Application of Ground-based 3D Laser Scanning Technology in Engineering Surveying

Xue Ting, Li Ting, Ni Jiahui

Xi'an Eurasia University, Xi'an Shaanxi, 710065

Abstract In this paper, the technological process of fixed ground-based 3D laser scanning technology in practical production of engineering survey is introduced, and application methods of the technology in topographic map surveying and mapping, earthwork calculation, road surveying, 3D modeling and other aspects are systematically discussed. Meanwhile, the paper summarizes the advantages and disadvantages of this technology compared with traditional surveying and mapping methods, discusses the application direction and prospect of ground-based 3D laser scanning technology in the future¹¹, and provide a reference for the application of this technology in urban engineering surveying.

1 Introduction

3D laser scanning technology is a technological revolution after GPS technology in the field of surveying and mapping. It breaks through the traditional single point measurement method and has the unique advantages of high efficiency and high precision. As a new high-tech product, 3D laser scanner has been successfully applied in many fields requiring surveying and mapping, like surveying and mapping of buildings, topography, mining, factories, large structures, pipeline design, aircraft and ship manufacturing, highway, and

railway construction, tunnel engineering, bridge reconstruction and so on. Furthermore, 3D scanning has unique advantages in the surveying and mapping of special-shaped surface and structure, especially the measurement of size, area, and volume. ¹¹,

At present, the Ground-based 3D Scanning Technology is much more popular among researchers and data collectors. As a new measurement method, it has also been widely used in surveying and mapping field in domestic and abroad.

Figure 1 data principle of 3D scanner

2 Classification and Principle of Ground-based 3D Laser Scanning

Ground-based 3D laser scanning technology can be divided into a fixed laser scanning system and a mobile laser scanning system according to the measurement method. A fixed laser scanning system, similar to the total station in traditional measurement, consists of a laser scanner and control system, a built-in digital camera, post-processing software, and so on. However, different from the total station, the fixed laser scanner does not collect discrete 3D coordinates of a single point, but a series of "Point Cloud" data. It is characterized by wide scanning range, high speed, high precision, and good field operation. The mobile laser scanning system is based on the vehicle-mounted platform, which is composed of the Global Positioning System (GPS) and the Inertial Navigation System (IMU) combined with the fixed 3D laser scanning system.

The core principle of 3D laser scanning technology is laser ranging. The working process of 3D laser scanning is a process of repeated data acquisition and processing. From obtaining the laser intensity received by the scanning reflection, the color grayscale of the scanning point is matched. Fixed ground-based 3D laser scanning technology is widely used in the field of engineering surveys, mobile equipment is still in the experimental development stage, so this paper focuses on the application of a fixed Ground-based 3D laser scanner.

3 Application of fixed 3D Laser Scanning in Engineering Measurement

The text The application of ground-based 3D laser scanning technology in the field of engineering survey can be divided into four aspects: topographic map mapping, earthwork calculation, completion survey, and 3D modeling. Its main workflow includes four parts: preparation before scanning, point cloud data acquisition, point cloud data registration, point cloud data processing (denoising, simplification, editing), and application.

Prepare before Scanning. Firstly, the surroundings of the survey area are investigated to determine the position of the scanner and the target. These scanning stations have to ensure that the acquired data can represent the complete measurement area. Meanwhile, the scanning station should be as few as possible to reduce the amount of original data. When Scanning the ground objects and special terrain in the survey area, taking pictures at the same time will be convenient for data processing and topographic map editing and modification in the later stage.

Figure 2 field data collection site

Acquirement of Point Cloud Data. Each station carries out a fine scan of 3-4 targets to determine the center point of the target. Meanwhile, the Reflectorless Total Station is used to accurately measure the 3D coordinates of the target center in the construction coordinate system, which can be used for the registration of subsequent multi-station data. The target should be evenly distributed and at a moderate distance from the scanner.

ScanWorlds Constraints			Constraint List		ModelSpaces	
Const...	ScanV...	ScanV...	Type	S...	Ve...	Error
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.006 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.000 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.000 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.003 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.003 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.003 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.003 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.000 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.003 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.003 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.002 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.000 m
Cloud...	Statio...	Statio...	Cloud: Cloud/M...	On	1.0000	0.001 m

Figure 3 Internal coincidence accuracy of point cloud data mosaic

Registration of Point Cloud Data. Registration requires the setting of control targets in different scanning areas so that there are no less than three control targets with the same name in the adjacent scanning point cloud data, which can be used for the coordinate of point cloud data in the different areas. Registration is divided into relative and absolute two ways. The relative mode is based on the coordinate system of a certain scanning station, and the coordinate system of other stations is converted to the coordinate system of this station. The absolute mode combines scanner and conventional measurement. The target coordinates of each station are accurately measured by the total station or other instruments, and the absolute coordinates of the target (such as coordinates in the engineering coordinate

system) are directly obtained. During registration, each measurement station is directly converted to the unified absolute coordinate system11,.

Figure 4 Point clouds before and after registration

Point Cloud Data Processing. The processed point cloud data can be applied in topographic map mapping, irregular volume calculation, road completion survey, 3D modeling, and other engineering surveys, which will be discussed below.

Figure 5 Cloud data import AutoCad

3.1.Application in Topographic Map Mapping

During topographic mapping, areas that are difficult to reach by conventional surveying and mapping methods, such as cliffs and broken walls, can be mapped by laser scanning technology through contact-free means. The main process of topographic map mapping is as follows: based on point cloud data processing, feature points like ground objects, topography, and other elements can be extracted, and then edited to form a topographic map.

3.1.1.Extraction and Drawing of Ground Objects.

Feature Extraction is to manually extract corner points of houses, center points of telephone poles and other points from the processed point cloud data by processing software after using 3D laser scanning. After output in a certain format, it is imported into large-scale digital mapping software to draw ground objects.

3.1.2.Generation of Contour Lines.

It's mainly used to remove data of vegetation, ground objects, and other non-geomorphic parts. With the elimination method combining automatic and manual, the average surface iteration method is adopted, that is, the obvious non-geomorphic data is first eliminated, and then the average surface is calculated using all the data. The data that is far away from the average surface is eliminated¹¹, and then the average surface is calculated,

and the relatively accurate geomorphic data will be obtained after repeated iteration for about 5 to 6 times.

Compared with the ground contour obtained by the traditional method, the contour obtained by the 3d laser scanning technology has higher accuracy, stronger reliability, and can more truly show the details of the actual landform.

3.1.3.Editing and Mapping.

Due to the local loss of contour line in the deleted geomorphic point cloud data, the phenomenon of local loss, distortion, and unsmoothness of the contour line is caused, so the relationship between contour line and other features of the topographic map needs to be edited and processed. Overlay ground object graphics and contour graphics, compare photos and point cloud data, edit and adjust manually. Finally, add the annotation to generate the outline and finish the drawing.

The ground-based 3D laser scanning technology is adopted to improve the topographic map surveying and mapping, can reduce the work intensity of field data acquisition, and get the detailed topographical features, however, its industry point cloud data processing workload is bigger, moreover, there is no integrated platform for collecting, editing and mapping at the same time, which makes the efficiency of this method not significantly improved compared with the conventional topographic map mapping method¹¹.

3.2.Application in Earthwork Calculation

In the field of engineering surveying and mapping, earthwork calculation is mainly achieved through the application of GPS RTK, total station instrument, level instrument, and other instruments to map the three-dimensional coordinates of the characteristic points of the uneven surface and build TIN calculation. The disadvantage of this method is that it requires a large number of scattered points to be collected in the field, which requires a large amount of work, large sampling intervals, and low precision. The fieldwork intensity can be reduced and the settlement accuracy can be improved by surveying and calculating earthwork volume with ground-based 3D laser scanning technology.

The main process of ground-based 3D laser scanning technology for earthwork calculation is as follows: based on map point cloud data processing, the datum level is firstly constructed, then ground objects are removed, and finally, DEM is generated and earthwork is calculated.

3.2.1.Building a Datum.

After the point cloud data processing is completed, it is converted to the engineering field coordinate system, which is usually carried out by the least square method. The accuracy of conversion depends on the accuracy of control points, target center fitting, and data stitching. Before the earthwork calculation, the design elevation and boundary should be used to build the starting datum, and the scanning point cloud should be cut¹¹. A general

datum is a plane with fixed elevation, but in some special engineering, surface datum should be built according to the requirements.

3.2.2. Ground Feature Removal.

Similar to the removal of non-geomorphic data in topographic map mapping, the point cloud data taken from the application of base plane cutting were removed.

3.2.3. DEM Generation and Earthwork Calculation.

The point cloud which has eliminated the non-essential data is used to establish the TIN of irregular triangular network, generate the high-precision digital elevation model, and then subtract it from the base level model to calculate the filling and excavation quantity.

The earthwork calculation process of ground-based 3D laser scanning technology is as follows:

The advantage of ground-based 3D laser scanning technology lies in that it can quickly acquire 3D point cloud data and reduce field mapping workload. The data collection density is high, so the earthwork calculation precision is high, which can meet the requirements of various earthwork calculations. It can not only complete the traditional earthwork calculation and the balance elevation calculation efficiently but also play a great role in the engineering calculation of variable datum or curved datum. For example, in a project, it is necessary to calculate the amount of earthwork to be filled and dug according to the data of the designed road¹¹.

First of all, the surface model of the designed road is constructed by using the designed road longitudinal and transverse data, road redline data, and slope data. Then the outdoor scanning data should be used to build the ground model on the field. After the coordinate transformation, the two models should be subtracted to calculate the amount of earth to be filled and dug.

3.3. Application in Road Completion Measurement

The most important work of the road completion survey is to obtain the road sample and longitudinal and transverse sections. Using the traditional method, it is necessary to map the road elevation point by point with the instrument such as level, which not only has a large outdoor workload but also does not have a high degree of automation in the indoor data processing. It can reduce the intensity of outdoor work and improve the efficiency of fieldwork by nearly 4 times.

The main workflow is as follows: based on point cloud data processing, coordinate system conversion is carried out first, and 3d coordinates of required points are extracted from the point cloud at certain intervals, contour lines are automatically generated, and road sample diagrams and vertical and horizontal faults are drawn.

Ground-based 3D laser scanning technology is applied to the road completion survey, which greatly improves the work efficiency and reduces the outdoor

labor, compared with the conventional operation mode, and the measurement data accuracy is excellent¹¹. Moreover, a large number of point cloud data are collected by this technology, and the topographic map, longitudinal and transverse section diagram and contour map formed after processing can truly reflect the change rules of elevation, which has obvious advantages over the traditional method.

3.4. Application in 3D Modeling

At present, ground-based 3D laser scanning technology, with its ability to build fine 3D models, has been more and more widely used in the work of cultural relics protection.

Through contact-free measurement of cultural relics' surface, high-density point cloud data, and three-dimensional model construction, 3d laser scanning on the ground can restore the detailed features of cultural relics, realize the measurement of arbitrary points and sizes, and do no damage to cultural relics.

Its main workflow is modeling and texture mapping. Based on the point cloud data processing model, there are mainly two ways, one is by point cloud data to construct the triangle mesh model, according to the requirement of modeling of a fine degree of point cloud data density degree, and to consider a triangulation can run independently and display in the software, at the same time orthogonal projection as the number of triangulation data should have enough texture information. The second way is to use 3DSMAX to model according to the point cloud data and draw the profile of the rule shape with the scanned point cloud data to produce the rule model that meets the accuracy requirements.

Texture mapping is the key to realize the sense of the reality of the 3D model. Using the digital camera mounted on the scanner to obtain texture information, and then carry out texture mapping on the surface of the building model¹¹. To make the texture look real and beautiful, it is necessary to correct, scale, and match the acquired texture image.

4 Conclusion

3D laser scanning technology is one of the most advanced technologies to obtain 3D spatial data in the world. As a beneficial supplement to the traditional surveying method, this technology can obtain the ground object information without contact, high density, high precision and fast, greatly improving the work efficiency of outdoor surveying and mapping, and has a good application prospect in engineering surveying.

However, as far as its current application is concerned, there are still some shortcomings. Firstly, the development of 3D laser scanning technology is not long, the introduction of domestic time is relatively short, and the instrument is expensive, the large-scale application situation has not been formed, the application in various fields is still in the exploration; Secondly, there is no unified verification standard for various rotation shafting

differences of the instrument, and the correction system of 3d laser scanner is not perfect, so the scanning result error is difficult to define. Thirdly, the ground-based 3D laser scanner obtained a large amount of data, internal industry processing software and hardware requirements are high, the existing data processing software lack of unified standards, poor compatibility, and point cloud data automatic identification ability is limited, the industry processing cycle is long, heavy workload.

Therefore, in the future, 3d scanning technology can seek breakthroughs in the following aspects: First, the development of a domestic 3D laser scanner.

Develop high precision instruments with independent intellectual property rights to reduce the cost of the instrument; The second is to formulate technical standards for 3D laser scanning. Speed up the formulation of the applicable standard and verification standard of the technology in surveying and mapping, improve the calibration system of a 3D laser scanner¹¹; Third, the construction of 3D laser scanning data processing platform. It is compatible with all kinds of scanning instrument data, realizes automatic and fast processing of point cloud data, and supports its application in various fields of surveying and mapping.

About the author

Xue ting (1979.09-), female, han nationality, born in taiyuan shanxi province, master candidat, associate professor, research direction: engineering management

Li ting (1991.12-), female, han nationality, born in xianyang, Shaanxi province, master candidate, assistant engineer, research direction: building informatization and intelligence

Ni jiahui (1999.11-), female, han nationality, born in jinhua, Zhejiang province, research direction: Real estate development and management

Mailing address: xi 'an Eurasia college, middle section of dongyi road, xi 'an, shaanxi, 13572195349

References

1. Robert J Stone. Virtual reality: toys or tools of the trade[J]. Aslib Proceedings, 1993:167-181.
2. Per Christiansson. Building Management And ICT Learning In Civil Engineering Education[J]. Computing in Civil Engineering, 2005: 1-12.
3. Idris Othman, Yasser Yahya Al-Ashmori, Yani Rahmawati et al. The level of Building Information Modelling (BIM) Implementation in Malaysia[J]. Ain Shams Engineering Journal, 2020
4. Daniel Paes, Javier Irizarry. A Usability Study of an Immersive Virtual Reality Platform for Building Design Review: Considerations on Human Factors and User Interface[J]. Construction Research Congress 2018: 419-428.
5. An Improved Point-to-Plane Registration Method for Terrestrial Laser Scanning Data. Tao W, Hua X, Yu K, et al. IEEE Access. 2018
6. Jiang Xue-zhi, LI Zhong-hua. Research status of virtual reality technology at home and abroad[J]. Journal of Liaoning University of Technology, 2004(02): 238-240.
7. Wang Kaiying, Liao Mingjun. Discussion on the application of virtual Reality technology in civil Engineering teaching[J]. Chinese modern educational equipment, 2010(21): 72-73.
8. ICP registration using invariant features. Sharp GC, Lee SW, Wehe DK. IEEE Transactions on Pattern Analysis and Machine Intelligence. 2002
9. Chen Jinxi and Liu Zeyang. An Analysis on the Key Points of Undergraduate Teaching in foreign architecture colleges -- Taking Sugao, Bartlett and Cornell as examples [J]. Journal of Architecture, 2017(06): 94-100.
10. Xiang Xingwei. Teaching research of Digital Architecture Design oriented by establishing teaching system [D]. Zhejiang university, 2018.
11. Yuan Jie, ZHAO Qianyi, TONG Huawei, SONG Jinliang. Curriculum Reform and Practice of Civil Engineering Construction Based on VR [J]. Research on Higher Engineering Education, 2019(03): 99-101+129.