Research on Mining Scheme Design Based on 3D Real Scene Model

Feifei Tang,1,*, Kun Wang2, Zhendong Leng2, Zhimin Ruan3, Cheng Shen1 and Yunyun Wang1

1School of Civil Engineering, Chongqing Jiaotong University, Xuefu Avenue, Chongqing, China 400074
2China Gezhouba Group Explosive Co.Ltd., C1 Saturn Business Center, No.2 Xingguang5th Avenue, Liangjiang New Area, Chongqing, China 401121
3China Merchants Roadway Information Technology (Chongqing) CO., LTD., Xuefu Ave., Chongqing, China 400067

*Corresponding author email: tangfeifei@cqjtu.edu.cn

Abstract. Reasonable mining scheme is of great significance for safety and efficiency of mining activity and environmental protection. In view of the limitation that the traditional mine surveying and mapping method can't provide accurate terrain data for the mining scheme design, moreover, the common mining design software can't be combined with the 3D real scene mining situation for scheme analysis and evaluation, this paper proposed a design method based on 3D real scene model by combining the UAV Remote sensing technology and 3D geographic information technology. This method can make the mining design agree with the demand of mining efficiency and environmental protection, improving the rationality of mining design.

Keywords: Mining scheme design; UAV remote sensing; 3D GIS; Mine surveying; 3D real scene model.

1. Introduction
A reasonable mining scheme is important for mining enterprises to ensure the safe and efficient production and protect the surrounding environment. The general method of mining scheme design is based on the topographic map and geological exploration data, then according to these basic data and the annual plan of mining volume, the appropriate mining sequence can be determined, finally, the vector data of mining design is created and stored by AutoCAD.

In the process of making mining scheme, the topographic map of mining district and the environment around the mine are important spatial reference information. However, there are two problems in the previous design methods. On the one hand, the topographic data acquisition mainly relies on the general surveying method, such as total station. In this way, the surface is represented by limited discrete points, the accuracy and integrity of the surface information are not enough, degrading the accuracy of the mining volume calculation in the scheme; on the other hand, mining design is usually carried out on vector topographic map, which is lacking of the intuitive visualization for natural environment impact assessment, reducing the rationality of mining design in environmental protection.

Due to the limitations of traditional design methods depicted above, scholars began to use 3D geographic information technology to provide more accurate terrain information and better visualization of the mine 3D environment for mining scheme design. The 3D real scene technology
mainly employs UAV (Unmanned Aerial Vehicle) remote sensing to obtain high-precision topographic map and 3D oblique model of the mine area. The UAV mapping method has been widely used to obtain large-scale topographic map of mine. It has been proved that even the requirements of high-precision mapping in complex topographic conditions can be met\[^{[1\text{-}3]}\], moreover, high-precision 3D model of mine area can be built\[^{[4]}\]. Compared with the traditional total station surveying method, it can obtain complete and much more accurate topographic information of the area. In addition to obtaining high-precision topographic map, the mining process can be monitored through UAV remote sensing. Li Dongqiang combined DOM (Digital Orthophoto Map) acquired by UAV and Google Earth data for detecting mining changes and vegetation damage range\[^{[5]}\]. Zhang Yuxia et al. obtained orthophoto images and 3D model by UAV oblique photography technology, calculating the area and volume of the pit and waste dump, achieving the purpose of environmental protection, supervision and management of mining activity\[^{[6\text{-}8]}\]. Li Chao etc. used the multi-phase DOM image of mine by UAV remote sensing technology and accomplished the mine reserves monitoring through ArcGIS spatial analysis function\[^{[9\text{-}11]}\]. In terms of digital supervision of mining progress, Zhang Bingbing etc. Combined UAV remote sensing technology with mine information management software, such as DIMENE to conduct digital management of mining progress and resource allocation\[^{[12\text{-}13]}\]. In addition, with the increased importance of the green mines construction, UAV remote sensing and 3D geographic information techniques have been gradually applied, providing support for geological disaster monitoring and environmental protection during the mining process\[^{[14\text{-}16]}\].

In the existing research, UAV remote sensing and 3D geographic information technology are widely used in the acquisition of terrain information, mining progress and environment monitoring, but for the design and decision-making of mining scheme, the advantages of 3D real scene model are still not fully utilized. In this paper, a 3D real scene design method is proposed for open-pit mining scheme design.

2. Method

2.1. Topographic Information Acquisition Based on UAV Remote Sensing Technique

The UAV remote sensing system collects the orthophotos or oblique images through the image sensor mounted on the rotor or fixed wing UAV platform, then the DOM (Digital Orthophoto Map), vector topographic map and high-precision 3D oblique model can be obtained through the stereo mapping and oblique modeling software.

In this paper, 243 orthophotos and 8423 oblique images covering 4.5 square kilometers open-pit mining area are collected by multi rotor orthophotography and oblique photography method. The ground resolution of the orthophotos and oblique images is 3cm and 5cm respectively. Through processing in pix4d, INPHO and context capture software, the DOM and and 3D real scene model of mine area are created and shown in Fig. 1 and Fig. 2. The contour map can also be obtained.

![Figure 1. The DOM of mine](image1)

![Figure 2. The 3D real scene model of mine](image2)

2.2. Analysis of Mining Status

In China, due to inaccurate terrain data on which the design scheme depends and the backward supervision technology of the mining process, the environment in some areas suffers from the illegal mining, some even result in potential geological disasters, destroying vegetation, threatening the safety of surrounding residents and natural environment. Therefore, adjusting the unreasonable mining behavior in time is demanded.
In this paper, the mining boundary is geographical referenced with the DOM to realize quick superposition of cross border mining. At the same time, it is found that the resource mining is not sufficient due to the unnecessary gap left between mining areas as shown in figure 3, about 300 meters gap exist between mining district 1 and district 2. In addition, the mining activity resulted in the geological hazard shown in 3D real scene model (Fig. 4). All the problems are due to the fact that the basic terrain information used in the design process does not agree with the actual scene accurately, leading to unreasonable situation during the mining scheme implementation.

Figure 3. Overlapping the DOM with mining border  
Figure 4. Potential hazards in mining activity

2.3. Mining Scheme Design Based on 3D Real Scene
In view of the adverse effect of traditional mining design method, a method based on 3D real scene model is adopted to adjust the unreasonable existing design. At first, the original two-dimensional vector design graph is transformed into three-dimensional polygons which meet the design requirements by AutoCAD and ArcGIS software. Then, in the 3D GIS platform, skyline, through the secondary development, the mining polygons can be imported into the mining scene and modified directly on the 3D mining model, and the terrain changes during mining process and the end of mining can be quickly visualized on this model, so that the designer can understand the impact of mining design on the surrounding environment intuitively and timely, and the mining volume in each stage can be calculated, too. These data and visualized information are necessary for scheme optimizing and adjustment. For the experimental area in this paper, according to the current mining topography, calculation results of mining volume and evaluation of natural environment, the original mining scheme of the three separate mining districts is finally adjusted to be combined to one continuous mining district (shown in Fig. 5). Moreover, the re green scheme can be designed on 3D real scene model (shown as Fig. 6). According to GIS spatial analysis and statistics, after mining scheme adjustment, the mining volume has increased 89%, and the re green area in mining districts and the whole area has increased 47.6% and 20% respectively (shown in Tab.1 and Fig.7).

Figure 5. Mining scheme adjustment result (the original design is shown as left figure, and the adjusted one is shown as right figure)
3. Conclusions
In this paper, UAV remote sensing technology is used to obtain high-precision terrain information and 3D real scene model of open-pit mine. Combined with 3D GIS platform, through secondary development, the mining scheme and 3D mining model are integrated. Then, the mining process, mining end and green restoration scheme are visualized on the 3D real scene model, additionally, the mining volume and green restoration area are analysis quantitatively. Different from the the traditional mining design method, the whole design process is developed on the 3D real scene model directly, which effectively assists the rationality evaluation of the mining scheme, and can provide much more conducive reference to the green mines construction.

Acknowledgement
This research is financially supported by Science and Technology Research Program of Chongqing Municipal Education Commission (Grant No. KJQN201900728), Basic Research and Frontier Exploration Project of Chongqing (Chongqing Natural Science Foundation) (Grant No. cstc2018jcyjAX0515), Special project of national key R & D plan subproject (Grant No. 2019YFB2102503).

References
[1] Zou Yuezhong. Application of UAV oblique photography technology in large scale topographic map survey of Mines [J / OL]. World nonferrous metals, 2019 (23): 42 + 45.
[2] Xie Meixiu, Tao Dandan. Application of UAV aerial survey technology in mine topographic mapping [J / OL]. World nonferrous metals, 2019 (20): 45-46.
[3] Zhang Kaixing, Xiao leirui. Application of UAV oblique Photogrammetry in mine surveying and mapping [J / OL]. World nonferrous metals, 2019 (20): 50 + 52

[4] Shahbazi, M., Sohn, G., Théau, J., Ménard, P. UAV-based point cloud generation for open-pit mine modelling. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 2015, 1W4, Vol.40(lof1): 313-320.

[5] Li Dongqiang, Xu Xianqing. Rapid mine monitoring by UAV aerial survey combined with Google Earth [J]. Jingwei tiandi, 2015, (4): 51-53.

[6] Zhang Yuxia, LAN Pengtao, Jin Yuanchun, Zhou Lin, Cui Yaoyao. Practice and exploration of UAV 3D oblique photography technology in open pit mine monitoring [J]. Mapping bulletin, 2017 (S1): 114-116.

[7] Shi Wenfang. Mining monitoring research based on UAV photogrammetry technology [J]. World nonferrous metals, 2018 (02): 60-61.

[8] Zhang Minxia, fan Gaolin, fan Donglin. Study on monitoring of open pit mining based on UAV low altitude photogrammetry [J]. World nonferrous metals, 2016 (17): 73-74.

[9] Li Chao. Application of UAV photogrammetry technology in dynamic monitoring of mine reserves [J]. World nonferrous metals, 2018 (02): 23-24.

[10] Tang Jian. Research on Application of UAV photogrammetry technology in dynamic monitoring of mine reserves [J]. World nonferrous metals, 2018 (13): 30 + 32.

[11] Tian Pengfei, An Tao. Research on the application of UAV aerial photography technology in the verification of mine reserves [J]. World nonferrous metals, 2019, (17): 137139.

[12] Zhang Zhonglei, Zhang Bingbing, Fang Xiang, et al. Construction and implementation of UAV production scheduling command system in opencast quarry [J]. China mining, 2019, 28 (9): 67-73.

[13] Zhang Bingbing, Yu Hong, Zhang Zhonglei, et al. Practice of digital fine management in open pit mining and stripping construction [J]. Gold science and technology, 2019, 27 (4): 621-628.

[14] Wang Gengming, Zhu Junfeng, Chen Jie, et al. UAV dynamic monitoring of green mine construction in quarry -- Taking Taizhen quarry in Guangzhou as an example [J]. Geological and mineral mapping, 2019, 35 (3): 29-30, 51.

[15] Liu Cong, he Yueguang, Chen Shuai, et al. Application of UAV mapping in land reclamation of an bauxite mine [J]. China manganese industry, 2016, 34 (1): 52-54.

[16] Lisiecka Ewa, Motyka Barbara, Motyka Zbigniew, Pierzchała Łukasz, Szade Adam. Possibilities of surface waters monitoring at mining areas using UAV. E3S Web of Conferences, vol. 36, April 9, 2018, BIG 2018 - 4th Nationwide Scientific Conference on Engineering-Infrastructure-Mining.