A Study on the Application of 3D Laser Scanning in the Deformation Monitoring for Open-pit Mine

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ABSTRACT: Deformation monitoring is a work to provide reliable data and a scientific basis for gaining knowledge and mastering the evolutionary process, catching the characteristic information in time and making a correct analysis, evaluation, prediction and control. New technology plays an important role in this research and application. In this paper, the basic principle and features of the 3D laser scanning are introduced, and the feasibility of its application in the deformation monitoring for open-pit mine is analyzed throughout a deformation monitoring case in Fushun City, China. Some unique advantages of this technology are illustrated compared with the traditional methods, such that it can fast acquire dense data with more detail information. Also it provides data in 3D visualization to make the research into a more visible way. In this article, we present the general processing flow from data acquisition to the final results, especially the information extraction based on point cloud. Some of the factors influencing the measured results are discussed based on on-site tests, including precision, registration and sensitivity. The monitoring results indicate that 3D laser scanning is a new suitable method to perform the qualitative analysis and quantitative research for deformation monitoring. It attributes to the research and application by providing a supplementary method for the real-time monitoring. It can be anticipated that the 3D laser scanning will be a very effective research tool for deformation monitoring and the health diagnosis for the land slide of open-pit mine.

KEYWORDS: 3D laser scanning, deformation, monitoring, mine

1 INTRODUCTION

Deformation monitoring is a daily work in open-pit mine for a safe working environment. Current monitoring based on GNSS and Total Station is the most popular method in open-pit mines. With the development of new technology in the past decades, 3D laser scanning has played an important role in modern surveying and mapping industry. It is called a revolutionary technology to make the measurement from single point to plane. It not only records the information of coordinates, but also the intensity and the real texture of the real world. So 3D laser scanning is also called Reality Recovery. It has many applications such as territorial surveying and mapping, culture heritage protection, architecture, road survey, and some monitoring on dams and high buildings[1-5].

In the daily work of construction and management, a serial of survey needs to be done, which includes topographic survey, checking and accepting survey, slope survey, waste dump survey, ore heap survey, deformation and displacement survey, Mined-out area survey, survey for underground pipeline and constructions. Due to the particularity of open-pit mine, the traditional measuring instruments have been unable to meet the efficiency and precision of the current open-pit mine surveying and mapping requirements. 3D laser scanning is a new technology with fast development in the past years. It is a non-contact measurement to acquire data in a fast way for complicated environments and target objects. With the advantage of fast data acquisition, high accuracy and comprehensive information including coordinates, intensity and texture, 3D laser scanning is considered a revolutionary technology to change surveying from single point to surface. It brings new opportunity and challenge for the monitoring theory and technology in open-pit mine.

Supported by a grant from the Major State Basic Research Development Program of China, the team in Spatial Information Engineering Research Center in Peking University has carried out some research on the 3D laser scanning in different applications. Led by first author, the research team has made a series of trials about the applications of 3D laser scanning in deformation monitoring and obtained some significant results. Herein some application results obtained from Fushun west open-pit mine are presented. Fushun west open-pit mine is the biggest one in Asia with a history of near one hundred years and now is still under operation. The long-time mining has resulted in many geological disasters such as slope landslide. In this paper, we used 3D laser scanning technology to do the deformation monitoring in 2013 to research the usability and suitability of this technology. Herein the partial application results obtained from this case study are presented.

2 A CASE STUDY

2.1 The Project Scheme

2.1.1 Selection of the scanner

Based on many experiments and according to the on-site environment, we chose RIEGL VZ-1000 3D Terrestrial Laser Scanner in this case study. The VZ-1000 provides high speed, non-contact data acquisition using a narrow infrared laser beam and a fast scanning mechanism. High accuracy laser ranging is based upon RIEGL's echo digitization and online waveform processing, which enables good measurement performance even during adverse environmental conditions and provides multiple return capability for the area with vegetation coverage. The VZ-1000 is suitable for the applications of topography, mining, as-built surveying and monitoring. The specifications of RIEGL VZ-1000 are show in Table 1[6].

Table 1 Specifications of RIEGL VZ-1000 scanner

Parameters	Specifications
Scanning Range	up to 1400m
Measurement Rate	122000 measurements/s
Laser Class	Class 1
Accuracy	8mm@100m
Precision	5mm@100m
Field of View	100° x360°
Data Transmission	LAN/WLAN
Weight	9.8 kg

2.1.2 Installation of the scanner

In light of the deformation of the open-pit mine and the accuracy of long distance scanning, the scanner is installed on the surface of a concrete ground with following configurations:

(1) The chosen scan area is on the south slope of the open-pit mine. And not far away from the south of the slope, there is a resident area. The scanner is placed on a concrete ground in south of the slope, which is a stable area from the deformation and is safe for operation. It has been ensured that the site is not affected by the deformation area. A ground point is marked and used for the scanner to be installed on for the two scanning in different months.

(2) Although the scanner has a maximum scanning range up to 1400 meters, we put the scanner about 300 meters away from the slope. Since the accuracy of the scanner is 5mm at 100 meters, it is better to install the scanner not too far from the slope as the accuracy of laser measurement is reduced as the distance goes far. To guarantee the accuracy for result, it is necessary to control the scanning distance within the monitoring requirements.

(3) The scanner is installed on a position with the full view to the target slope. With the 100° x360° field of view, RIEGL scanner can capture data just form one station. One station scanning not only means less on-site time and high proficiency, but also reduces the registration error for multi-stations.

2.2 Data Acquisition

To make a good representation of slope, we chose a dense full-dome scanning model to acquire data with the resolution of 2cm at 100 meters, which means the distance between two adjacent points is 2cm at the distance of 100 meters away from scanner. The full-dome mode captures all the data except a small blind spot under the scanner. At this resolution, one single stations of scanning generates about 1.47G point cloud data in ASCII format (*.xyz). Beside the full-dome scanning data, we also have a detail scan for some features on constructions in the nearby resident area. The purpose for detail scan is to have a more precise automatic registration in data processing.

Besides the coordinate information, we also use the external digital camera to capture image for texture mapping for a better further information interpretation based on point cloud with true color.

Since the information we need in deformation monitoring is the relative change of the slope in two different time, it is not necessary to transfer the coordinate system to an absolute coordinate. We use the scanner's internal coordinate for the two scans in different month.

2.3 Data Processing

The scanning data is acquired in November and October in 2013 respectively. The data processing includes several steps such as registration, noise reduction, vegetation reduction, and generate the mesh grid. First step is registration, which is to merge the multi-station data to a unified coordinate. There are several methods to do the registration and there are a lot of research on the theory and accuracy. Normally, there are two kinds of registration: one is based on public targets, which is use the common points in both scan stations to calculate the parameters of coordinate transform. Another method is based on point cloud, without any public targets. The ICP (Iterative Closest

Point) method is an iteration close point algorithm , which are often used in point cloud to point cloud registration. [7][8]

In our study, registration is done in RIEGL's incidental software RiSCAN PRO by Straightforward Global Registration function. Some feature points are chosen to improve the calculation. The internal registration accuracy is within 2cm.

The second step is to delete the noise data which is not necessary for the analysis and may affect accuracy of the result, especially the vegetation on the ground. Vegetation on the slope must be removed in data processing because it will result in negative effect on the accuracy of analysis. Vegetation reduction is also done in RiSCAN PRO software by its internal function, because REIGL scanner has the multiple return capability which enables it to capture ground points crossing the vegetation.

After having the unified data and clean the noise, we import the data in some professional 3rd-part software to do the related qualitative and quantitative analysis for deformation monitoring.

3 ANALYSIS OF THE DEFORMATION

3.1 The Qualitative Analysis

To make a qualitative analysis of the slope deformation in two different phase, we import the pre-processed data in to Geomagic software to generate two mash grids and put them together. Here we use a method called chromatography, which calculates the difference of the two phase in a visual way by giving different color according to the changed value. Normally the warm color describes the positive change and the the cold color describes the negative change, and the deeper the color is, the bigger the change is. Fig. 1 shows the result of the change in two different time. From the color we can intuitively see that in the observation period, most area of the slope has change and has subsidence of about more than 2 meters.

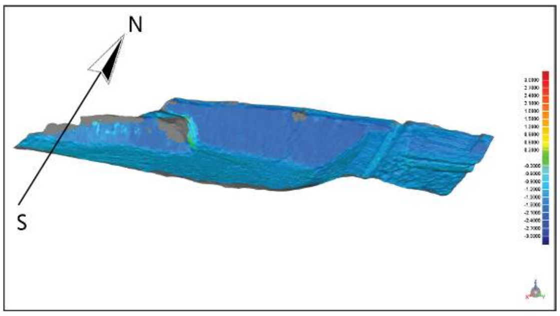

Figure 1 Deformation by chromatography method

3.2 The Quantitative Analysis

To make a quantitative analysis of the slope deformation, we import the point cloud data to Cyclone software. First we generate mesh grids based on point cloud. Fig. 2 shows one mesh grid we make. The color on the mesh is assigned according to the height. Then we put the two mesh grids together, and make profile cut lines according to the South-North direction.

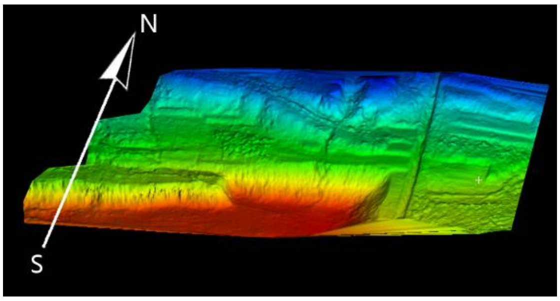

Figure 2 Mesh grid based on point cloud

We make three cut lines on the two mesh grids from a selected ground point and the interval for the cut lines is 50 meters. The cut line profiles are showed in Fig.3, which are generated from South-North direction. In each graph, the above line refers to the data of first time and the below one is the second time. The unit of grid in Fig.3 is 1 meter.

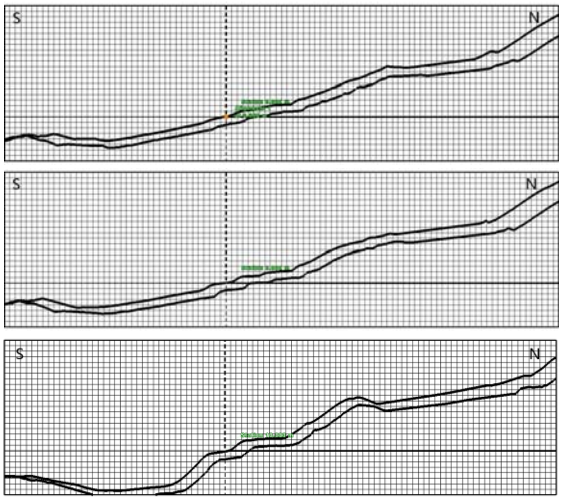

Figure 3 S-N profile cut line of slope in two phase

From the profile cut lines we can clearly see that, from the south to the north, the slope deformation becomes bigger in vertical direction. This means that the south area is stable and the north of the slope has drastic change. In the north of the slope, the deformation reaches more than 2 meters. This result is consistent with the observed value by a GNSS receiver on site. By this method, we can make profile cut lines in any point with any direction, to find the overall deformation of the slope. And the changed value can be calculated in a detail quantitative way.

One issue needs to be discussed is the monitoring accuracy of the 3D laser scanning. The accuracy is affected by some factors such as the instrument's measuring accuracy, the registration and modeling. We cannot change the accuracy of measuring and modeling, but we can improve the registration. According to our research and experience, the current accuracy for slope monitoring based on long-range scanner is about 5cm-10cm. Hence it is suitable for slope with an obvious deformation.

Another issue to be discussed is the timeliness of this technology for monitoring. Due to the dense scanning, the scanned mass data of point cloud is time consuming for the data processing. Also some pre-processing is not totally automatic in computer such as the noise reduction. It needs artificial intervention for a precise and correct result. Compared with traditional methods, 3D laser scanning is not a real-time monitoring. It relies on the development of science and technology to improve the data processing in the future for a real-time monitoring and an early prediction.

4 CONCLUSIONS

According to the case study of deformation monitoring based on 3D laser scanning, we verify the usability and suitability of this new technology. As illustrated in the paper, deformation monitoring by point cloud from 3D laser scanning has distinguishing features such as fast data acquisition, high accuracy and total digitalize processing. It can record the real world very fast and provides a new method in monitoring by totally changing the way of measurement from single points to surface. An important thing to emphasize is that 3D laser scanning is a trend monitoring, not a real-time monitoring, so currently it is a good supplementary method to traditional way for a comprehensive and accurate analysis of deformation. With the unique technical advantages and with the improvement of this technology, 3D laser scanning technology will be a trend in the future to provide support for modern deformation monitoring in open-pit mine and other related applications.

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