Application of 3D Laser Scanning Technology in Inspection and Dynamic Reserves Detection of Open-Pit Mine

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Abstract. The traditional open-pit mine mining rights verification and dynamic reserve detection means rely on the total station and RTK to collect the results of the turning point coordinates of mining surface contours. It resulted in obtaining the results of low precision and large error in the means that is limited by the traditional measurement equipment accuracy and measurement methods. The three-dimensional scanning technology can obtain the three-dimensional coordinate data of the surface of the measured object in a large area at high resolution. This paper expounds the commonly used application of 3D scanning technology in the inspection and dynamic reserve detection of open mine mining rights.

1. Introduction
At present, the mining rights verification and the dynamic reserve detection of the open-pit mine are based on the means that measures the turning point coordinates of mining surface contours through the total station and RTK, so the accuracy of the measurement is too low, and the information of the coordinates is too little. The results are mainly based on the coordinates of the turning points to build model, resulting in low accuracy and being impacted easily by human factors, thus the final results have more interference. Three Dimensional Laser Scanning Technology, also known as "real copy technology", is a high-speed laser scanning measurement method, which has fast access to three-dimensional coordinate data of the surface of the measured object with large-area and high-resolution [1]. Therefore, mining rights verification and dynamic reserves detection of open-pit mine can use three-dimensional scanning technology [2].

2. 3D laser scanning mine verification process
According to the area, surface, mining surface and other characteristics, three-dimensional laser scanner station location and the number of stations are planned. The original station scattered point cloud can be gained after the completion of the field work.

After the above pretreatment work, the obtained point cloud data can be used for GIS analysis, such as transboundary analysis, resource reserves calculation and other results. Open-pit mine three-dimensional laser scanning technology process is shown in Fig.1, the main point cloud GIS analysis results are shown in Fig.2.
3. Three-dimensional laser scanning mine verification work

The three-dimensional laser scanner pilot work takes a limestone mine in Chongqing as an example. Scanning instrument is the Leica C10 three-dimensional laser scanner. The main processing software is Cyclone7.0, Map3D, and ArcGIS10.0.

3.1 Point cloud preprocessing

Open pit mines generally have more ups and downs and dense stones. Excavators work together, resulting in three-dimensional laser scanner’s narrow perspective, and resulting in station-intensive station. Open-pit mine layout of three-dimensional laser scanner station should follow the principles below:

1), the vision of station field should be larger, which can cover a larger area, with the scanning surface angle closer to 90° better;

2), the station should be arranged in a more stable area, around no large equipment operations or artificial stripping operations;

3), the station should have common characteristics, such as poles, signs and so on.

Results analysis needs the entire mine as the object, so the various sites point cloud data should be stitched into a complete point cloud. The Scanning adopts the method of no target and station with free way, and it should be noted that the stations must contain a common point between the cloud points, the outside work takes a short time, but inside work would take long time to stitch point cloud of characteristics. Such as limestone mine have a number of security warning signs around the layout, which can be used as a common point between the stations cloud. The characteristic points are shown in Fig.3.

Point cloud can be stitched through the [Create Registration] tool of the Cyclone software. Point cloud stitching can be divided into small parts to stitch, and then the larger parts into a whole point cloud. Point cloud stitching should pay attention to the error column value size of [Constraint List], which shows the two stations point cloud compliance, generally about 0.02m. If the value is large, it should be needed to re-find the characteristics of objects re-stitching.
After stitching, a complete original point cloud is gained, as shown in Fig.5. There are some obstacles in the original point cloud that do not belong to the mine itself, such as staff, vehicles, equipment, and the point cloud trajectory caused by these objects during the scanning process, which need to be removed manually[3].

Free local station mode needs to convert the local coordinate system to Xi’an 80 coordinate system. The coordinates of two or more points should be collected by using RTK at the same time, shown in Fig.6. Due to the same vertical direction of two coordinate system, the scale factor is consistent, it only need to give a rotation factor and basis elevation. The entire point cloud coordinate system is converted to Xi’an 80 coordinates through the Cyclone software [Set Coordinate System from Pick Points] tool. The basic available point cloud data for open-pit mine can be accessed by above preprocessing steps.

It is necessary to convert point cloud data which is too large to process directly in ArcGIS into a raster image, the raster image stores coordinates as pixel location and elevations as pixel color. Map3D software is used to convert the gray scale image, because ArcGIS does not provide good support for point cloud data file conversion. Using the [MAPPOINTCLOUDMANAGER] command to load the point cloud file. Using the [MAPSURFACEMANAGER] command to generate, as shown in Fig.8. The blue line is determined by the two mining boundaries, red line for the mine management department to provide the mine turning point coordinates.

Using the [Extraction] tool in the ArcGIS [Spatial Analyst] tool to extract the elevation gray scale in the excavation boundary extracted in the previous section as a mask to facilitate the subsequent analysis. The first time scan of the TIN digital elevation model is generated by the [Export Raster] tool in the ArcGIS [3D Analyst] tool. Fig.9 is a TIN top view of the excavation boundary after the first time scan.
Using the ArcScene software to open the above generated TIN digital elevation model file, through the [Export TIN] tool to get the scope of the boundary of TIN, according to the scope of the boundary elements of the polyline elevation, stretching the surrounding boundary, the elevation of basic polygon feature should be set 510m. Fig.10 shows the TIN model for the first 3D laser scanner, with the bottom boundary being the lowest mining point (510 m). The total volume of the model is the total remaining amount currently in the current excavation area.

3.2 Transboundary analysis
The current mining boundary is determined according to Fig.8. As shown in Fig. 9, the east side step has been beyond the boundaries of the application area. The maximum value exceeded is 29.8m after the measurement, blue area is dug, and the red area is filled. The color red and blue staggered at the east and north sides of the mine, the elevation has not changed, so the step did not change. The conclusion is that the mine has crossed the border but did not continue.

Fig.12 shows the superposition of the TIN and the lowest mining plane. Obviously, the mining surface has a great distance between the lowest mining plane (510m). The lowest mining elevations of two times were 557m, 547m, vertical space is 37m from lowest mining plane after the measurement. So in the vertical direction is not exceeded.

3.3 Resource reserves calculation [4]
Using the [raster calculation] tool in ArcGIS [3D Analyst], scanning changes in the raster image has been obtained with the two elevation gray scale subtraction, through the raster image, we access to the elevation difference TIN map, As shown in Fig.13. the elevation difference TIN map with the same pond, white for the water, then no elevation changes, white below has been excavated area, the deeper the color, the deeper the dig by configuring the tone. It can get the data cut or filled through [Cut Fill] tool in [Raster Surface] toolset. Fig.14 shows the excavation volume, blue indicates the excavated area, and red indicates the unexcavated area. After the statistics, the total area of the two excavations is 39250m2, the resource reserves in using is 256203m3, the average excavation depth is 6.5m, and the deepest excavation depth is 20.7m.
3.4 Step analysis
According to the design requirements of the given slope, such as mining slope angle of the limestone mine is 55 °, the slope of the mining area symbol system to "classified" way, as shown in the red area is 55 ° or more area. In this way, it is possible to quickly judge whether the slope angle of the open pit is in compliance with the requirements.

3.5 Profile
Using the [3D Analyst] tool to obtain a profile of the corresponding position which required, as shown in Fig.16. With elevation or slope as the data source, we can quickly get the required elevation profile and slope profile, elevation distribution of the section line in elevation profile can be saw intuitively.
Figure 16 Mine elevation profile

3.6 Other results
Contours can be obtained with opening the front generated elevation gray scale and setting the contour distance through [Contour] tool in [Raster Surface] tool, then it generate contours automatically, it can be exported to CAD format for the other software to use[5,6] after some other labeling.

4. Conclusion
Through the three-dimensional scanning of the open pit mine, three-dimensional laser scanner method can achieve the open-air mine cross-border determination, step height, width, mining slope analysis, the use of resource reserves calculation, TIN numerical elevation model (three-dimensional model), contours and other results. At the same time we can obtain the following conclusions:

1. High precision. As three-dimensional laser scanner method is to obtain all the information on the surface and the traditional means of measurement is to obtain the contours of the transfer point according to the vertical section method (the mine is divided into multiple sections, cross-section between the ladder, truncated cone or pyramid to estimate) to estimate dynamic reserves, so the accuracy is superior to traditional means of measurement.

2. Good intuition. In the traditional measurement concept, the data obtained by the final output are two-dimensional form of the results, but with the development of digital mines, three-dimensional management model has gradually replaced the two-dimensional, because the two-dimensional results are difficult to accurately describe mine key information.

3. Rich results. Three-dimensional laser scanning technology is the mine surface of the full point of information, so to obtain more rich than the traditional means of the results, such as open-air mine anywhere in the direction and direction of the section, and open-pit mine three-dimensional model.

5. References
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