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Environmental Monitoring and Management System Based on K-Means Algorithms

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ABSTRACT

In order to build a resource-saving and environment-friendly society, adjust the economic structure, change the mode of growth and improve the quality of people's lives, it is proposed that advanced network video surveillance system technology should be integrated into the related fields of environmental protection, and the comprehensive management of polluting enterprises and ecological environment should be closely monitored and managed. The work content and process of environmental protection standard management are sorted out, the difficulties and problems to be solved in the management of environmental protection standards are summarized, and the data and technical support needed for the informatization of environmental protection standards are discussed. The application technology of data mining is studied and combed, and K-Means algorithm is selected and improved to enable it to be applied in the management of environmental protection standards. The demonstration system of environmental standard information management is constructed to provide reference for the construction of environmental standard information management system. The results show that through in-depth study on the framework of environmental video surveillance system, the system design scheme is formed, and the project implementation and operation maintenance management mechanism of environmental video surveillance system is established, which provides an effective overall solution for system implementation, optimization, improvement and application promotion.

INTRODUCTION

With the rapid development of China's economy and the continuous improvement of people's living standards, the emission of pollutants has increased rapidly. Environmental pollution has become a major factor restricting the further development of China's economy and society and the further improvement of people's living and health level. The threat posed by many problems such as global climate change has made more and more people realize the importance of saving resources and protecting the environment. They have joined in various public welfare activities of environmental protection. In just a few years, the "Earth Hour" activity, which has attracted worldwide attention, started from a limited scale and quickly swept the world at an amazing speed, becoming the world largest environmental protection action.

The main technical means of environmental protection is to use remote environmental monitoring system to monitor pollution sources or sewage discharge and pollution control equipment. There are two characteristics of remote environmental monitoring system: one is remote, which can greatly reduce the investment of human resources, and at the same time keep people away from the harsh environment such as high pollution and high noise; the other is information, which means quantitative and qualitative analysis of real-time collected data, providing scientific decision support for environmental management and enhancing the ability of environmental protection law enforcement (Zhao et al. 2015). Environmental information is also more conducive to protecting the public's right to know, supervise and participate in environmental protection, and mobilizing and giving full play to the public's enthusiasm to participate in environmental protection public utilities.

PAST STUDIES

With the rapid development of the internet, the development environment of video surveillance system based on broadband internet is becoming more and more mature, and the development process is accelerating. The combination of environmental monitoring system and video monitoring system has been widely used. In 2015, a new information system was introduced which combines internet of things (IOT), cloud computing, geographic informatics (remote sensing, RS), geographic information system (GIS), global positioning system (GPS) and environmental monitoring and management electronic science (Yue et al. 2015). In 2016, a research proposed an intelligent indoor environment monitoring system (IDEMS) based on ZigBee wireless sensor network technology, which is used to store and process

HBase environmental data. The working mechanism of the system is divided into three stages: data acquisition, data processing and information monitoring (Mois et al. 2016). In 2015, a study used wireless communication and internet map service that have great potential in regional environmental management projects and natural habitat protection. They proposed to develop mobile GIS tools and wireless internet map server (IMS) services to promote environmental monitoring and management tasks (Huang et al. 2015). A previous research put forward a conceptual framework for the development and maintenance of an effective ecological monitoring program. Two main monitoring functions can be identified in the design: early warning and early control functions (Lu et al. 2016). Based on a recent study, Yang (2015) adopted a new top-down life cycle assessment (LCA) method based on input-output analysis using national statistical data to assess the environmental impact of construction and property (real estate) management departments. Lowell (2017) proposed that Aegis system design can be used to integrate various environment, emergency and process monitoring sensor systems and it can use flexible modular architecture to be easily configured in any number of industrial, commercial or government sites. A study put forward a strategy of integrated monitoring, GIS and modelling, which used general client-server architecture, object-oriented design, embedded expert system technology and multimedia user interface to support easy access, and easy to use complex urban environmental management analysis tools (Luque et al. 2018).

MATERIALS AND METHODS

The design of environmental monitoring system should follow the following principles: practicality principle, standardization principle, openness principle, safety principle and economy principle. The main work of the system project can be divided into two parts: the lower computer and the upper computer, that is, the environment acquisition instrument and the municipal monitoring system. The modules needed to be completed in each part are as follows: the lower computer includes data acquisition module, data management module, communication module, power module and the design of the box which reaches a certain level of protection; the upper computer includes data receiving module, database and data storage module, data delivery module and data management information module with friendly user interface (Fig. 1).

Clustering algorithm divides a group of objects into several disjoint subsets. The members of each subset have strong similarity, and the members belonging to two subsets have strong dissimilarity. K-Means is the most widely used algorithm and takes distance as its index. The smaller the distance between two objects is, the greater their similarity is. In this algorithm, the matrix is represented by a close-range object, so the aim of this algorithm is to obtain compact and independent clusters.

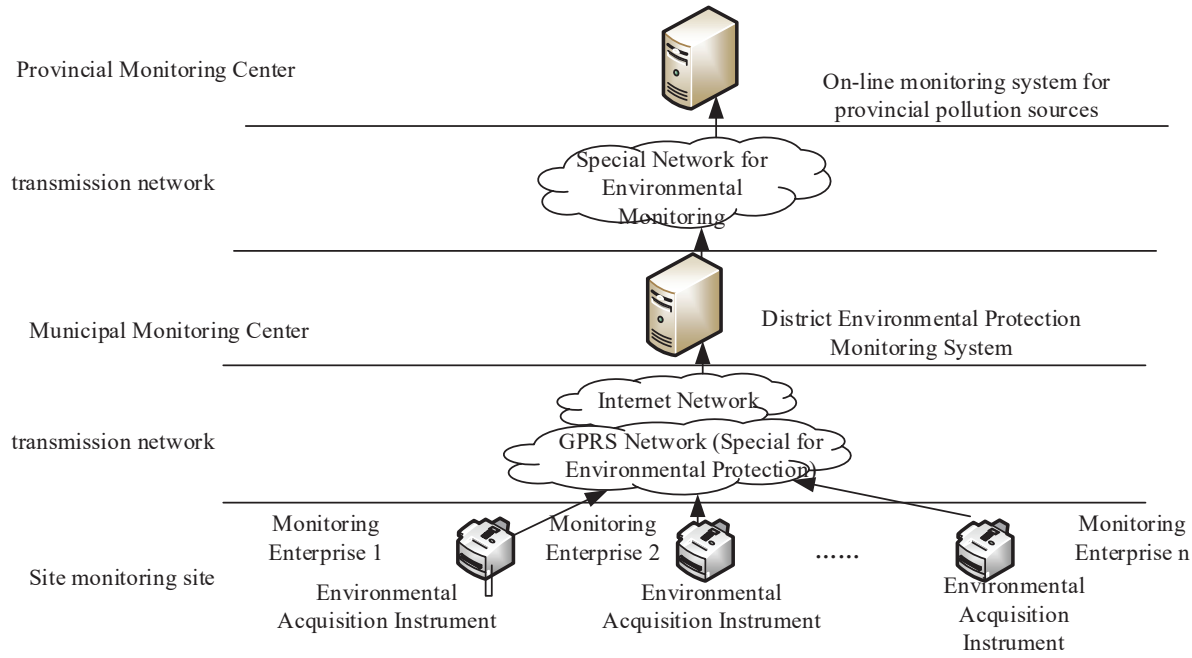

Fig. 1: Overall structure of the system.

Fuzzy c-means (FCM), also known as fuzzy K-Means, is one of the most widely used fuzzy clustering methods. The basic idea of FCM algorithm is to introduce a fuzzy coefficient m based on HCM (hard c-means) algorithm and membership matrix of samples belonging to various types, and to establish the objective function.

$$J = \sum_{n=1}^{N}\sum_{k=1}^{C} u_{nk}^{m} \left\| x_n - \mu_k \right\|^2 \quad \ldots(1)$$

In Formula (1), m is a fuzzy index, generally valued between [1.5, 2.5]; $U = \{\mu_{nk}\}$ is a membership matrix, and μ_{nk} denotes the membership degree of the nth point belonging to the K clustering centre, which is usually expressed by distance.

$$\mu_{nk} = 1/\sum_{j=1}^{C}\left(d_{nk}/d_{jk}\right)^{2/(m-1)} \quad \ldots(2)$$

In Formula (2), $d_{nk} = \|x_n - \mu_k\|$ is the distance from object x_n to cluster centre μ_k. And $0 < \mu_k < 1$, the constraint is: $\sum_{k=1}^{C} \mu_{nk} = 1$. The formula for calculating cluster centres is as follows:

$$\mu_k = \frac{\sum_n (\mu_{nk})^m \bullet x_n}{\sum_n (\mu_{nk})^m} \quad \ldots(3)$$

RESULTS AND DISCUSSION

Design of acquisition module of environmental acquisition instrument: The system integration method is adopted in the design and implementation of the acquisition instrument, which is mainly divided into four parts: acquisition module, display module, communication module and power module. Individualized customization of the function and parameters of each module can greatly save the development cycle and ensure the normal operation of the acquisition instrument in high temperature and high dust industrial environment.

The working process of the acquisition instrument is as follows: using PLC to collect the switching status of production equipment and control equipment for storage and processing; transmitting equipment status information to the host computer or receiving query instructions from the host computer through GPRS communication module connected to the communication port 0 of the PLC; reading the corresponding register status of the PLC by the display module at the communication port 1 of the PLC. Displaying module can display each register status in real time and inquire the cumulative running time of each device, and the switching status of production equipment and corresponding control equipment is compared and inquired in the form of trend chart. The power module provides power is the whole system (which can provide two hours' endurance when the external power is off).

PLC collects the switching information of the device in real time and sends real-time data to the host server every 30 seconds and stores the data to the data table every 5 minutes. During the three fixed periods of time each day, it can interrupt and enter the receiving state. It receives information from the host computer and determines whether the historical data needs to be supplemented. If the host computer needs to be supplemented, the corresponding data blocks in the historical data table will be submitted to the host computer. If the host computer does not need to be supplemented, the receiving interrupt program will be withdrawn. In this way, the integrity of data in the host server can be ensured. For the above work process, the structured programming method is adopted to realize in PLC. The flow chart of the program is shown in Fig. 2.

Software framework of upper computer monitoring system: The functions of the host computer monitoring system include receiving data from several field acquisition devices, storing them in the database, checking whether the information in the database is complete or not in a predetermined time interval, and sending data replenishment requests to the corresponding acquisition devices and obtaining the replenishment data if there is missing data. The monitoring system provides a friendly graphical interface, simulates the operation status of the monitoring site, and has the functions of user management, real-time status, historical status, alarm records and other information management. The monitoring system can also provide WEB publishing, allow multiple clients to access through browsers, and achieve office remote monitoring.

For the realization of this system, two modes of C/S+B/S coexistence are adopted. C/S structure is used in data receiving and transmitting program, which is mainly responsible for receiving and forwarding field data. B/S structure is used in the design of monitoring interface, so that users can access it through WEB. The software framework of the monitoring system is shown in Fig. 3. The data sending and receiving layer is developed by Visual Basic and the application layer is implemented by configuration software.

The advantages of using the above system structure are obvious. VB has powerful network communication and data processing capabilities. The functions of receiving, storing and forwarding data are handed over to the VB background program. Then, the user interface and various statistical recording functions are realized in the configuration software with the SQL SERVER database as the intermediary.

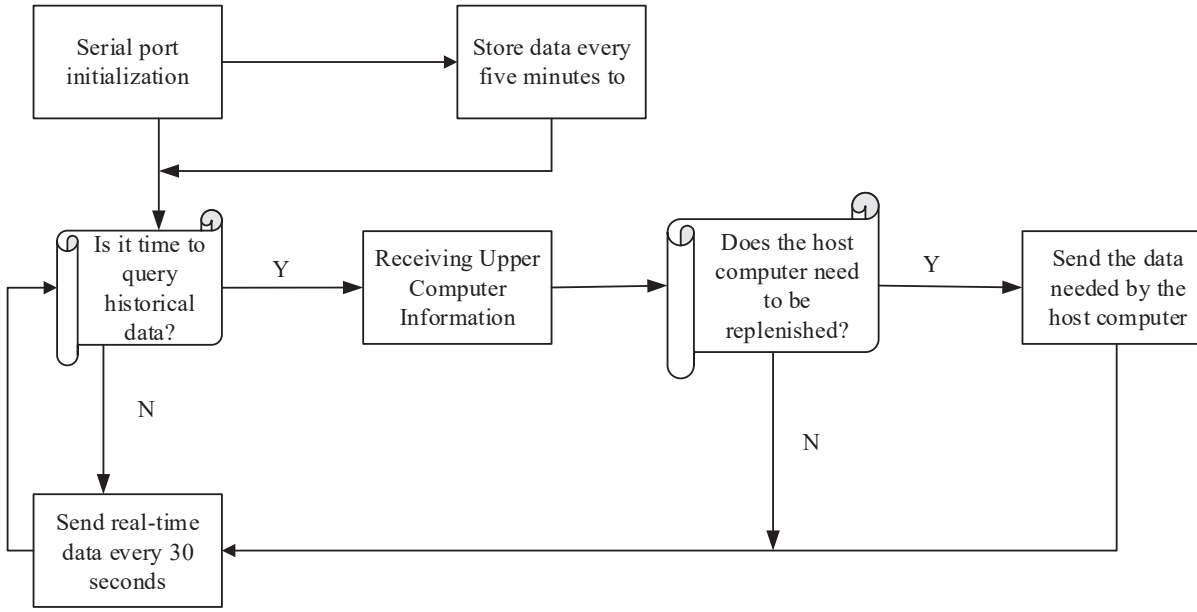

Fig. 2: PLC program flow chart.

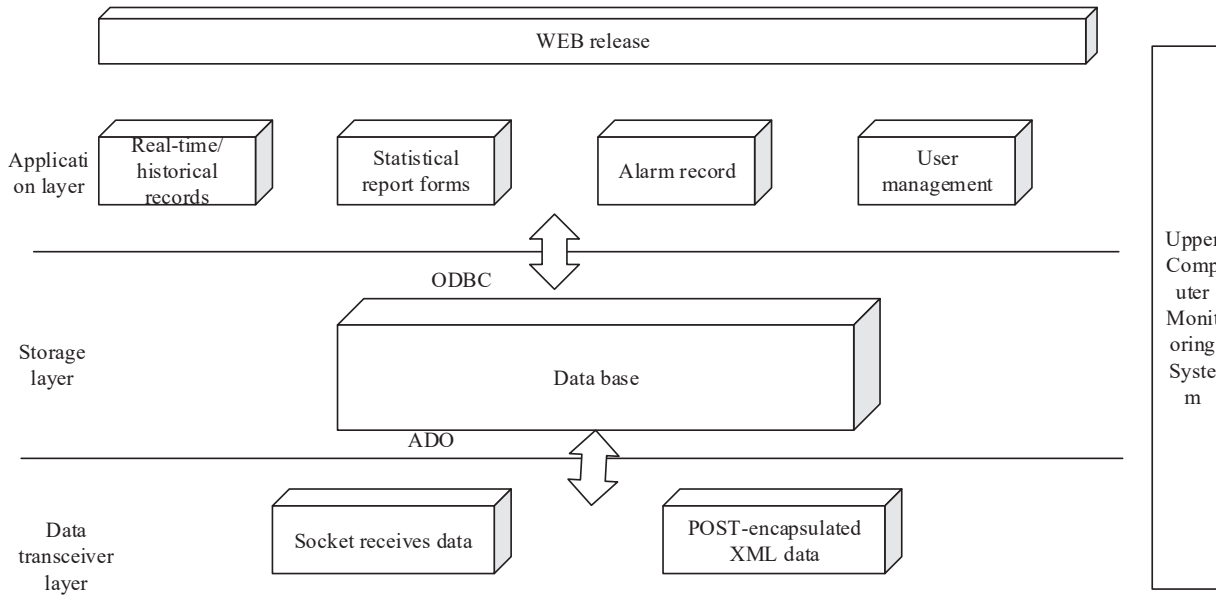

Fig. 3: Software framework of upper computer monitoring system.

Design of database: For the establishment of database of environmental monitoring system, ER model design method is adopted. ER model is a problem-oriented conceptual design model, which describes the real data in a simple graphical way (ER diagram) but does not involve how these data will be implemented in the database system. There are three basic components in ER model: entity, connection and attribute.

The idea of using ER model to design relational database is to introduce an intermediate step in the design process, that is, to design a system model (the system model is purely a reflection of reality, but has nothing to do with storage

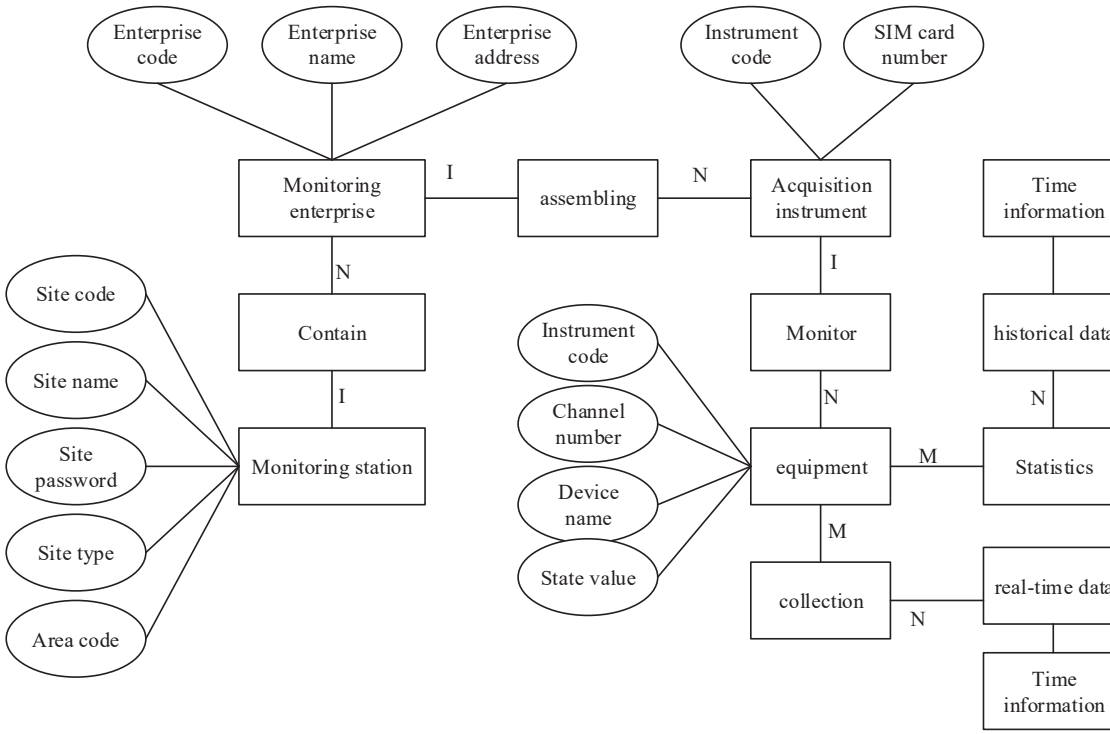

Fig. 4: ER diagram of database.

structure, access mode, etc.), and then convert the system model into a data model on a database management system, which is a conceptual data model. There is a connection between the monitoring site and the monitoring enterprise, which belongs to one-to-many relationship; a connection between the enterprise and the acquisition instrument is "assembled", which belongs to one-to-many connection; a connection between the acquisition instrument and the equipment is "monitored", which belongs to one-to-many connection; and there is a connection between the equipment and the "real-time data" and the "historical data", respectively. According to this, the ER diagram of the database can be drawn as shown in Fig. 4:

According to the ER chart of monitoring system data and the attribute of an example, the relational data structure can be derived. The established data tables include site information table, enterprise information table, instrument information table, equipment information table, real-time data table and historical data table. For this purpose, two data tables need to be established for the auxiliary use of configuration software, mainly in user management and equipment alarm records. The two tables are designed according to the requirements of configuration software, and the establishment of database is completed (Table 1).

Implementation of data transmitting and receiving layer: The functions that need to be realized in the data sending and

Table 1: User log-off record table.

Field name	Field type	Field length
Operator name	Text	20
Sign of success	Text	20
Event type	Text	20
Event date	Text	20
Event time	Text	20
Workstation name	Text	20

receiving layer are: receiving data from several field acquisition devices, storing them in the database, checking whether the information in the database is complete in a predetermined time interval, and sending data replenishment requests to the corresponding acquisition devices and obtaining the replenishment data if there is missing data.

The data format reported by field acquisition instrument is hexadecimal byte array, which has three formats: first, hexadecimal array with 12 members; second, hexadecimal array with 2 members, which is the complementary query instruction; third, hexadecimal array with 199 members, which is the supplementary data reported. The specific process of data reception is as follows: receiving real-time data from field acquisition instrument every 30s; generating a data every 5 minutes from historical data table and taking the real-time state as the historical state within 5 minutes. If the real-time state at that time is empty, the state of historical data table is also set to empty, but its position is still reserved and waiting for replenishment.

ADO (ActiveX Data Object) is an important part of Microsoft's Universal Data Access development strategy. It will replace DAO (Data Access Object) and RDO (Remote Data Object) technologies. ADO achieves access to different types of data sources through OLEDB. OLEDB is an underlying programming interface that supports relational or non-relational data sources, such as various types of databases, spreadsheets, e-mail and text files. Fig. 5 shows the model for accessing data through ADO.

In VB, there are two main ways to access database by ADO, one is non-programmable access mode, which uses ADOData control mode to access data in the database by binding controls; the other is ADO object model programming access mode, through defining objects and writing code to achieve access to data. When using ADOData control to connect database, it does not need to create connection objects and record set objects. It can simplify programming by directly setting related attributes. However, it has some limitations in function. It is difficult to change the connection of database when the program is running, and the efficiency of accessing large database is relatively low. If the database is connected by object model programming, the operation of the database is very flexible, and the efficiency will be greatly improved. There are many ways to use the database data in the data receiving and receiving program, so ADO object model programming is used in this program to access the data.

CONCLUSION

According to the national total pollutant emission reduction and the requirement of speeding up the capacity building of automatic environmental monitoring system, combined with the reality of current environmental management, based on the principle of "high starting point planning, high standard construction and high efficiency operation", an advanced environmental video monitoring system is gradually established. The system integrates the development of

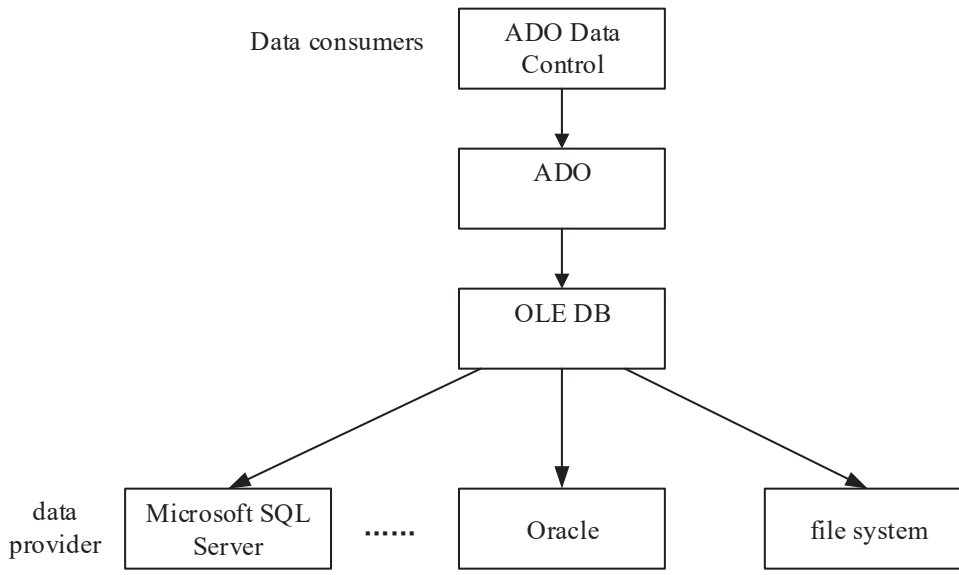

Fig. 5: ADO access data model.

communication technology and digital video monitoring technology to make the decentralized and large-scale remote video surveillance system applied to environmental video surveillance system become a reality. The video surveillance information management system is a network, digital and intelligent image management system, which uses advanced information technology and technology as a means to realize the transformation from "artificial random monitoring" with human as the subject to "remote real-time monitoring" with science and technology as the subject. The system is an important part of the province's environmental automatic monitoring and management system supported by science and technology. As an important means of achieving harmonious and modern urban management, it has become the basic guarantee of creating a "healthy and harmonious" society.

Although this system can meet the project requirements of Environmental Protection Bureau, there are still many areas to be improved to make it become a system with higher application value, such as optimizing the database design. Because of the continuous operation of the monitoring system, a large amount of data has been accumulated in the database, which may cause greater access pressure to the database server. It can be considered to optimize the design of database by using triggers of relational database and non-standardization technology to ensure the efficient operation of the whole system.

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