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Development of Boreholes Construction Deviation Tracking Software System: BCDTracking

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Abstract: Thousands of boreholes must be constructed for coal gas pre-drainage in China underground collieries. The hostile working environment made them so easy to deviate from design and facilitated coal gas outburst accidents. By combining statistical process control chart and automatic drawing technique based on office web components, a comprehensive software system for boreholes construction deviation tracking, named as BCDTracking, was developed. Taking the coal mining working face as a whole, the database of boreholes was built. Using three-tier architecture, the software system was divided into data access layer, business logic layer and user show layer. As the system kernel, business logic layer was implemented through a complex class and its functions involved two parts. One part was a successive workflow, including reading original data, computing inspective data series, computing statistics and drawing control charts. Another part was used for assistant data operations such as data inserting, updating, deleting and exporting. Results showed that BCDTracking was fully considering user experiences and could automatically track boreholes construction deviation effectively.

Key words: Coal gas pre-drainage, SPC, three-tier architecture, data preprocessing, BCDTracking

INTRODUCTION

In last decades, a large number of coal gas outburst and explosion accidents happened, which seriously threatened miners' lives and has caused heavy casualties. This situation was getting more and more violent as the underground coal exploitation extends to depth rapidly (Liu and Zhou, 2010; Hou *et al*., 2013).

Lots of theoretical achievements and practices proved that coal gas pre-drainage was the most rational approach to prevent coal gas outburst or explosion accidents (Cheng *et al*., 2009). In practice, thousands of boreholes were constructed, sealed and connected into the global coal gas drainage system with negative pressure and their construction quality directly determined the effect of coal gas drainage.

However, due to the hostile working environment with sightless coal strata reserves, paths of boreholes were very easy to deviate from design as constructed. The coverage inhomogeneity of boreholes leaded to residual gas reserves in some ranges of coal mass beyond control, which gave rise to probability of gas hazards (Hou and Zhang, 2013).

In last years, many achievements about the software systems of coal mining industry were reported (Samal and Sarangi, 2001; Cai *et al*., 2009; Xiong *et al*., 2012; Duskey, 2006; Trenczek and Wasilewski, 2008), such as Micromine, DataMine, PENDM, Minesight32D, etc., They well supported businesses such as coal reserves calculation, production plan design, equipment management, etc. They all devoted themselves to coal production system and marketing rather than coal gas pre-drainage.

In this study, by integrating statistical process control chart, database technology and automatic drawing techniques based on office web components into coal gas pre-drainage field, a comprehensive tracking software system for boreholes construction deviation was developed and named as BCDTracking. By the data structure analysis of boreholes, the background database

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was built in SQL Server. Based on X-R_s control chart, the theoretical tracking method was designed as a complete workflow, including inspective data series generation, statistics computation, X and R control chart drawing. Then, using three-tier architecture (Fowler, 2002), Data Access Layer (DAL), Business Logic Layer (BLL) and User Show Layer (USL) was accomplished. Results showed that BCDTracking was fully considering user experiences, easy-to-use and could automatically track boreholes construction deviation in time.

DATABASE DEVELOPMENT

In spite of various boreholes of coal gas drainage, their data structure was mainly common. The most popular measure of coal gas pre-drainage, cross-seam boreholes combining with along-seam boreholes as shown in Fig. 1 could be described as the follow (SAWS, 2009):

- Drive a floor rock roadway under the given coal seam about 20-30 m
- Construct borehole fields on side of the floor rock roadway
- Construct upward cross-seam boreholes in fields, whose paths should traverse coal seam at least 0.5 m and form regular gird distribution to extract coal gas of the strip range around the designed coal roadway
- After coal mass of the strip range was proved to be safe, miners begin to drive coal roadways, including mechanical roadway, ventilation roadway and open-off cut
- Construct along-seam boreholes in coal roadways to extract coal gas of working face

In Fig. 1, all components, namely floor rock roadway, boreholes fields of the floor roadway side, mechanical roadway, ventilation roadway, open-off cut, terminal line, working face, cross-seam boreholes and along-seam boreholes, constituted a integrated geographic scene. To describe their space properties and relations, a three-dimensional spatial coordinate system was built. Its origin located at the intersection point of the terminal line and ventilation roadway.

To describe the flat working face and related spatial coordinate system, the following vector was designed:

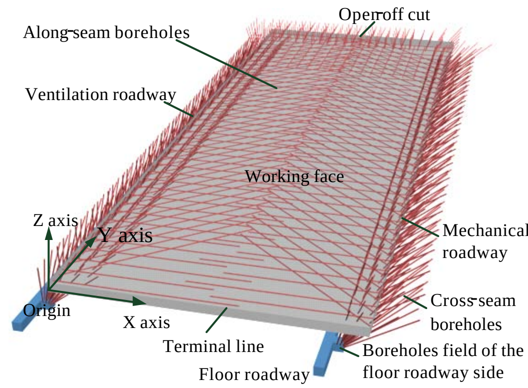

Fig. 1: Schematic diagram of coal gas pre-drainage project by cross-seam boreholes and along-seam boreholes

$$\vec{W} = (\text{id, coalname, name, width, length, thickness, inclination, origindepth, originelavation, originlatitue, originlongitude}) \quad (1)$$

where, $\vec{W}$ is working face vector; id is the identifier; coalname is coal seam name; name is working face name; width, length, thickness and inclination is the average width, length, thickness and inclination angle of the coal seam, /m; origindepth, originelavation, originlatitue and originlongitude is to describe related coordinate system and respectively records the cover depth, elevation, latitude and longitude of origin, /m.
Each borehole was rendered as a slender cylinder and could be described as the following vector:

$$\vec{D} = (\text{id, wfid, name}, x, y, z, \alpha, \beta, l, \phi) \quad (2)$$

where, $\vec{D}$ is the design vector; id is the identifier; wfid refers to the working face it belongs to; name records the borehole name string; x, y and z records the coordinate of drilling position, /m; α records the azimuth angle, /degree; â is the inclination angle, /degree; l is the borehole length, /m; ô is the inner diameter of borehole, /mm.

In correspondence with the design described in (2), the construction parameter can be recorded as vector:

$$\vec{D}' = (\text{id, bdid}, x', y', z', \alpha', \beta', l', \phi') \quad (3)$$

where, $\vec{D}'$ is the construction vector; id is the identifier; bdid refers to the identifier of its related design records in (2); the rest elements have the same means as design.

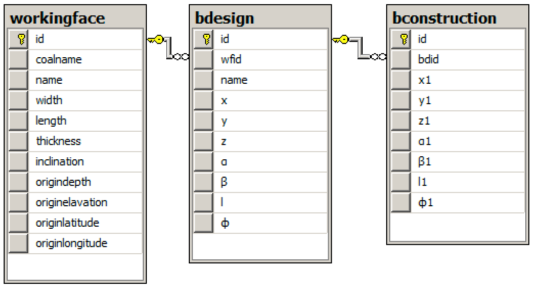

Fig. 2: Database model of BCDTracking

Therefore, background database could be designed as three primary data tables and two foreign key relations, as shown in Fig. 2.

TRACKING METHOD

Statistical process control chart has been successfully used in various industrial fields, such as petrochemical engineering, machinery manufacturing and electronic information, etc. It has been proved that rational control chart would significantly improve tracking and control ability of industrial process.

Principle of statistical process control chart: Running status of mainly all industrial process can be well reflected by inspective data series. They fluctuate under influence of random factors and system factors. The former cannot or needn't be controlled and the later leads to anomalies (Montgomery, 2008). Under stable status, the fluctuation should be slight and around its average and when anomalies emerge, the fluctuation may show three types of characteristics: break bound, chain and trend, as shown in Fig. 3.

According to statistical principle and wide practices, setting of three control limits, CL (Central Line), UCL (Upper Control Limit) and LCL (Lower Control Limit), has reached a consensus named as 3σ principle: UCL= $\mu+3\sigma$, CL= μ and LCL=$\mu-3\sigma$, where μ is the average and σ is the standard deviation of the data samples.

Among several types of statistical control charts, X-R_s is relatively suitable for coal gas pre-drainage project, in which value X is to track individuals fluctuation and the moving range R_s is to track fluctuation amplitude of the inspective data series . Assuming there are n data samples and the n-th sample marked as x_i, the average is:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{4}$$

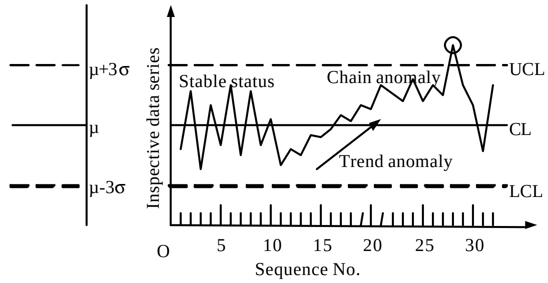

Fig. 3: Principle of the statistical process control chart

The range of adjacent samples is:

$$R_{si} = \left| x_{i+1} - x_i \right| \quad i = 1, 2, \cdots, n-1 \tag{5}$$

The average of R_{si} is:

$$\bar{R}_s = \frac{1}{n-1}\sum_{i=1}^{n-1} R_{si} \tag{6}$$

Inspective data series: Although there are many variables in the database of BCDTracking, several primary variables, x, y, z, α, β, l, φ of table bdesign and x1, y1, z1, α1, β1, l1, φ1 of the table bconstruction, are more primary to describe construction status and others are mainly used for assistant description. Further, x, y, z and x1, y1, z1 is to record construction coordinate and don't like to deviate; φ and φ1 is often constants determined by drilling machine. Thus, α, β, l and α1, β1, l1 composed the principle components.

To describe deviation between construction and design, the difference transformation was done as the following:

$$\begin{aligned} \Delta\vec{D} &= \vec{D}'_p - \vec{D}_p \\ &= (\alpha', \beta', l') - (\alpha, \beta, l) \\ &= (\Delta\alpha, \Delta\beta, \Delta l) \end{aligned} \tag{7}$$

where, $\vec{D}'_p$ is the principle components vector of $\vec{D}'$; $\vec{D}_p$ is the principle components vector of $\vec{D}$; $\Delta\alpha$, $\Delta\beta$ and Δl describes the deviation of azimuth angle, inclination angle and borehole length.

As time goes on, $\Delta\vec{D}$ forms inspective data series of coal gas pre-drainage project.

X-R_s control chart establishment: To establish X-R_s control chart, four steps must be done as following:

- Collect original data and save them into database as shown in Fig. 2
- Compute inspective data series through difference transformation illustrated in (6)
- Compute average μ and standard deviation σ of the individuals data series {X} and moving range data series $\{R_s\}$ and then gain CL, UCL and LCL
- In rectangle plane coordinate system, make serial number as X axis and individuals value of {X} as Y axis to draw X control chart;
- Make serial number as X axis and moving range value of $\{R_s\}$ as Y axis to draw R_s control chart

DEVELOPMENT OF BCDTRACKING

Based on background database and theoretical method elaborated above, the target software system named as BCDTracking, was developed by using .Net Framework 4.0 techniques.

Three-tier software architecture: In recent years, three-tier architecture was the most popular approach to develop complex software (Fowler, 2002) and has been widely successfully used in various industrial fields. It is a logical middleware located between user and database system, consisted of Data Access Layer (DAL), Business Logic Layer (BLL) and User Show Layer (USL). DAL is to transform database access into object operations, which encapsulates data operation details and satisfied demands of the upper layer. BLL, also named as domain layer, is the logical implementation of domain business such as rules, workflows and special demands, etc. BLL is located in the middle of three-tier architecture and is the most important layer that directly determines the system performance. USL that is composed of some user interfaces, also named as UI (User Interface) is to receive user demands, validate input, transfer data into system and feedback results.

DAL development: The main work of DAL is to encapsulate details of database operation into classes. For this, three classes, named as CWorkingface, CBDesign and CBConstruction, were implemented and abstracted from their common characteristics, base class, CDALBase was defined.

CDALBase included two virtual methods, reading() and saving(), which must be implemented in subclasses to read and save related data. It also included two protected properties that were datatable and currentindex. The former was the corresponding memory data table and the later was current index of this table.

The three subclasses were mainly the encapsulation of related database table. Meanwhile, they all implemented the virtual methods of base class, reading() and saving(), as shown in Fig. 4.

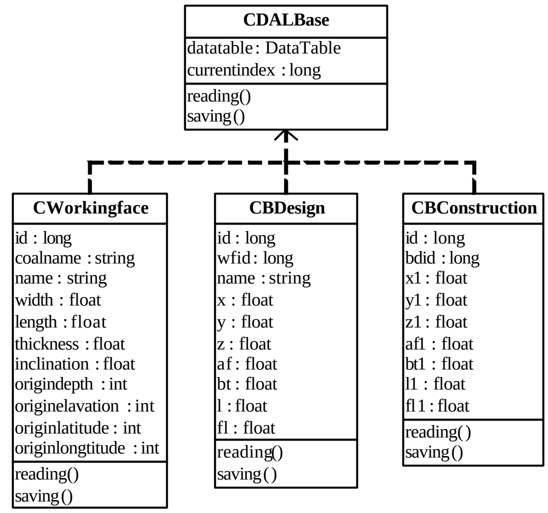

Fig. 4: Class diagram of DAL

BLL development: In order to track the construction quality of boreholes, BLL received user demands of upper USL and finished the following works:

- Call DAL to gain the original data and compute inspective data series
- Transform inspective data series into individuals data series {X} and moving range data series $\{R_s\}$
- Compute statistics, including the average μ and standard deviation σ of {X} and $\{R_s\}$ and then achieve CL, UCL and LCL based on 3σ principle
- Draw X control chart and R_s control chart;

As the same time, BLL also dealed with assistant data operations such as input, update, delete and export.

BLL was developed as an integrated class, in which each business was implemented in one method, as shown in Fig. 5.

In Fig. 5, properties workingface, bdesign and bconstruction are type of CDALBase to call DAL. Properties inspective, X and R_s are type of ArrayList to respectively store inspective series, individual series and moving range series. Properties avgofX, sdofX are the average value and standard deviation of X series and avgofRs, sdofRs are average value and standard deviation of R_s series. Properties chartofX and chartofRs are type of Image to store control chart of X and R_s.

Method readorgdata() is to read the original data by properties workingface, bdesign and bconstruction. Method computeins() is to transform the original data into the inspective data series that are stored in the property inspective. Method computeXandRs() is to compute individual series and standard deviation series that are stored in properties X and Rs. Method computesta() is to

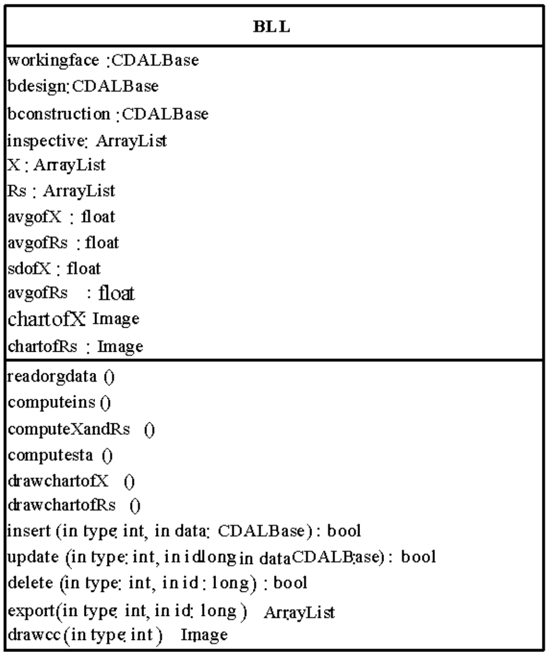

Fig. 5: Class diagram of BLL

compute related statistics that are stored in properties avgofX, avgofRs, sdofX and avgofRs. Methods drawchartofX() and drawchartofRs() are to draw control chart of X and Rs as two images that are saved in properties chartofX and chartofRs.

Methods insert(), update(), delete() and export() are to implement assistant data operations. Parameter type is used to distinguish types of CWorkingface, CBdesign and CBconstruction; id is the identifier of object; data is the content waiting insert or update; returns of insert(), update() and delete() are the status successful or failed; return of export() is the exported data list.

Among these Methods, readorgdata(), computeins(), computeXandRs() and computesta() were developed according to the theoretical methods illustrated above in this study and insert(), update(), delete() and export() were implemented through calling DAL, in which the well known ADO.net techniques were used and they wouldn't be described in detail here.

By contrast, drawchartofX() and drawchartofRs() have no direct components to use. For this, based on OWC (Office Web Components), a common drawing method for control chart named as drawcc() was developed as the following code (written in C#).

```
/// this method is to draw control chart based on OWC
/// input parameters type
/// 0 means X control chart; 1 means Rs control chart
/// return parameters is the control chart of Image
private Image drawcc(int type)
{
// gain data series and validate them
ArrayList arr = null;
if(type == 1) arr = this.X; else arr = this.Rs;
if(!datavalidate(arr)) return null;

// format data series to a1\ta2\ta3\t…
// format {a1, a2, a3, …} -> a1\ta2\ta3\t…
string[4] categories = null;
string[4] values = null;
this.format(ref arr, out categories, out values);

// initialize chart
Microsoft.Office.Interop.Owc11.ChartSpace
chartspace = new
Microsoft.Office.Interop.Owc11.ChartSpace();
Microsoft.Office.Interop.Owc11.ChChart
chart1 = chartspace.Charts.Add(0);
chart1.Type =
ChartChartTypeEnum.chChartTypeLineMarkers;
chart1.HasLegend = false;
chart1.HasTitle = false;
chart1.Axes[0].HasTitle = true;
chart1.Axes[0].Title.Caption = "time";
chart1.Axes[1].HasTitle = true;
if(type == 0)
chart1.Axes[1].Title.Caption = "X value";
else
chart1.Axes[1].Title.Caption = "Rs value";

// add four series: X or Rs, CL, UCL and LCL
for(int i = 0; i < categories.Length; i++)
{
chart1.SeriesCollection.Add(0);

// set category
chart1.SeriesCollection[0].SetData(
ChartDimensionsEnum.chDimCategories, (int)
ChartSpecialDataSourcesEnum.chDataLiteral,
categories[i]);

// set series value
chart1.SeriesCollection[0].SetData(
ChartDimensionsEnum.chDimValues, (int)
ChartSpecialDataSourcesEnum.chDataLiteral,
values[i]);
}

// export control chart to image as return value
string locpath = "\\cc.gif";
int w=600, h=600;
chartspace.ExportPicture(locpath,"GIF", w, h);
return Image.FromFile(locpath);
}
```

USL development: To satisfy excellent user experiences and simplify user operation, USL only contained several succinct and easy-to-use interfaces. Their functions involved working face data management (insert, update and delete), boreholes design data management, boreholes construction data management, control chart display and related data export. They were integrated in four corresponding menu items, as shown in Fig. 6.

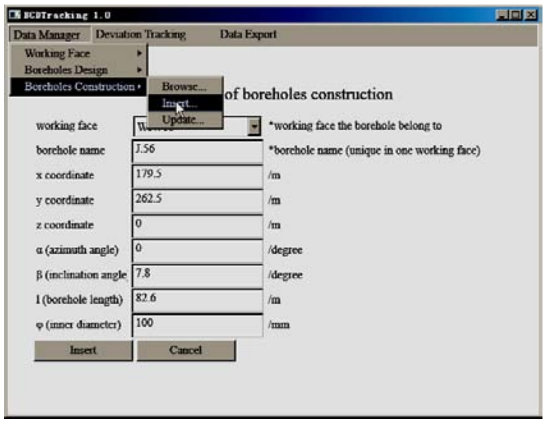

Fig. 6: Interface of boreholes construction data management

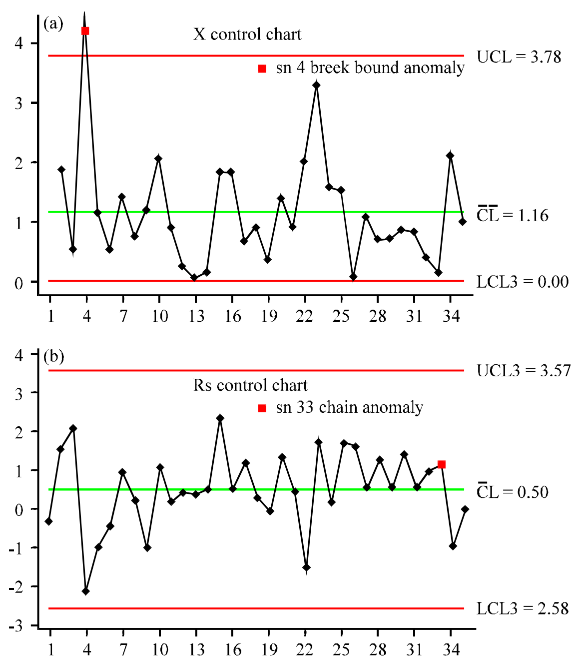

Fig. 7(a-b): Interface of boreholes construction deviation tracking

The kernel function, borehole construction deviation tracking based on X-R_s control chart, could be activated by clicking menu item Deviation Tracking, as shown in Fig. 7.

CONCLUSION

Based on statistical process control chart and automatic drawing techniques of OWC, a comprehensive tracking software system for boreholes construction deviation was developed and named as BCDTracking, in which the following works were accomplished:

- Database development. Taking working face as a whole to build spatial coordinate system, the data structure of boreholes was described as vectors and then database was established in SQL Server
- Tracking method. In order to describe borehole construction deviation, difference transformation between construction and design was done to gain inspective data series. Using X-R_s control chart, relevant statistics were calculated and control chart based on 3σ principle was drawn
- Software system development. Based on three-tier architecture, software system BCDTracking was developed. As system kernel, business logic layer involved the most important functions such as data process, statistics computation and control chart drawing

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REFERENCES

Cai, W.L., X. Gao and J.G. Ren, 2009. Computerized mine model in gand planning at Jiangxi copper company limited mines. Comput. Appl. Miner. Ind., 29: 179-182.

Cheng, Y.P., J.H. Fu and Q.X. Yu, 2009. Development of gas extraction technology in coal mines of China. J. Mining Safety Eng., 26: 127-139.

Duskey, M.R., 2006. Digital-control updates let old shovels give new models a run for their money. Eng. Mining J., 207: 66-69.

Fowler, M., 2002. Patterns of Enterprise Application Architecture. 1st Edn., Addison-Wesley Professional, UK., ISBN-13: 978-0321127426, Pages: 560.

Hou, S.J. and Y.W. Zhang, 2013. A novel algorithm for the coverage homogeneity analysis of along-seam boreholes in the coal gas drainage project. Energy Educ. Sci. Technol. Part A: Energy Sci. Res., 31: 1803-1812.

Hou, S.J., Y.W. Zhang and Y.P. Cheng, 2013. A computer aided design and simulation system for upward cross-seam boreholes. J. Applied Sci., 13: 2538-2543.

Liu, L. and F.B. Zhou, 2010. A comprehensive hazard evaluation system for spontaneous combustion of coal in underground mining. Int. J. Coal Geol., 82: 27-36.

Montgomery, D.C., 2008. Statistical Quality Control: A Modern Introduction. 6th Edn., John Wiley and Sons, UK., ISBN-13: 978-0470233979, Pages: 760.

SAWS, 2009. Coal and gas outburst prevention regulations. State Administration of Work Safety.

Samal, A.R. and P. Sarangi, 2001. Micromine in the world of mineral exploration and mining. Proceedings of the Indian Conference on Computer Applications in Mineral Industry, March 17-18, 2001, New Delhi, pp: 123-134.

Trenczek, S. and S. Wasilewski, 2008. Innovativeness of power supply systems, computer technologies and automation involved in technological processes of coal mining. Gas-Podarka Surowcami Mineralnymi-Mineral Resour. Manage., 24: 89-102.

Xiong, S.M., L.G. Wang, J.X. Huang and J.H. Chen, 2012. Parametric data model for underground mine 3D visual production management and control system. J. Centr. South Univ. Sci. Technol., 43: 273-277.