Developing a Coal Quality Detection Management System for Power Plants

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***Abstract*—A Coal Quality Detection Management System is developed in Visual C++ based on Client/Server mode, and the system combines several techniques, such as the open database connectivity, serial communication, and Excel object linking and embedding. The system is composed of three modules: a receipt/allocation module, a data acquisition module, and a detection data management module, and the modular structure endows the system with a series of functions, such as real-time data collection, query results, data processing, data auditing, data storage, and report printing. Recently, the system was applied in two coal-fired power plants for managing coal quality detection, which greatly improves the detection efficiencies and reduces the manual works.**

***Index Terms*—Coal quality detection, Power plants, Fuel management, Client/Server mode, Open database connectivity, Serial communication**

I. Introduction

The coal quality detection is an integral part of the fuel management, and the coal quality and the economic benefit of power plants depend on coal detection results. Meanwhile, the detection results can provide a significant guarantee for safe operation and environmental protection in power plants [1]. Hence, the coal quality detection is considered as one of the critical areas to face the competition in the energy market.

Currently, the coal quality detection has become a routine analysis in most coal-fired power plants, and the routine analysis involves many coal quality parameters, such as total moisture, total sulfur, ash yield, volatile matter, calorific value, and so on. The parameters are generally determined by various detection instruments, and the data processing of detection results is based on the Access local database. However, some shortcomings exist in most coal quality detection management:

(1) Non-fully networked. Most of the detection instruments run independently, and they are not connected to the Internet. Hence, the detection results cannot be transmitted in real-time and cannot be shared through a network.

(2) Non-standard operation. There are not operation instructions for some detection procedures, and non-standard operations are generally performed in conventional detections, for example, parallel detections are not conducted.

(3) Heavy workload. The measurement data obtained from the instruments must be collected manually, followed by a series of data processing and statistics, which needs to do a huge amount of paper work and manual labor.

(4) Low data reliability. The detection results are generally recorded manually, and most instruments do not have the function of data statistics. Therefore, the influence of human factors on the accuracy of detection results cannot be avoided.

To eliminate the above shortcomings, it is necessary to develop a set of coal quality detection management system (CQDMS) with characteristics of automation, network, and information. However, studies on CQDMS for power plants are rarely reported. Though some papers have reported on software development for fuel management in power plants and for coal quality management in coal preparation plants [2-4], the coal quality detection management is briefly mentioned as one of many modules and not described in detail.

Based on the current situation of the coal quality detection management in most coal-fired power plants, a CQDMS is developed, aiming at program control of the coal quality detection process. In practice, the CQDMS can automatically receive and allocate coal samples, and collect all the detection results. Moreover, the CQDMS can perform a series of statistics on all the detection results according to the national standards, audit the detection results, and produce reports.

II. Requirements Analysis And The Use Case Model

A. Requirements Analysis

In the initial stage of software development, it is necessary to perform a requirements analysis. Sufficient requirements analysis can complement the flaws and shortcomings in the design. Consequently, the development efficiency and the software quality will be improved.

a. The functional requirements of CQDMS.

(1) Receive/Allocate samples. The system can identify the bar code on sample bags and allocate a laboratory's code for each sample automatically or manually.

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(2) Real-time detection data collection. All the measurement data from each detection instrument are collected automatically in real-time. When the data in the local database on the detection instruments are updated, the data in the system will be updated in real-time correspondingly.

(3) Real-time weight data read. The weight of each sample can be read automatically from an electronic balance in real-time.

(4) Data statistics. The system can perform a series of statistics on all the detection results according to the national standards and summarize all of the results of one sample.

(5) Audit. The detection results are audited through two levels.

(6) Report. A coal quality report can be generated automatically based on the qualified results.

(7) Query historical data. The historical data can be queried based on a date.

b. The performance requirements of CQDMS.

(1) High-reliability. High-reliability and stable operation are the basic requirements for data processing, transmission, and display.

(2) Real-time. The system can accurately display the detection records on the interface in real-time.

(3)Easy to Operate and Maintain. Users can operate the system skillfully in a short period of time.

(4) Openness. The system can be integrated with other third party systems to form an enterprise wide application.

B. Use Case Model

The first step to create a use case model is to identify the main actors [5], and the main actors of the CQDMS are a recipient, a laboratory assistant, a primary auditor, and a secondary auditor. There are seven use cases in the use case model of CQDMS: receive sample, detect sample, summarize data, print report, audit result (primary), audit result (secondary), and query historical data. Different users access the system with different user's permission. Based on the requirements analysis of the system, the use case diagram is shown in Fig. 1.

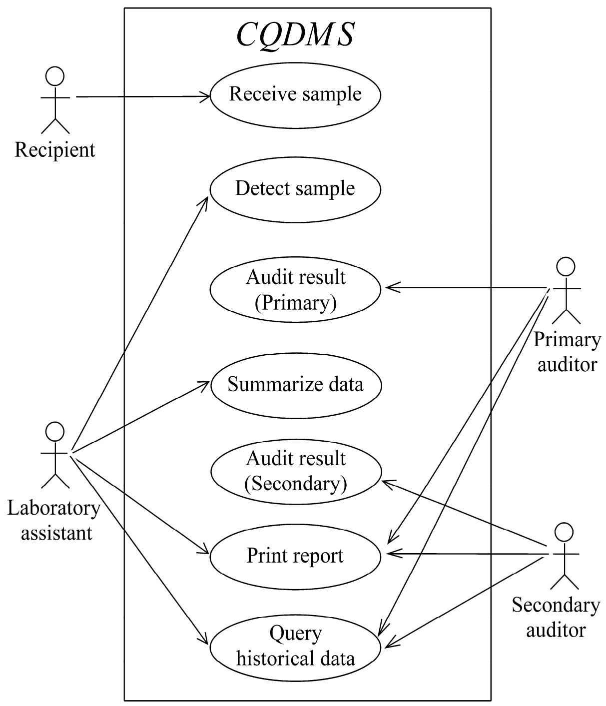

Figure 1. The use case diagram of the CQDMS.

III. The Overall Architecture

The detection results on coal quality are important data for the fuel management in power plants, because the data is the foundation not only to make payments or adjustments but also to blend coal. Therefore, the data security and timeliness should be guaranteed in the CQDMS. Client/Server (C/S) mode can make the system relatively closed, resulting in a high extent of data sharing and a high execution speed of applications [6-8]. In the CQDMS, Microsoft SQL Server 2008 is chosen as the background database, which is very convenient to start the background database service programs and to provide database services for the client applications. In a coal quality detection laboratory, the local server and the client are connected through a LAN [9]. Therefore, even if some problems occur in the enterprise backbone network, the system can run normally, ensuring the security of the data. The network topology structure of the CQDMS is shown in Fig. 2.

The central management machine in the laboratory network is the data management center, by which the main operations of the system are performed and a series of functions are implemented. The server in the laboratory network primarily interacts with the back-end database to realize remote data query and collection of the detection results, and to dock with other enterprise information systems according to the need made based on the collected data and the summarized data. On the other

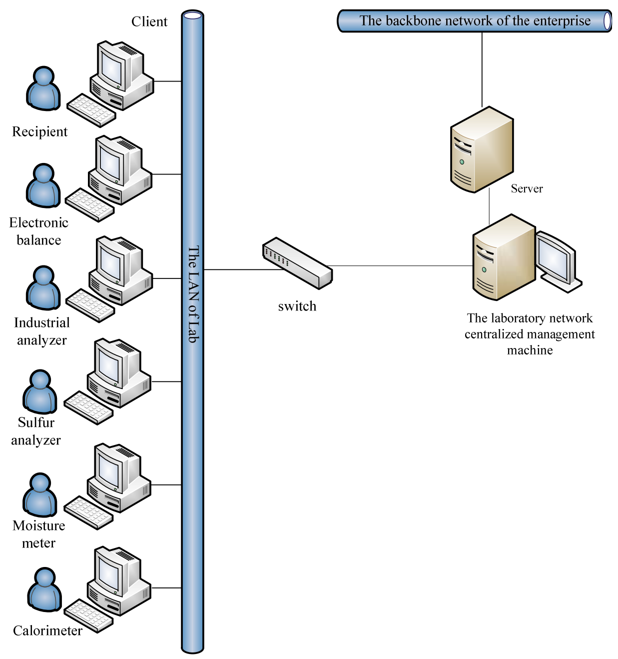

Figure 2. The network topology of the CQDMS.

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hand, the client installed on each detection instrument reads the detection data stored in the local database.

IV. Development Platform And Key Techniques

A. Development Platform

The CQDMS software is designed based on C/S mode, in which Microsoft Visual Studio 2010 MFC is used as the development platform and the latest SQL Server 2008 is used as the background database. These softwares run under the Microsoft Windows 7 operating system.

B. Database Connection - the Open Database Connectivity (ODBC) Technique

ODBC is a database component of the Microsoft Windows Open Services Architecture, consisting of applications, driver manager, database drivers, data sources, and other components. The ODBC architecture is shown in Fig. 3. Applications can access the data in different data sources through ODBC application programming interface (API), and each of the different classes of these data sources is supported by an ODBC driver.

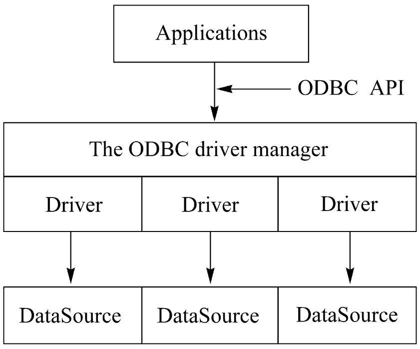

Figure 3. The ODBC architecture.

Besides the independence and the openness, ODBC has the following characteristics: occupying less memory, easy operation, high-speed storage, and regardless of the specific programming language and the specific database system [10]. Therefore, the ODBC technique is adopted to connect the system to SQL Server, Access, and Oracle databases.

C. Data Acquisition from Electronic Balance - Serial Communication Technique

Serial communication, a long distance communication

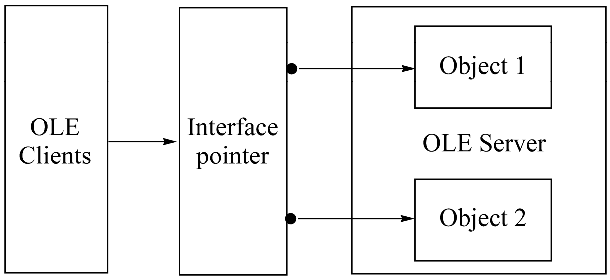

Figure 5. The interaction between OLE Clients and OLE Server.

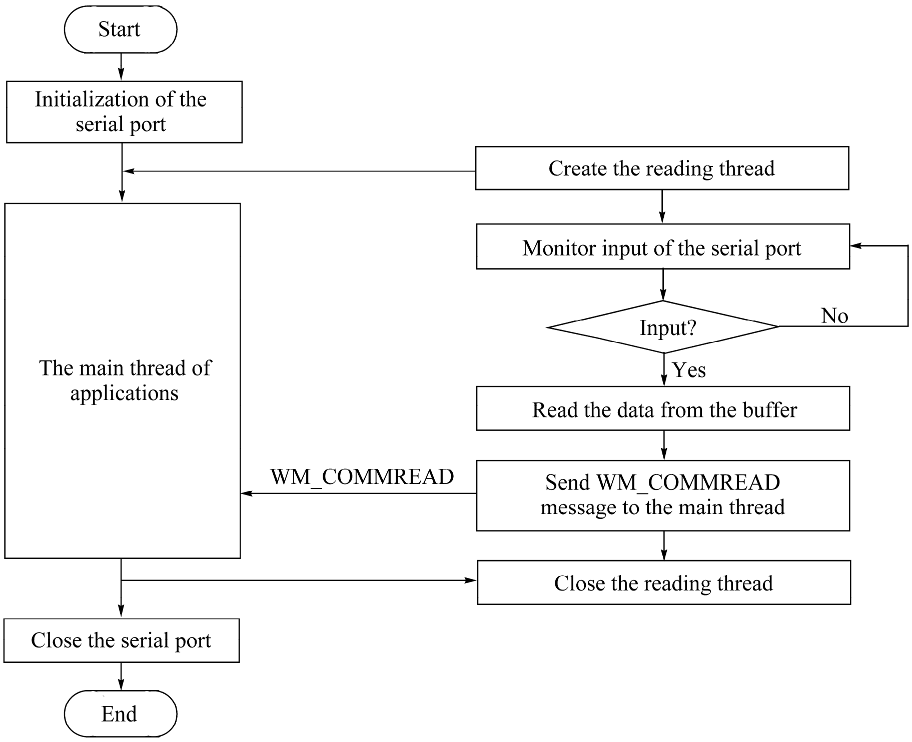

Figure 4. The serial communication flow chart.

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between computers and peripherals, is a communication mode in which the data are sent bit by bit. The RS232C interface is one of the most commonly used serial communication interfaces. At present, most electronic balances are equipped with an RS232C interface.

There are several advantages in access the RS232C serial port with Win32 API function, such as flexible control and rapid response, and this access way is usually applied in higher quality real-time data acquisition systems [6]. Hence, the Win32 API function is adopted in the CQDMS, and the serial communication between computer and electronic balance is based on multi-thread, asynchronous I/O operations, and event-driven serial communication technique [8,11]. The flow chart for the serial communication in the CQDMS is shown in Fig. 4.

D. Report Generation - Excel Object Linking and Embedding (OLE) technique

When the coal quality parameters for a sample are determined, a detection report is formed and printed. However, MFC is not very convenient for the input and output of a report, especially for those of some complex reports. So a perfect report is hardly obtained with MFC applications. Nevertheless, Excel is not only the outstanding part of the Microsoft Office suite, but also by far the world's most widely used spreadsheet program with powerful number crunching, creating charts, organizing lists, and accessing other data [12]. It is convenient for MFC applications to operate Excel with Excel OLE, which can improve the development efficiency. Therefore, we choose Microsoft Office Excel 2010 as the program for report generation.

OLE automation is a practical technique based on Component Object Model, and the data exchange

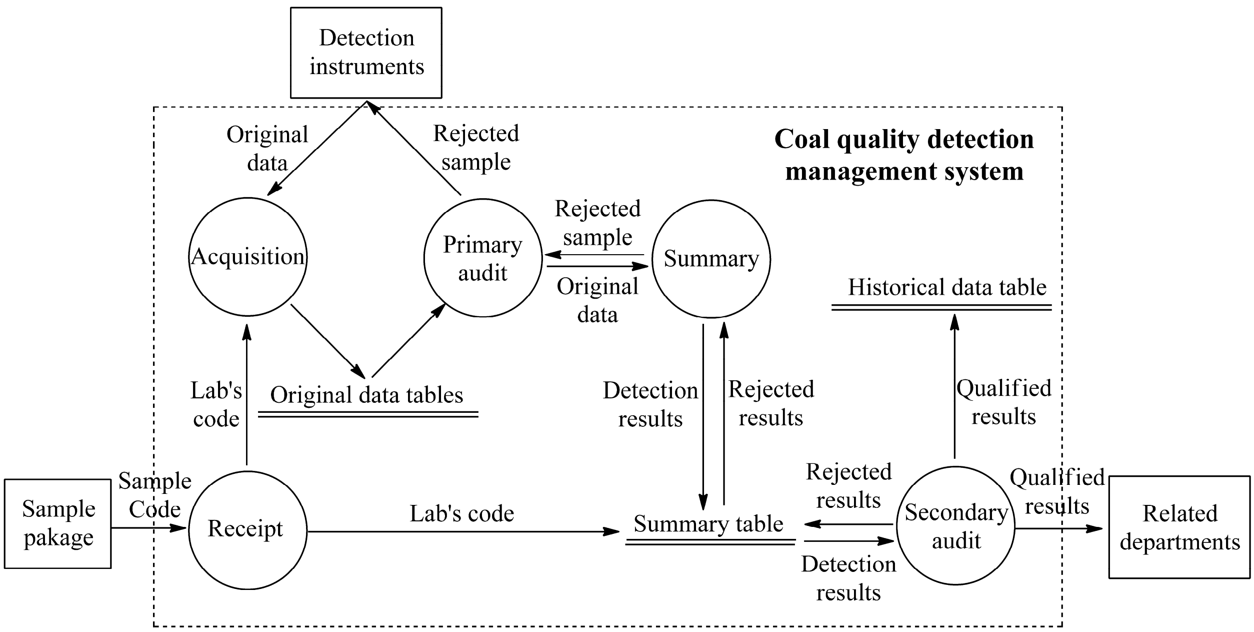

Figure 6. The data flow diagram.

TABLE I.
DATA STRUCTURE OF THE ORIGINAL DATA OF TOTAL MOISTURE

Column Name	Data Tyep	Descriptions	Nullable	Default
ID	int	Primary key	No	
LABCODE	nvarchar(30)	Lab code	No	
SAMPLEMASS	decimal(10,5)	The original sample mass	Yes	0
POTMASS	decimal(10,5)	The original pot mass	Yes	0
MTL	decimal(10,5)	The original left mass	Yes	0
WATERPER	decimal(8,3)	Total moisture	Yes	0
TESTDATE	datatime	Detection date	Yes	
AUTONUMB	nvarchar(30)	Automatic code	Yes	
EQUIPMENTID	nvarchar(30)	Equipment code	Yes	
NUM	int	Detection number	Yes	1
MANUAL	nvarchar(10)	Manual mark	Yes	A
OPERATOR	nvarchar(20)	Auditor	Yes	
STATUS	nvarchar(10)	The status of review	Yes	

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TABLE II.
DATA STRUCTURE OF DETECTION RESULTS

Column Name	Data Tyep	Descriptions	Nullable	Default
ID	int	Primary key	No	
LABCODE	nvarchar(30)	Lab code	No	
MT	decimal(8,2)	Total moisture	Yes	0
MAD	decimal(8,3)	Air-dry moisture	Yes	0
AAD	decimal(8,3)	Air-dry Ash	Yes	0
VAD	decimal(8,3)	Air-dry volatile matter	Yes	0
STAD	decimal(8,3)	Air-dry total sulfur	Yes	0
QBAD	decimal(8,3)	Air-dry basis bomb calorific value	Yes	0
AAR	decimal(8,3)	As received ash	Yes	0
AD	decimal(8,3)	Dry basis Ash	Yes	0
VADF	decimal(8,3)	Dry ash-free basis volatile matte	Yes	0
STD	decimal(8,3)	Dry basis total sulfur	Yes	0
QNETAR	decimal(8,3)	As-received basis net calorific value	Yes	0
HAD	decimal(8,3)	Air-dry Hydrogen	Yes	0
DATE	datetime	Detection date	Yes	
AUDITOR	nvarchar(20)	Auditor	Yes	
STATUS	decimal(10)	The status of review	Yes	

between two applications is carried out in C/S mode. In C/S mode, applications that expose the properties and methods of some objects to other applications are known as OLE Server, whereas the applications with these methods and properties are known as clients. The interaction between OLE Clients and OLE Server is shown in Fig 5 [13,14]. As an OLE server, Excel offers a structured collection of objects, methods, and events that can be used by automation clients at run time.

V. DESIGN AND IMPLEMENTATION

A. Design of Database

The database is the key to the normal operation of the CQDMS, and the quality of the data structure will affect not only the efficiency of the CQDMS but also the effectiveness of the implementation. In practice, a logical data structure design can improve the efficiency of data storage and ensure the data integrity and consistency, and is conducive to the realization of the program as well. Hence, it is essential to choose a database with high performance, stability, security, usability, and powerful system compatibility. In addition, the data amount and the data security must be taken into account in the design. In the coal quality detection management, the amount of

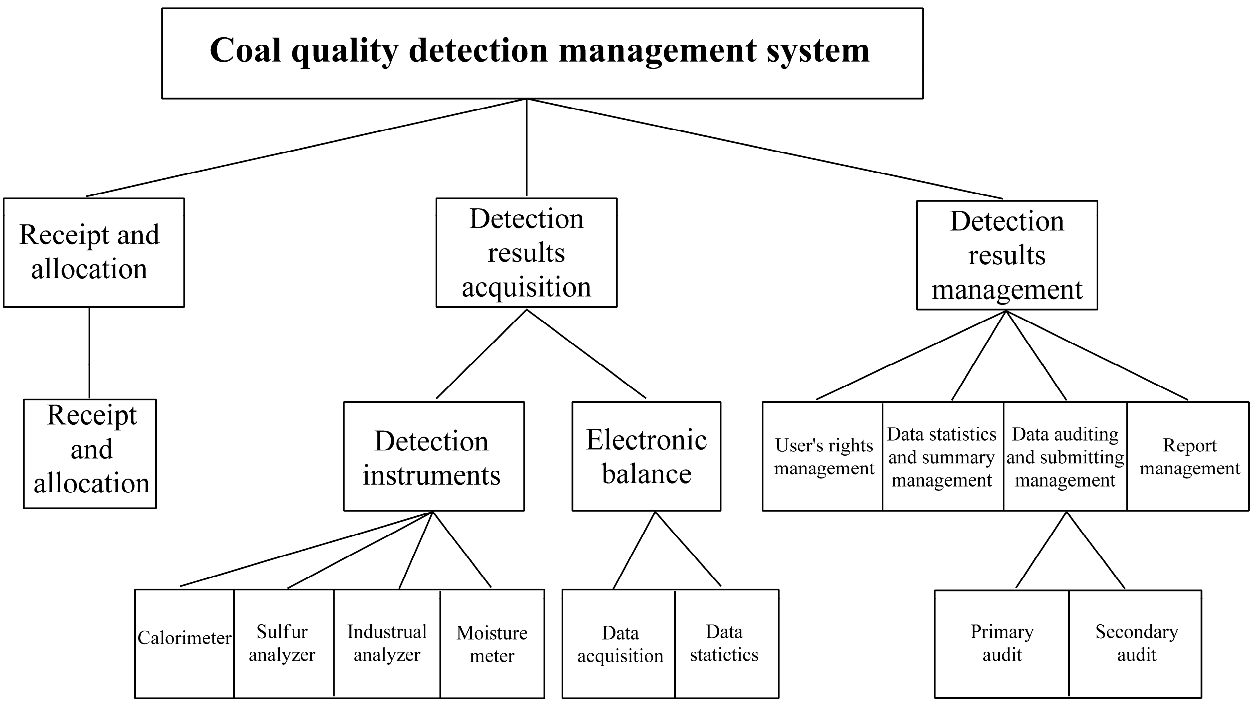

Figure 7. The function module chart of the CQDMS.

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the data is not very large and the computer skills of some operators are not excellent. Thus, Microsoft SQL Server 2008 is chosen as the background database platform, which has the characteristics of easy operation [15].

a. Data Flow Diagram

The function of the CQDMS is to manage the detection results of coal samples, and the detection results can be stored in the local SQL Server 2008 database and can be

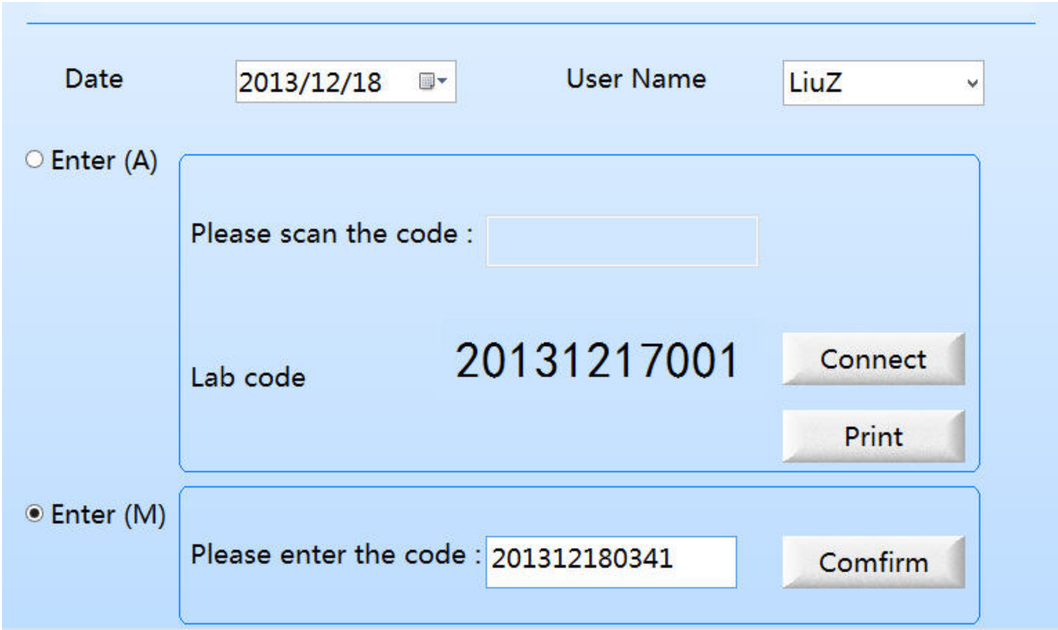

Figure 8. The operation interface for the receipt and allocation module.

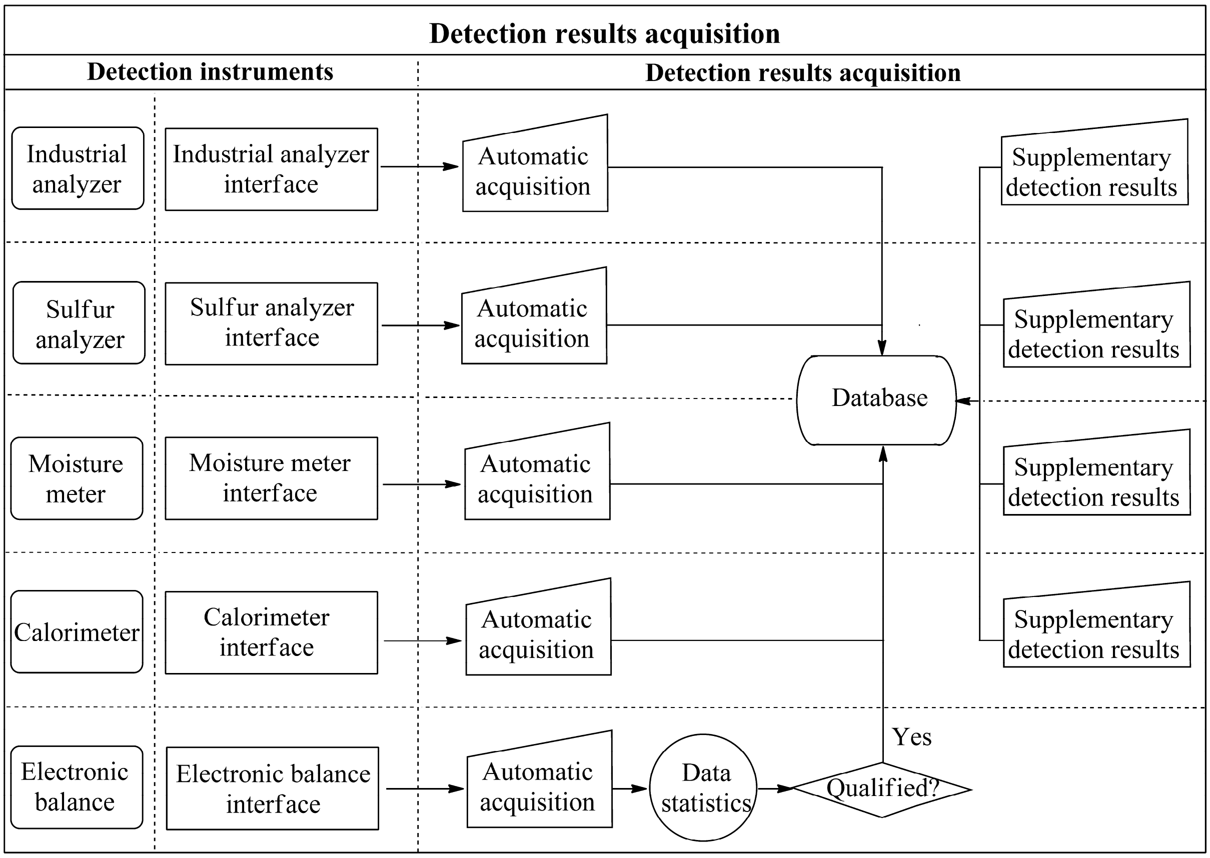

Figure 9. The data acquisition flow chart.

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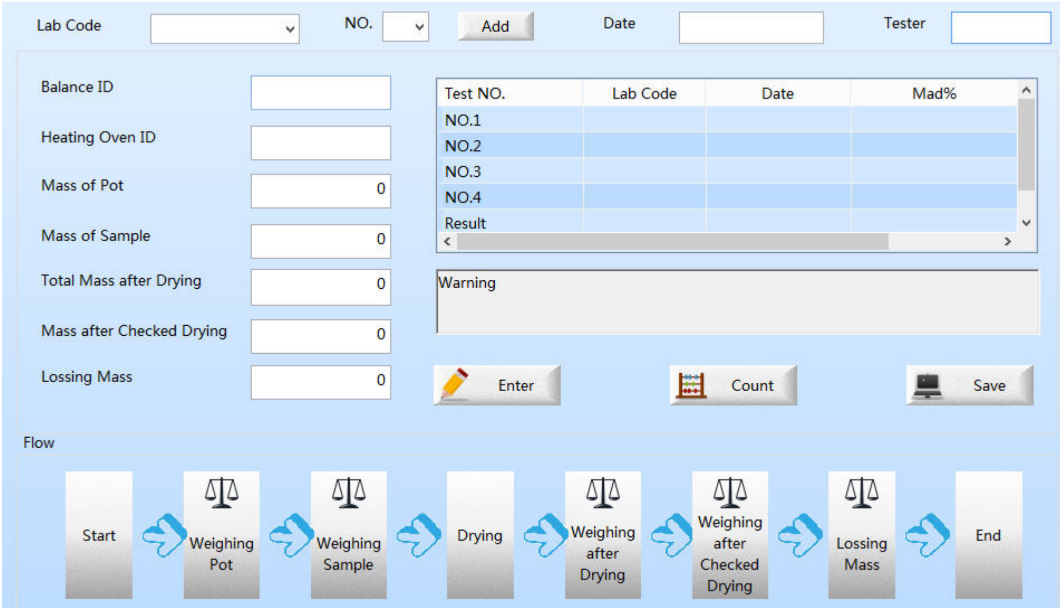

Figure 10. The interface of the electronic balance.

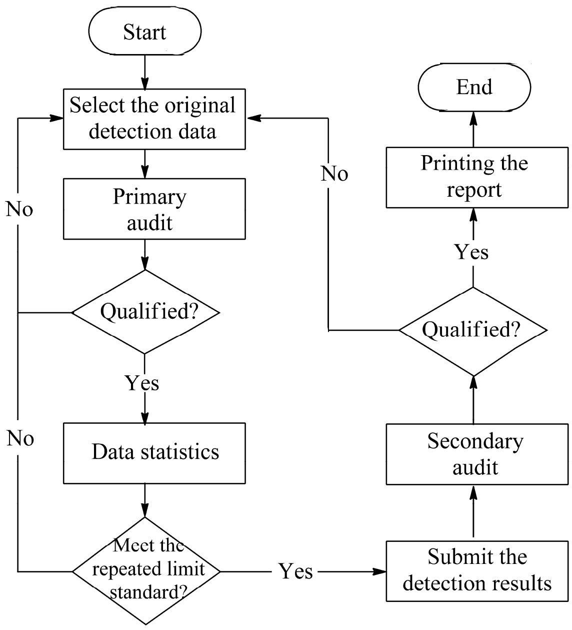

Figure 11. Data processing.

uploaded into the enterprise database. Fig. 6 shows the data flow diagram, which is designed based on the network topology and the functions of each module in the CQDMS. The data of the CQDMS are stored in the local database, mainly including the summary table, the historical data table, and the original data tables of total moisture, air-dry moisture, air-dry ash, air-dry volatile matter, air-dry total sulfur, and calorific value. As shown in Fig. 6, the original measurement data obtained from the automatic detection instruments are stored in the original data tables. After the primary audit, the qualified original data are summarized, and the detection results are stored in the summary table, followed by the secondary audit, then, the qualified detection results in the summary table are moved into the historical data table.

b. Data Structure

The main designed data items and data structures are shown in Table I and Table II. The data structures of original total moisture, air-dry moisture, air-dry ash, air-dry volatile matter, air-dry total sulfur, and calorific value are almost the same. Thus, Table I only shows the original records of total moisture, whereas Table II shows the detection results, and both tables are related by the lab code item.

B. Function Design and Implementation

Based on the laboratory network topology structure and the characteristics of the data statistics on the detection results, the CQDMS is designed to be a modular structure, which is easy to maintain and upgrade because the functions of each module are relatively independent. The function module chart of the CQDMS is shown in Fig. 7.

(1) Receipt/Allocation module

This module is mainly designed to identify the bar code on sample bags and allocate a laboratory's code for each sample automatically or manually. The module improves the confidentiality of the system and facilitates the laboratory assistants perform detections and data processing.

The IDs of coal samples can be input into the system by both automatic and manual methods. In the automatic entry method, the bar code is input into the system by a scanning gun, and the system randomly assigns a laboratory number to the corresponding sample. In the manual entry method, first, input the bar code into the system manually, then, click the button of "Confirm", and a laboratory number is randomly assigned to the

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corresponding sample. The operation interface for this module is shown in Fig. 8.

(2) Data acquisition module

The main functions of the module are to collect the data obtained by the detection instruments and to perform the collection and statistics on the weight data obtained from an electronic balance. The data acquisition flow chart is shown in Fig. 9.

The measurement data stored in the local database on the light-wave moisture meter, industrial analyzer, sulfur analyzer, and calorimeter can be read in real-time by this module, running in the background mode without interface. Therefore, when the data in the local database are updated, the data in the SQL Server 2008 tables will be updated correspondingly in real-time. In addition, the measurement data obtained on any date can be manually sent into this module by the operator, in case that data can not be successfully uploaded due to a sudden interruption of networks and other external causes.

The basic design ideas for the automatic data collection are as follows.

It is required that the original detection data should be

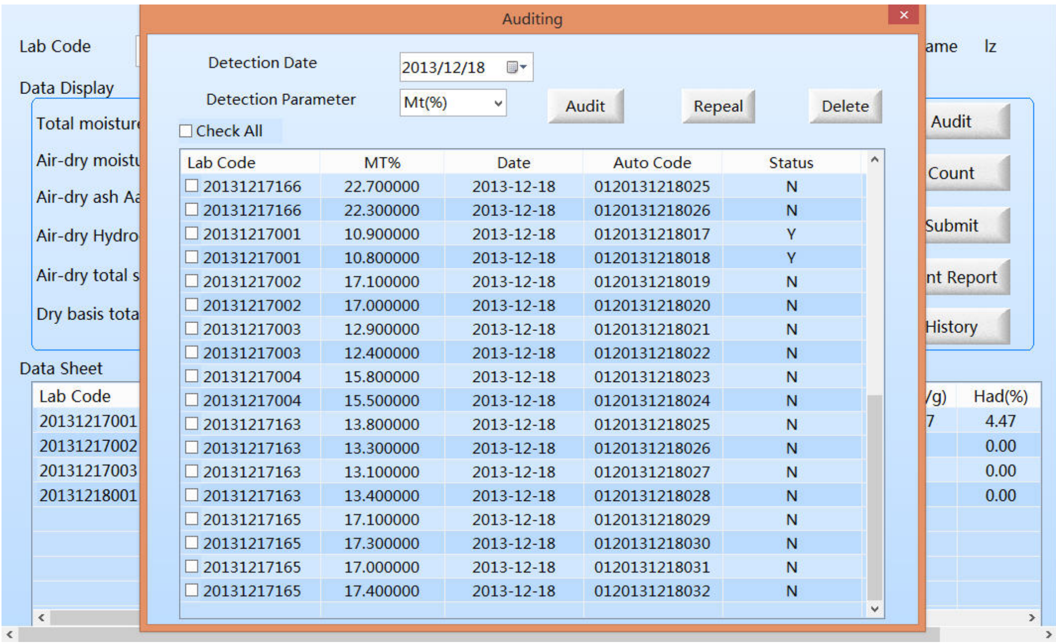

Figure 12. The interface of the audit for detection results.

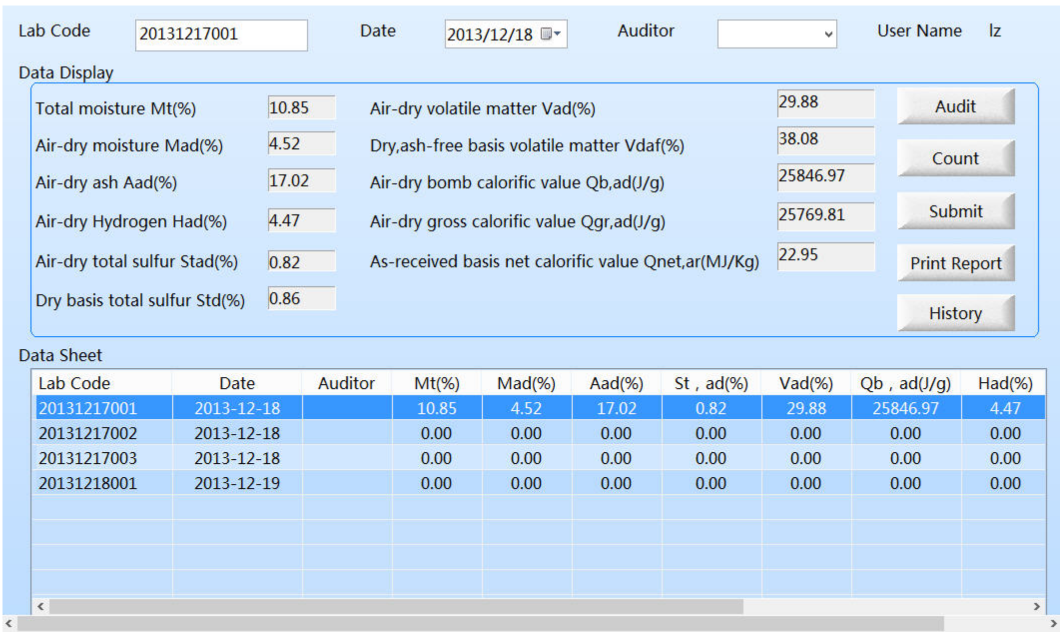

Figure 13. The interface of the detection result management.

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transmitted in real-time. Thus, the monitoring time interval is set to 5 minutes in the system. As soon as the data in the local Access database are changed, the system starts to collect the data. The system combines the way of date mark with the way of absolute increment ID to capture data. The way of date mark is to choose a field in the data table as a condition and to configure the field in a time range (such as less than two days). If the field of a data is in the configured time range, the system will extract the data. The way of absolute increment ID is to make the primary key of the data table as a condition and each time to collect data saving the current maximum ID as a condition for the next acquisition. Once the data is successfully uploaded to the original data table, any information cannot be changed.

Besides the parameters obtained from the detection instruments, the total moisture, ash content, and volatile matter content are determined by an electronic balance, and the weight data can be input into the data boxes in the interface of the CQDMS via the serial port of the balance. The data boxes in the interface are for the exclusive data input from the balance, in which the data cannot be modified manually. When these original weight data are collected by the module, the system will conduct a series of calculations on these data according to the standard formulas and store the calculated results in the original data table. The interface of the electronic balance is shown in Fig. 10.

(3) Detection results management module

This module is the laboratory data management center

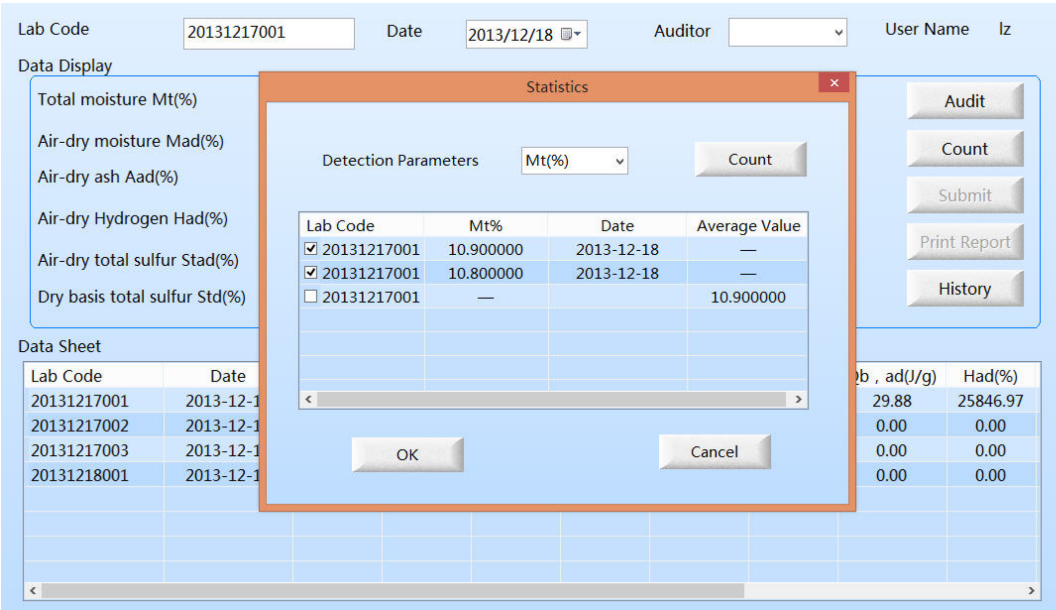

Figure 14. The interface of the data statistics.

Determination report for coal sample as received					
Lab Code		20131217001	Detect date		2013/12/18
Parameter		Result	Standard Method		
Total moisture, Mt(%)		10.9	GB/T211-2007		
Air-dry moisture, Mad(%)		4.52	GB/T212-2008		
Air-dry ash, Aad(%)		17.02	GB/T212-2008		
As received ash, Aar(%)		15.89	GB/T212-2008		
Dry basis ash, Ad(%)		17.83	GB/T212-2008		
Air-dry volatile matter, Vad(%)		29.88	GB/T212-2008		
Dry, ash-free basis volatile matter, Vdaf(%)		38.08	GB/T212-2008		
Air-dry total sulfur, St,ad(%)		0.82	GB/T214-2007		
Dry basis total sulfur, St,d(%)		0.86	GB/T214-2007		
As-received basis net calorific value, Qnet,ar(MJ/Kg)		22.95	GB/T213-2008		
Second Auditor	Manager	First Auditor	Manager	Operator	Manager

Figure 15. A printed report.

mainly providing functions of result query, data processing, data auditing, data storage, and report printing. The detection results management flow chart is shown in Fig. 11.

After the original measurement data are audited, the data with large deviation or wrong can be found in time, and the corresponding samples must be re-detected. The interface of the audit for detection data is shown in Fig. 12.

The query results function is designed for the original measurement data, via which the original results for a selected sample can be displayed in a list. The final result is an average value based on the results of 2~4 parallel detections per sample. The system automatically stores the qualified final results and calculates other parameters according to datum transformation standards in the summary table. The unqualified data will be reported to the laboratory assistants. The data auditing function is designed for the users who are permitted to audit the detection results, via which the qualified results can be

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reported to its higher system, and a final report is printed and stored, whereas the samples with rejected results need to be detected again.

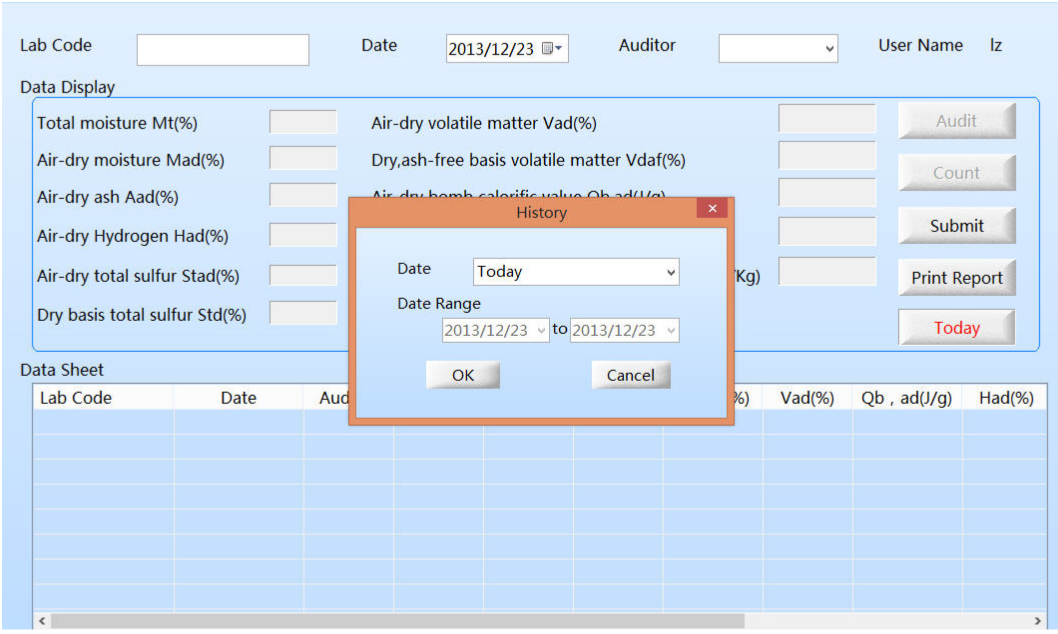

Figure 16. The interface of the historical data.

To better demonstrate the functions of data statistics and printing report, Figs. 13-16 show the interfaces of the detection result management, data statistics, report printing, and historical data.

C. Security Design

In the design, only the authorized users are allowed to access the applications, whereas unauthorized users are prohibited viewing the information in the CQDMS. Therefore, the system is designed to possess the function of authentication and authorization. For authentication, the system can only be entered through the login page, providing the correct user ID and password corresponding to certain applications, and cannot be accessed by any other middle dynamic page. For authorization, the system is designed to different access levels for different users, and the system can be operated based on the user's permission.

VI. Characteristics Of The System

(1) Multiple Functions

The CQDMS is designed based on the workflow in the common laboratories for coal quality detection, by which multiple functions are performed, such as recoding the received samples, real-time data acquisition, original data transmission, data statistics, data query, and data auditing.

(2) Good practicability

The real-time data acquisition technique simplifies the detection data entry, and various detection data can be collected automatically. Moreover, data processing involves a large number of statistical formulas and empirical formulas, and employing the CDQMS can overcome the shortcomings of cumbersome and error-prone in manual data statistics. In addition, report printing brings a great convenience to laboratory managers.

(3) Easy Operation

In the user-friendly design system, the human-computer interaction is fully taken into account, and all operations are simple and clear.

(4) High Security

Permission settings are strict. The user right management is hierarchical, using layers down principles. When a user is logging in the system, the corresponding interface will be displayed depending on the user's rights, which ensures the security of the system.

(5) Easy to Maintain

The CQDMS is designed based on C/S mode, and the applications are organized by a modular structure, in which each part is clarity. When some errors appear in the running, it is easy to find and correct them. Therefore, the CQDMS is easy to maintain.

VII. Conclusions

To deal with the unreasonable situation and to resolve the problems in coal quality detection management in power plants, a set of coal quality detection management system is developed based on Client/Server mode, open database connectivity, and serial communication. The system can implement a series of functions, such as real-time data collection, query results, data processing, data auditing, data storage, and report printing. Applying the

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system in coal quality detection management can reduce the manual intervention and calculation, improve the work efficiency, and guarantee the accuracy of detection results.

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