Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 84 (2014) 860 – 867

Procedia Engineering

www.elsevier.com/locate/procedia

“2014 ISSST”, 2014 International Symposium on Safety Science and Technology

Three-dimensional information acquisition and visualization application in goaf

LOU Shuhan[a,b,]*, YANG Biao[b], LUO Zhouquan[b]

[a]*Zhejiang Institute of Safety Science and Technology, Hangzhou 310012, China*
[b]*School of Resources and Safety Engineering, Central South University, Changsha 410083, China*

Abstract

Mastering the shape, size and variation of goaf is important to goaf disposal, disaster control and mining optimization. A method is presented to realize goaf precision monitoring and 3D visualization by cavity monitoring system (CMS). On this basis, Goaf 3D modeling, goaf-model visualization transmission and display based on network, visible calculation method of mining loss and ore dilution during actual mining, 3D blasting design of complicated boundary pillar during actual mining, dynamic monitoring of goaf, stability analysis of tunnel above goaf, 3D survey and analysis of tunnel destruction caused by goaf collapse, numerical simulation of goaf stability and all other related technologies are researched and applied by using numerical software and network. Results showed that 3D space information of goaf could be accurately acquired by CMS, and visualization application based on the information is reliable. These research and application are of great practical significance to recover mineral resources and assure safe mining.

Peer-review under responsibility of scientific committee of Beijing Institute of Technology

Keywords: goaf; CMS; visualization; numerical; simulation

1. Introduction

Goaf is one of the accident-prone zones in underground mining. 3D information of goaf such as shape, boundary and size are the basis of goaf management and pillar recovery[1-4]. Total station method, ground-penetrating radar

* Corresponding author. Tel.: 15382373966.
E-mail address: lucklsh-pisces@163.com

1877-7058

Peer-review under responsibility of scientific committee of Beijing Institute of Technology
doi:10.1016/j.proeng.2014.10.507

method and high density resistivity method are traditional means of goaf detection, but these methods can't be satisfied with the requirement of goaf safety analysis, goaf assessment, disaster forecast and goaf disposal[5-7].

Cavity Monitoring System (CMS) is a system based on laser, and can be used in goaf 3D precision monitoring[4,5,8]. In this paper, CMS, numerical software tools and network technology were used to generate 3d goaf model, which is of high visualization and well edit-ability. Furthermore, model information has been transmitted on the network and displayed in user computers by making use of web technology.

Base on 3d goaf model, the following techniques were studied: visible calculation method of mining loss, visible calculation method of ore dilution, 3D blasting design of complicated boundary pillar, dynamic monitoring of goaf, safety analysis of goaf roof-laneway, 3D survey and analysis of tunnel destruction cause by goaf collapse, and numerical simulation of goaf stability. Practice shows that the use of CMS to accurately obtain 3d goaf information is effective. Related visualization applications carried out on this basis are reliable enough, and it has important practical significance to the full recovery of valuable mineral resources and safe mining.

2. Goaf 3D information acquisition and visualization

There is the basic method: firstly, scanning the goaf by CMS to get mined-out area by software modelling 3 d entity model, and then transforming the 3 d entity model into web 3 d model that could be browsed by web through the network technology, the web browsing, lastly, designing web pages to browse model. So goaf 3d information acquisition and visualization could be realized. Steps are shown in Fig. 1.

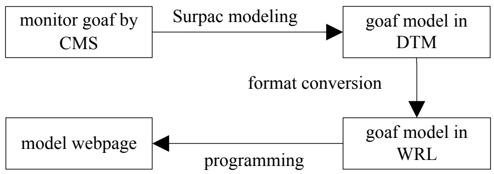


Fig. 1. Steps of goaf online visualization.

2.1. Goaf 3D information acquisition

CMS collects distances and angles of points by scanner of laser rangefinder, the scanner can rotate 360°.After completing a circle scan, the scanner automatically elevates its elevation to a number that set by operators, and continues rotating until all the survey points in goaf have been acquired. Monitoring results can be directly displayed in mine software, such as Surpac. Steps are shown in Fig. 2[8,9].

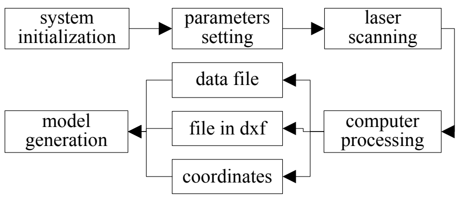
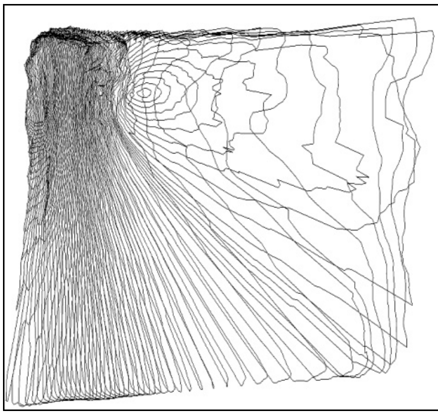


Fig. 2. Simple operation steps of CMS.

2.2. Goaf visualization based on measurement

Monitoring data created by CMS can be outputted in ASCII format, or converted to DXF format; this data can be used in generating 3D grid graph of goaf (Fig. 3) in CAD or solid model of goaf (Fig. 4) in Surpac.



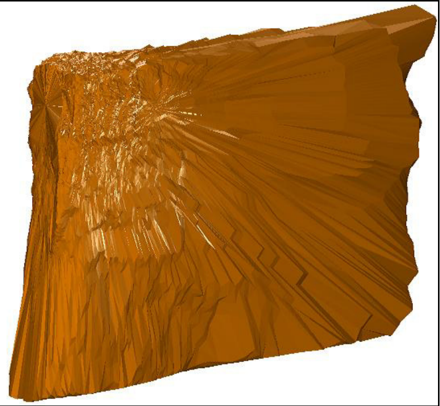


Fig. 3. 3D grid graph of goaf. Fig. 4. 3D solid model of goaf.

VRML is a new graphical description language developed by the International Organization for Standardization, it is used for 3D modelling and graphics rendering. Model generated by Surpac or Datamine can be defined by VRML and saved as wrl format in web server, user can browse goaf solid model online via Internet Explorer (Fig. 5). Goaf model data is transmitted to the user computer when browse the model at the first time, and it would take no more network flow during model browsing and human-computer interaction. This technology solves the problem that 3D model can be displayed only in mine software, which will play an important role in safety education, mine design and goaf disposal.

3. Application of goaf 3D-information

3.1. Visible calculation method of mining loss and ore dilution

With the help of CMS, mining loss rate and ore dilution rate can be accurate calculated based on CMS measured data and geological information of stope design. There are steps of calculation[10,11]: Firstly, model upper chamber, lower chamber, interface between ore and rock, fault, mullock in ore body and stope unit by 3d modelling software (such as Surpac). Secondly, do some Boolean operations between the models in order to generate over-excavated mullock model, under-excavated ore model and retention ore model. Lastly, calculate total mining amount, mined ore amount, mined mullock amount, retention amount, mining loss rate and ore dilution rate. S2 is a pillar stope in a mine and there are formation of retention 3D model (Fig. 6), visualization of under-excavated ore (Fig. 7) and calculation results of its mining index (Table 1)

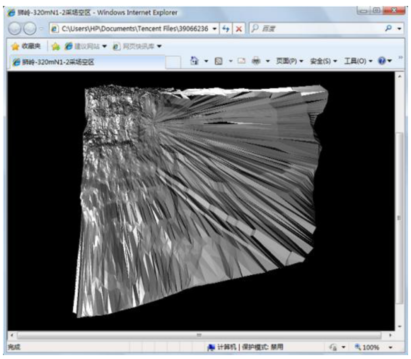


Fig. 5. Browse 3D solid model of goaf online.

Table 1. Calculation results of S2 mining index.

under-excavated ore/t	mined mullock /t	mined backfill /t	retention (backfill) /t	mined ore /t	total mining /t	ore dilution rate /%	mining loss rate /%
1696	2608	762	111	14178	17548	18.57	9.66

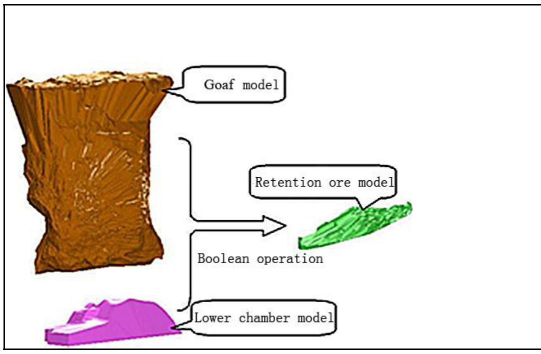


Fig. 6. Formation of retention 3D model.

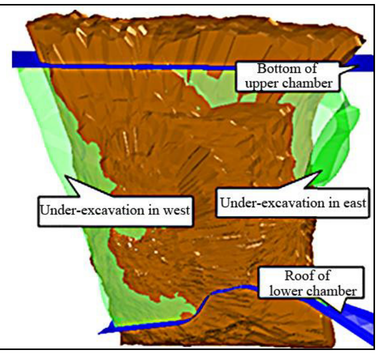


Fig. 7. Visualization of under-excavated ore.

3.2. 3D blasting design of pillar with complicated boundary

There are lots of factors such as blasting, deviation of design and construction, roof fall of goaf when mining rooms. These factors result a discrepancy between actual boundary and designed boundary[4,9,12]. If mining pillar in this time, it would lead to resource-wasting, dilution aggravation and life-threatening accidents[12]. Therefore, obtaining the actual boundary of pillar is the key to safe mining. The method is as follows:

(1) Survey room-goafs on both sides of pillar, then model them (Fig. 8);

(2) Model deposits, and combine it with room models (Fig. 9);

(3) Do Boolean operations between deposits model and room models in order to generated pillar mode (Fig. 10), then the actual boundary of pillar is determined;

(4) Make 3D blasting design of pillar in Surpac or other mine software according to the actual boundary of pillar.

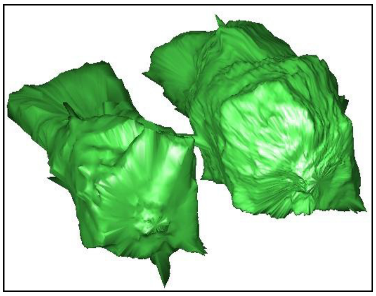
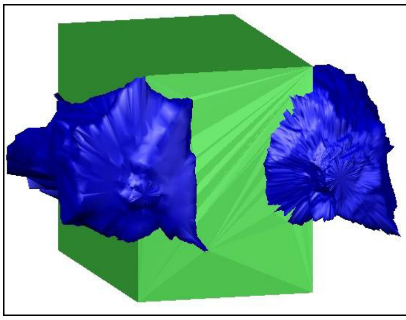


Fig. 8. Mined room 3D model.



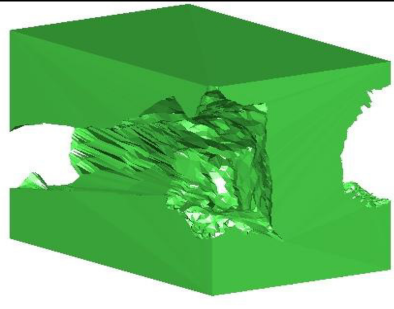


Fig. 9. Compound model of partial deposits and room.

Fig. 10. Pillar 3D model.

3.3. Dynamic monitoring of goaf

3D information of goaf in different periods can be acquired by CMS, dynamic monitoring of goaf would realized through contrast and analyse goaf model. As a result, changes of goaf can be shown. It's help to assess goaf safety and provide the key information of disaster prediction. There is a comparison among the last three monitoring (Fig. 11), it well reflects dynamic changes of goaf.

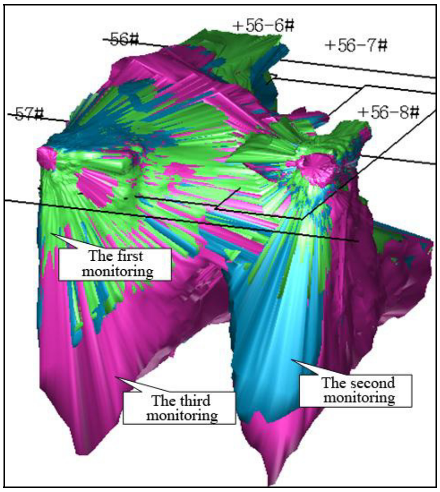


Fig. 11. Comparison among the last three monitoring.

3.4. Stability analysis of tunnel above goaf

Stability of tunnel above goaf can be assessed by comprehensively analyzing monitoring-data and other mine data[13]. Take 52-6# stope in a mine for example. What's shown in Fig. 12 is a compound model of designed stope and monitored goaf. It's easy to find that upper boundary of goaf is outside designed boundary. Draw a vertical section through the top point of goaf model (the top point is usually the most dangerous place), compare the section with designed section of blast (Fig. 13), and calculate the distance between the bottom of upper tunnel and the top boundary of goaf. Obviously, the distance is 2.8–5.9m. Goaf has endangered the upper tunnel, and it must be sealed to prevent injuries or death due to geologic failures.

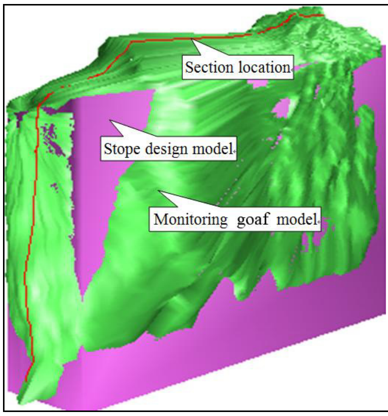


Fig. 12. Compound model of designed stope and monitored goaf.

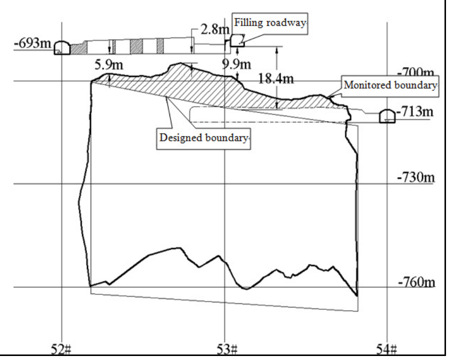


Fig. 13. Stability analysis of upper tunnel above goaf.

3.5. 3D survey and analysis of tunnel destruction cause by goaf collapse

Because of lacking monitoring means, it is difficult to assess the degree of tunnel destruction which is caused by goaf collapse in the past. Model tunnel in collapse area according to tunnel engineering information, and compare it with collapsed goaf model. As a result, accurate information of tunnel destruction will be well master. Take the goaf in a mine for example. It is nearby 21# line of -390m. Collapse of the goaf has lead to adjacent tunnel destroyed permanently. Make a comparison between goaf 3d model and tunnel 3d model (Fig. 14), there are conclusions:

(1) The volume of collapsed goaf is 177749.2m^3;

(2) Both tunnel adjacent to 21# line and tunnel adjacent to 23#line has been destroyed (Fig. 15);

(3) Collapse of tunnel adjacent to 23# line has caused the instability of east bottom rock, therefore, the zone between tunnel adjacent to east collapsed area and air-shaft in the end of tunnel is a danger zone;

(4) The boundary of collapsed area has reached 2# drill shaft, which means there is partial collapse in 2# drill shaft. And 1# drill shaft also should be seen as a danger zone for its closing to the collapsed boundary.

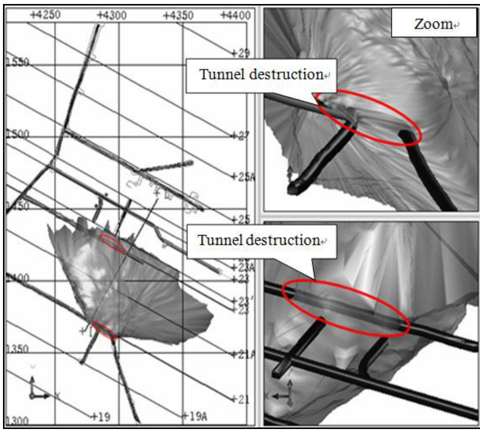


Fig. 14. Compound model of goaf and tunnel.

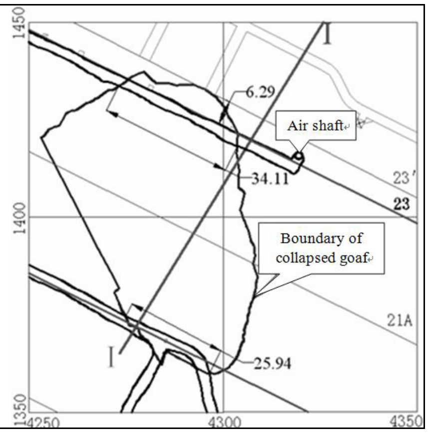


Fig. 15. The section of collapsed goaf in -386m.

3.6. Numerical analysis of goaf stability

A successful numerical analysis of goaf stability is based on the accurate mechanics model which can depict actual goaf shape and right locations. 3D information of goaf acquired by CMS is transferred into Surpac, then couple Surpac with Phase 2 (Fig. 16), FLAC 3D (Fig. 17) or other numerical simulation software. In this way, data of 3D geological model in Surpac can be imported to numerical model. The method simplifies modelling and meshing during simulation and improves the reliability of numerical simulation[6,9,14,15].

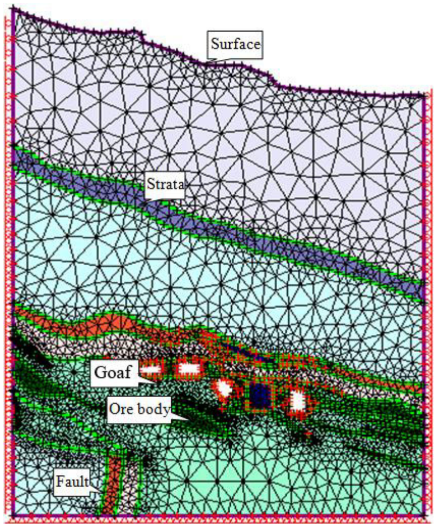


Fig. 16. Numerical model of goaf stability analysis in Phase2.

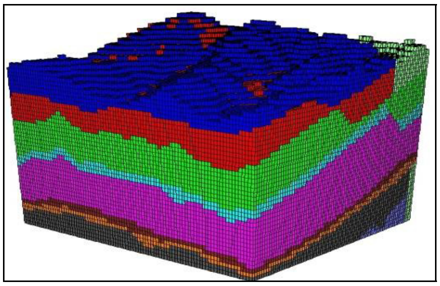


Fig. 17. Numerical model of goaf stability analysis in FLAC 3D.

4. Conclusions

(1) Cavity Monitoring System is an excellent technology in monitoring goaf. It can be used in acquiring space information of goaf, such as actual boundary, volume, 3d shape; et al. Visualization application based on the space information provides a new mind to develop mine technology.

(2) Goaf visualization transmission and display based on network was achieved by integrally using CMS, 3d modelling and network technology.

(3) Visible calculation method of mining loss and ore dilution during actual mining, 3D blasting design of complicated boundary pillar during actual mining, dynamic monitoring of goaf, stability analysis of tunnel above goaf, 3D survey and analysis of tunnel destruction caused by goaf collapse, numerical simulation of goaf stability are researched in the paper. They provide guidance for mine production and a reference method for further research.

References

[1] LUO Zhou-quan, LIU Xiao-ming, LUO Zhen-yan, et al. Geology automatic plotting based on secondary development of Surpac [A]. 2009 Second Asia-Pacific Conference on Computation Intelligence and Industrial Applications: Vol [4]. Wuhan: PACIIA, 2009:357-360.
[2] HU Jian-hua, RUAN De-xiu, ZHOU Ke-ping, et al. Identification and synergic use of operating environment safety based on structure effect of goafs in residual mining [J]. Journal of Central South University: Science and Technology, 2013,3(44):1122-1129.
[3] LYU Shuran, LYU Shujin. Research on governance of potential safety hazard in Da'an Mine Goaf[J]. Procedia Engineering, 2011, 26: 351−356.
[4] LUO Zhou-quan, LIU Xiao-ming, YUAN Wen-ni, et al. CMS Applications in Metal Mines of China [A]. 2009 Second Asia-Pacific Conference on Computation Intelligence and Industrial Applications: Vol[4]. Wuhan: PACIIA, 2009:353-356.
[5] XU Bi-gen, WANG Chun-lai, TANG Shao-hui, et al. Study on large goaf management and its monitoring scheme design [J]. China Safety Science Journal, 2007, 17(12): 147−151
[6] LIU Xiao-ming, CHEN Qing-fa, et al. 3D dynamic monitoring of collapse area based on CMS-Surpac [A]. Proceedings of 2009 2nd IEEE International Conference on Computer Science and Information Technology: Vol [4]. Beijing: ICCSIT, 2009:637-641.
[7] LIU Dun-wen, GU De-sheng, XU Guo-yuan, et al. Exploration study of gob filling by ground penetrating radar and its application[J]. Journal of University of Science and Technology Beijing, 2005, 27(1):13-16.
[8] Optech System Corporation. Cavity monitoring system wireless user manual [M]. Toronto: Optech System Corporation, 2004.
[9] LIU Xiao-ming, LUO Zhou-quan, SUN Li-juan, et al. Research and application of cavity monitoring system in China [J]. Journal of Xi'an University of Science and Technology, 2008, 28(2):215-218.
[10] LI Xi-bing, LI Di-yuan, ZHAO Guo-yan,et al. Detecting, disposal and safety evaluation of the underground goaf in metal mines[J]. Journal of Mining and Safety Engineering, 2006, 23(1):24-29
[11] SHI Lin-ke, LIU Hong-yi, Leng Yuan-bao. Application of high density resistivity survey in mined-out areas[J]. Journal of North China Institute of Water Conservancy and Hydroelectric Power, 2010, 31(5):122-124.
[12] FANG Zhi-heng, WANG Li-guan, XIONG Zhang-you. Mining Disturbance Analysis in Metal Mine Based on Micromine-FLAC3D Coupling Technology [J]. Journal of Mining and Safety Engineering, 2012, 6(29):870-874.
[13] Deng Qiao. Metal mine cavity instability analysis and measurement verification[D]. Changsha: Central South University, 2011.
[14] LIAO Qiu-lin, ZENG Qian-bang ,LIU Tong, et al. Automatic model generation of complex geologic body with FLAC3D based on ANSYS platform[J]. Chinese Journal of Rock Mechanics and Engineering, 2005, 24(6): 1010-1013.
[15] LUO Zhou-quan, WU Ya-bin, Liu Xiao-ming, et al. FLAC3D modeling for complex geologic body based on Surpac [J]. Rock and Soil Mechanics, 2008, 5(29):1334-1338.