information support for planning decisions, such as evaluation, forecasting, planning and other services.

5. Testing and Evaluation
The intelligent urban environment monitoring terminal is tested and identified by Jilin Institute of Metrology. The main performance parameters are shown in Table 1. The appearance of the terminal is shown in Figure 2.

| Parameter                  | Range    | Resolution | Accuracy   | Unit      |
|----------------------------|----------|------------|------------|-----------|
| **Gas Detection**          |          |            |            |           |
| CO                         | 0~200    | 0.01       | ±2%FS      | ppm       |
| SO2                        | 0~1      | 0.001      | ±2%FS      | ppm       |
| O3                         | 0~1      | 0.001      | ±2%FS      | ppm       |
| NO2                        | 0~1      | 0.001      | ±2%FS      | ppm       |
| VOC                        | 0~50     | 0.01       | ±2%FS      | ppm       |
| H2S                        | 0~50     | 0.001      | ±2%FS      | ppm       |
| PM2.5                      | 0~1000   | 1          | ±5%        | µg/m³     |
| PM10                       | 0~1000   | 1          | ±5%        | µg/m³     |
| **Inhalable Particle**     |          |            |            |           |
| Detection                  |          |            |            |           |
| Wind Velocity              | 0~60.0   | 0.1        | ±(0.3+3%)  | m/s       |
| Wind Direction             | 0~360    | 1          | ±2         | °         |
| Accumulation Precipitation| 0~200.0  | 0.1        | 5%         | mm        |
| Air Pressure               | 600~1100 | 0.1        | ±0.5(0~30°C) | hPa      |
|                           |          |            | ±1(-52~+60°C) |          |
| Air Temperature            | -52~+60  | 0.1        | ±0.3       | °C        |
| Relative Humidity          | 0~100    | 0.1        | ±3(0~90%)  | % RH      |
|                           |          |            | ±5(90~100%)|           |

Distributed intelligent urban environment monitoring system is applied in Changchun. The total surface water resources in Changchun is 12.9 billion cubic meters, and Yitong River is 1.96 billion cubic meters, accounting for 15.2%. The demonstration application system selected a total of 15 monitoring points along the middle basin of Yitong River and the surrounding. The distance between the selected points is maintained at 2-3km and the radiation area reaches 160km². The distribution of the monitoring points is shown in Figure 3. At present, the system has been running normally.
Figure 2. The appearance of the terminal

Figure 3. The distribution of the monitoring points

6. Conclusion
Distributed intelligent urban environment monitoring system is divided into the hierarchical structure of the sensing layer, the transport layer, the data layer, the platform layer and the application layer. The system is a highly integrated use of new generation information technology, such as Internet of Things and large data processing technology. Based on the electrochemical sensor, this paper designs a small, low-cost, easy to layout urban environmental quality monitoring terminal, and multi-terminal constitutes a distributed network. The system has been small-scale demonstration applications and has confirmed that the system is suitable for large-scale promotion. The system is important for improving the efficiency and level of social management and public services.

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