Status and development trend of 3D laser scanning technology in the mining field

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***Abstract*—3D laser scanning technology to a complete and high-precision reconstruction scan physical and quick access to the raw survey data, the most important feature is high precision, fast speed, approaching the prototype, has been widely used in various fields of mapping and other. In this paper, based on the three-dimensional laser scanner application elaborated on the basis of the domestic situation, and focuses on the application in the mining field, including: 3D reconstruction and measurement of open pit, headframe deformation monitoring, mining subsidence monitoring, construction land reclamation regulatory, difficult arrival region survey of coal gangue dump, landslide monitoring, deformation monitoring of underground mined area. Finally, the five aspects of the future development trend were forecasted and analyzed.**

***Index Terms*—3D laser scanning technology, mining field, status, development trend.**

I. INTRODUCTION

3D laser scanners have been more than a decade of history in the country, has gradually become a new mapping technology has been widely used. In the mining sector in recent years, some scholars related applied research has yielded some results. Briefly on the basis of three-dimensional laser scanning technology development status is summarized in the mining areas of environmental monitoring application status, and the last to make a few forecasts of future trends.

II. DEVELOPMENT STATUS OF 3D LASER SCANNING TECHNOLOGY

3D laser scanning technology, also known as virtual replication technology, capable of complete and high-precision reconstruction scan physical and quick access to the raw survey data, the most important feature is high precision, fast approaching the prototype. A wide variety of three-dimensional laser scanner and, in general, the entire scan and the data processing process is similar. The different characteristics of various scanners odometry range, scanning the field of view, scan rate, ranging accuracy, angle measurement accuracy. Production company: Switzerland, Leica, United States Trimble, Faro, Canada's Optech, Topcon Corporation, Japan, Austria Riegl company.

3D laser scanner in a wide range of applications in the field of surveying and mapping, engineering survey applications include measurement and modeling of complex industrial equipment, ribbon, and local topographic surveys, road measurement, large-scale civil engineering shape measurement, deformation monitoring[1]. Also in the preservation and restoration of historic buildings, based on the application of reverse engineering, industrial and medical measurement, disaster assessment and disaster mitigation applications, create 3D city models and other fields has been a certain application.

3D laser scanning technology, especially hardware technology is relatively backward, but has also been some preliminary results. As early as in the 1990s, the Institute of Remote Sensing Applications, Chinese Academy of Sciences, Professor Shukai Li presided study airborne line scan first principle prototype is currently being further improved and perfected. Wuhan University in 2000, Professor Qingquan Li presided over the development of terrestrial laser scanning system, but not integrated directional system, mainly for accumulation of measurement. In 2008, Beijing General Research Institute of Mining and Metallurgy deformation monitoring for underground goaf mine application independent research and development with our own intellectual property downhole the empty district deformation monitoring of a three-dimensional laser scanner [2]. Guangzhou Hi-target Satellite Navigation Technology Co., Ltd. to produce homemade HD LS 300 3D laser scanner prototype in November, 2012.

III. APPLICATION STATUS

For three-dimensional laser scanner in the field of mining, in recent years, some scholars related applied research, research, classified in accordance with the application direction summarized as follows:

(1) 3D model reconstruction and measurement of open pit. The use of 3D laser scanner to scan the entire surface mine, the three-dimensional model can be applied to the extraction of contour lines, section lines, the top of the hill line, slope bottom line; production accounting; analysis of the rock formations, coal layer height. Rich point cloud data not only for measuring the effective guarantee, more mines digitized, mine design, blasting a three-dimensional real. Application of full digital three-dimensional laser scanning technology to carry out the opencast mines measurement work significantly better than traditional mine surveying technology, the

opencast mines Geological Survey, the most effective, most efficient, most economical and safest technology means.

Some scholars to do research: Qisan Duan to Haerwusu opencast coal mine as the research object, the Leica 3D laser scanning instrument HDS 8800 in the open air mining aspects of data acquisition, process flow, using software to quickly build data mode, generate DEM, and access to the open pit three-dimensional model[3]. Jian Li and et al three-dimensional laser scanning, has occurred in two large-scale landslides in Coal Pingshuo East open pit slope based on comprehensive improvements the ICP Algorithm completed open pit slope of about 2km three-dimensional model reconstruction [4].

(2) Application of headframe deformation monitoring. The local details of the measurement of the 3D laser scanning technology for large area or surface complex of objects measuring its objects, and calculate the target surface, volume, cross-section, the cross-section, contour mapping personnel to break through the traditional measurement technology to provide a new data access means. Xiaoyang Huang and et al applications such as Trimble GX 200 terrestrial 3D laser scanner on a mine in Shandong frame derrick point cloud data acquisition. First scanning program design, denoising acquired point cloud data filtering and scanning accuracy test, followed by the center of the target plate fitting coordinate analysis of the vertical deformation of the derrick, and finally by plane fitting equation analysis derrick tilt deformation. The results show that relative to traditional measurement methods, the three-dimensional laser scanner point cloud data can better analysis of the headframe overall deformation, mine derrick safety measure to provide an efficient, high-precision method [5].

(3) Applications of mining subsidence monitoring. For the study of the surface caused by mining subsidence, the traditional approach has the following disadvantages: limited by surface conditions, difficult cloth Station; measuring points difficult to maintain a serious lack of measurement points in the observation process; observation of a heavy workload, less access to data. Scholars to conduct research, made some achievements in this regard have been, are: Shu Zhang and et al according to the characteristics of the three-dimensional laser scanning technology to analyze the feasibility of mining subsidence monitoring. 3D laser scanner observations, ground subsidence caused by mining can get the sinking value of the entire region, the movement and deformation of the entire monitoring area can be obtained by setting part of the fixed points, to obtain the level of mobile value. Using three-dimensional laser scanning mine subsidence monitoring is fully capable of ensuring the efficiency to meet the accuracy requirements [6].

Dawei Zhou and et al three-dimensional laser scanning and RTK combine to form a new surface movement observation station and a new method for mining subsidence surveying. Accuracy analysis shows that the combination of the two is feasible to establish mining subsidence observation station, cloth Station, data acquisition and processing methods, and comparison with the conventional observation station, new observation stations with cost savings, time, high efficiency, Get more amount of data, and difficult maintenance of the measuring point and the lack of the Fengfeng mine as an example to test the usefulness of this method [7].

Zhengquan Xing and et al with the Trimble GX 3D scanning system simulation test results show that three-dimensional laser scanning technology in mining subsidence monitoring its accuracy fully meet the observation needs. Subsidence surface model to get a scan, calculate the volume of surface contour drawing. Time lag were collected twice data modeling treated to import the same project, the use of the paired surface monitoring software tools, analysis of the two measurements of the resulting surface model, resulting in subsidence surface subsidence difference and the sinking value of the area at any point or any line sinking further analysis [8].

In addition, Huayang Dai and et al based on 3D laser scanning technology is proposed application houses feature point extraction mining area housing movement and deformation method, and through error analysis theory and direct access to the data and the accuracy of the data calculated indirectly evaluate the three-dimensional laser scanning, the results show its accuracy meet the housing movement and deformation monitoring requirements. The application of three-dimensional laser scanning data, analysis of mining area housing movement and deformation of guiding significance Safe Mining village houses. 3D laser scan data to provide a reliable basis for the analysis of the relationship between of housing deformation and surface subsidence [9].

(4)Construction land reclamation regulatory. 3D laser scanner provides important technical means of the measurement of the land, compared with the conventional measurement, it has an intuitive image data, measurement data can not be change audit convenient. Zengfeng Li application of three-dimensional laser scanner somewhere homestead reclamation and mine reclamation field scanning test study results show that: the image of a rich visual data analysis model is intuitive, do not have to field reconnaissance will be able to make the managers of reclamation plots at a glance, immersive feel truly aware of, and can effectively prevent and put an end to fraudulent happens, and calculating the actual reclamation area and directly on the picture, the main management department also no longer need complex field measurements of cultivated land, saving administrative costs, and accelerate the document review, the progress of the review and acceptance, improve the quality of the work of the review and acceptance, realize the full regulation of all reclamation projects, reached the area of real, quality assurance, comprehensive supervision, do not fall out of this whole thing, the purpose of the standard operation [10].

(5) Difficult arrival region survey of coal gangue dump. The waste dump vegetation recovery calculation of the amount of work involved in the project, most of the need to rely on the accuracy of the information provided preliminary topographic maps, due to the waste dump, there are many artificial unable to pole set point of the fracture surface and

slope the steep geographical (called difficult and regional), so that the traditional measurement methods difficult to carry. The application of three-dimensional laser scanning technology, give the mining area is difficult to bring about a new way to reach the area administered. Shuang Liang encounter abandoned mine gangue hill steep facade area is difficult to measure the data points to Beijing abandoned mine waste dump steep facades for instance, using a three-dimensional laser scanning technology, a difficult and regional steep facades scan measurements, including industry good 3D reconstruction, and the amount of earthwork slope statistics by design, provide the scientific data support the planning and design staff in waste dump, greatly accelerating the waste rock Mountain region as a whole of the progress of the mapping and planning [11].

(6) Landslide monitoring. The use of GPS monitoring and surveillance of the landslide in China's major disaster area of the landslide body weight. The disadvantage is that the long period of observation, to be embedded and fixed point on the surface, only observing the displacement of the surface of a finite number of points, and must reach the observation point to be able to obtain the observed data, workload, and sometimes very difficult. Terrestrial 3D laser scanner is another after following GPS space positioning technology mapping technology innovation, and provides a new alternative program for landslide monitoring. Guoliang Zhao and et al such as Berlin coal mine select four Chuanda bamboo Bureau of Mines for the study, a long-term monitoring of landslide hazard caused by the western mining area due to coal mining, comparative analysis of the data measured by conventional measurement methods, that the three-dimensional laser scanner can acquire The complex terrain three-dimensional surface array geometry data, the reaction surface movement of the landslide area special law [12].

(7) Deformation monitoring of underground mined area. For underground goaf deformation, traditional rock internal deformation monitoring using multi-point displacement meter, drilling inclinometer means empty area (including roadways) deformation monitoring roof settlement gauge convergence gauge extensometer, and Level, theodolite and other surveying methods and means. Traditional the deformation monitoring methods exist to the point of observation, observation data less unable or difficult to monitor the unmanned space area artificial observation, inefficient, labor-intensive and timeliness, not quantitative observations goaf caving shortcomings. Kai Chen and et al developed underground goaf 3D laser scanning deformation monitoring system, including three-dimensional laser scanning measuring instrument, the mined-out area of the measuring probe inserted into the device, the underground laser scanning controller, underground goaf monitoring real-time data transmission to the surface communication systems and surface monitoring system. The system can achieve remote monitoring of Inoue, real-time control of three-dimensional laser scanner by sending instructions can be scanned, scanning the empty point cloud data can be uploaded to a remote monitoring system through the communications system. The scan control the scan sequence can be divided into axial priority scan and radial priority scan, the standard stride scan and adaptive step away from scan can be divided in accordance with the step angle changes. Through the VTK build three-dimensional visualization environment, it is possible to achieve the 3D point cloud data translation, rotation, scaling, color settings, wireframe mode, three-dimensional reconstruction, volume calculations [13].

IV. DEVELOPMENT TREND

3D laser scanner has been in a number of areas of the domestic application of its own, there are many shortcomings, such as: (1) The basic price of the instrument in 1million yuan, it is difficult to meet the ordinary demands; (2) instrument and precision the calibration difficult single calibration method, the reference value to strike a complex, poor accuracy evaluation; (3) point cloud data processing software is not unified, each manufacturer has its own software, incompatible; (4) accuracy, ranging contradictory relationship with the scan rate. Based on these inadequacies, to forecast the development trend of the future three-dimensional laser scanner as follows:

(1) Accompanied by the continuous improvement and development of three-dimensional laser technology, as well as three-dimensional control information needs increase, the three-dimensional space technology and modern classical measurement technology merging, the new space as a means of data collection, the three-dimensional laser scanning technology has broad development of new technical means to become a widespread application in the field of surveying and mapping, will bring new opportunities for the development of surveying and mapping disciplines.

(2) Further improve the hardware, the laser scanner has higher accuracy and faster sampling speed, and low price. Further expand the scan range, the full sphere scan, display measured scene space is three-dimensional virtual entity. Integrated camera, scanned images of objects to improve the accuracy of point cloud data and image matching. I believe can be widely used in precision engineering measurements and industrial measurement, I believe will continue to expand new areas of application.

(3)Further improve and develop post-processing software, so that the greater amount of data processed faster data processing, software easier to operate. Point cloud data processing software utility and multi-functional, real-time data sharing and massive data processing. In particular, the localization of the three-dimensional modeling software should also be strengthened.

(4) Three-dimensional laser scanner localization precision instrument developed with independent intellectual property rights. Total station and GPS receiver can go the path of development, I believe that the localization of the three-dimensional laser scanner in the near future, and gradually occupied the domestic market, will play an important role in the popularization and application of the 3D laser scanner. Another instrument calibration and application of national standards as soon as possible.

(5) 3D laser scanning technology is used in a variety of mining work will be a challenging task, and I believe that will be applied in many ways. Will have broad application prospects, 3D laser scanners underground goaf in mining subsidence monitoring deformation measurement and security monitoring applications is a three-dimensional laser scanning technology industry-specific applications, miniaturized, portable, long-range, high-precision, sturdy reliable is the development trend of the technology in the underground mine, safety monitoring applications.

V. CONCLUSION

Based on 3D laser scanner elaborated on the basis of application of the domestic situation, mainly on the application in the mining industry, including: open pit 3D reconstruction and measurement, headframe deformation monitoring, mining subsidence monitoring, supervision of construction land reclamation, coal gangue difficulties in the mountains and regional mapping landslide monitoring, deformation monitoring of underground mined area. In addition, the five aspects of the future development trend were forecasted and analyzed. We believe that the near future of 3D laser scanner in the field of mining depth to provide some measure of protection for the construction of digital mine.

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