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Application of 3-D Ground Laser Scanning Technology to Measure The Scenic Spot of The Best Spring in the World

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Abstract. This paper introduces the main types of 3-D ground laser scanners in the field of surveying and mapping, provides a technical scheme of applying 3-D laser scanning technology to measure ancient buildings in scenic spots, and uses the pulsed 3-D laser scanner which can transmit and receive infinite echoes to solve the problem that vegetation in the surveying area seriously blocks buildings. As an example, the feasibility of the proposed technical scheme is confirmed and the reliability of the proposed technical scheme is demonstrated by precision verification experiments at the scenic spot of the best spring in the world.

Keywords: 3-D Ground Laser Scanning; Ancient Architecture Measurement; Section Survey.

1. Introduction

The first spring scenic area is the first 5A scenic spot in Jinan, by Baotu, Black Tiger Springs, five dragon pools, Daming Lake and moat and other attractions with typical spring features, covering an area of about 3.1 square kilometers, is an important part of the Spring City features an important part of the iconic area. In order to implement the city's strategic plan of "creating four centers and building a modern spring city" and improve the quality of the scenic area, Jinan City has identified "a city, a lake and a ring" as the main focus of about 4.78 square kilometers of the landscape lighting program design. To meet the landscape lighting project design, construction, management and other work on the building layout, form, structure, color and other information needs, the ring park, Daming Lake, Wulongtan, Baotu and other parks all buildings, the use of mapping means to collect architectural elements, drawing the current building plan, elevation, section.

Total station as the representative of the conventional measuring instruments in the building level, vertical, sectional mapping has the advantages of high accuracy and technical maturity[1], but there are high labor costs, inflexible mode of operation, external workload, low efficiency and other deficiencies, and three-dimensional laser scanning technology as a non-contact, active, rapid access to the target object three-dimensional point cloud technology, can directly access a variety of complex, irregular As a non-contact, active and rapid acquisition of 3D point cloud of target objects, 3D laser scanning technology can directly acquire 3D spatial data of various complex and irregular objects or environments, which is expected to improve the efficiency. At present, 3D laser scanning technology has been applied in the fields of section measurement[2], deformation monitoring[3, 4] and 3D modeling of buildings[5, 6], among which 3D laser scanning technology in longitudinal and transverse section measurement is mainly applied to the section measurement of various tunnels, and few studies have been conducted on the measurement of building sections. In this paper, the 3D laser scanning technology is applied to the mapping of ancient buildings, and the plan, elevation and section of ancient buildings are drawn.

1.1. Technical Principle

The laser pulse body emits the laser pulse, and the reflector rotates so that the pulse can reach the surface of the measured object. Through this process, the actual distance between the instrument and the object can be calculated. The encoder of the instrument can calculate the Angle of pulse emission, and then the three-dimensional coordinates of each point can be calculated.

It can be seen from the above that the original data of point cloud information obtained by the three-dimensional laser scanner mainly include: horizontal scanning Angle α and longitudinal scanning Angle θ of the laser pulse, distance value S between the instrument and the target calculated by using the time from pulse transmission to reception, and reflection intensity of point cloud data. Therefore, its measurement principle can be expressed in Figure 1.

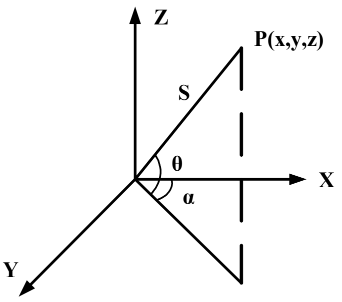


Fig 1. Schematic diagram of basic principle

The coordinates of the target point P can be calculated as:

$$\begin{cases} x = S\cos\theta\cos\alpha \\ y = S\cos\theta\sin\alpha \\ z = S\sin\theta \end{cases} \quad (1)$$

1.2. Instrument Introduction

The main measurement instruments used are the phased 3D laser scanner FARO Focus X330 and the pulsed 3D laser scanner RIEGL VZ-1000, shown in Figure 2 and Figure 3, respectively, and their main performance parameters are shown in Table 1 and Table 2. Among them, the former has high accuracy, high point density, true color, no acquisition blind area at the top and light weight, which is suitable for buildings with complex structures, multi-story and more indoor structures. The latter can penetrate vegetation and is suitable for scanning buildings with severe vegetation occlusion.

Fig 2. Phased 3D laser scanner

Fig 3. Pulsed 3D laser scanner

Table 1. Phased 3D laser scanner technical parameters

Model	FARO Focus X330
Measurement range	330m
Three-dimensional distance measurement accuracy	±2mm
Scanning Range	360°×300°
Scanning speed	976,000 points/second
Panoramic camera pixels	70 million

Table 2. Pulsed 3D laser scanner technical parameters

Model	RIEGL VZ-1000
Measurement range	Greater than 1400m
3D distance measurement accuracy	5mm at 100m
Scanning Range	360°×100°
Scanning speed	300,000 points/sec

1.3. Measurement Area Introduction

The first spring scenic area, with a total area of 3.1 square kilometers, by "a river (moat), a lake (Daming Lake), three springs (Baotu, Black Tiger Springs, five Dragon Lake three spring group), four gardens (Baotu Park, City Park, five Dragon Lake Park, Daming Lake scenic area)," the scope of the operation area shown in Figure 4.

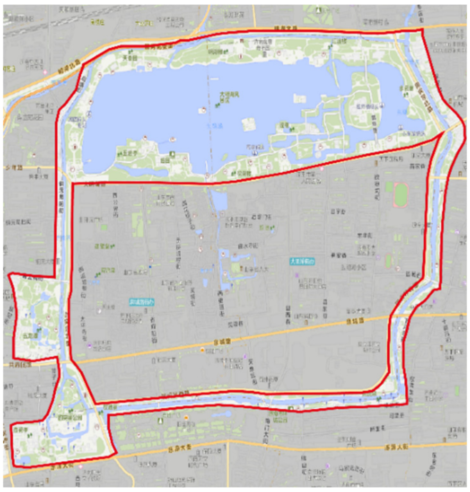


Fig 4. Schematic diagram of the operation area

2. Project Implementation

The main work of the data collection and preparation stage is to collect existing topographic map information, field survey, and develop field data collection plan, including a control plan, station setting plan, target laying plan and texture collection plan. The data collection and processing stage includes point cloud data collection, data processing, and horizontal and vertical profile mapping. The accuracy assessment stage mainly uses the total station and rangefinder to obtain data to verify the relative accuracy of the plane and elevation of the point cloud, and to judge whether the results of the drawings meet the specification requirements.

2.1. Data Acquisition

The building spacing in the survey area is small, the density of building clusters is large, the height is undulating and complex, and the general visibility conditions have a certain impact on the length and range of scanner measurements. Therefore, multiple scanning methods were used to obtain the complete point cloud data of the buildings. The field collection data is shown in Figure 5.

As some of the historical buildings in the survey area are seriously obscured by trees and vegetation, the ordinary 3D laser scanner cannot penetrate the dense vegetation, resulting in the missing point cloud data of historical buildings, which affects the mapping. To address this problem, the RIEGL VZ-1000 pulsed 3D laser scanner is used to scan buildings with serious vegetation obstruction, which is capable of transmitting and receiving infinite echoes, and when the vegetation is obstructed, the infinite echo laser can continue to penetrate the vegetation until the effective information of the target is obtained, ensuring the integrity of the point cloud data and mapping accuracy.

Fig 5. Field data acquisition

2.2. Point Cloud Data Processing

Data processing mainly includes two major parts: point cloud data processing and output data denoising, the former includes import, denoising, stitching, stitching accuracy check, and output.

Figure 6 shows the collected single-site cloud data, which is firstly pre-processed and de-noised to generate a common surface slice based on the point cloud data, and the connected station areas are stitched together in turn, followed by an accuracy check, as shown in Figure 7, to ensure that the stitching accuracy between two stations is controlled within 1 cm. The stitched point cloud data are de-vegetated and de-mangled, and finally only the building point cloud data are retained.

Fig 6. Single-site scan data

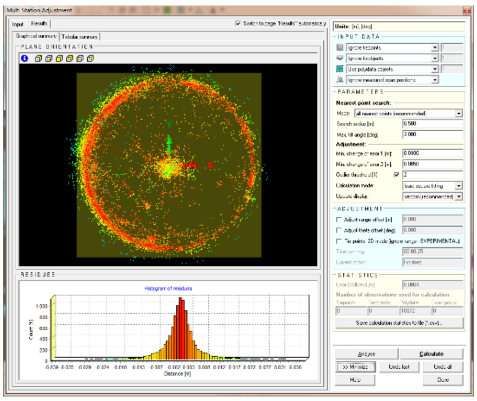
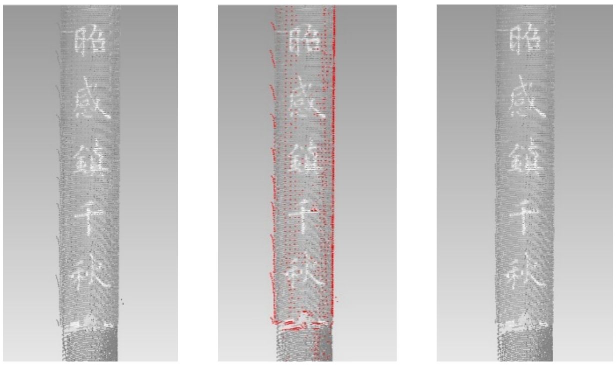


Fig 7. Two-station data splicing accuracy check

Due to the characteristics of 3D laser scanning, part of the point cloud data will produce discrete noise at the angular boundary of the building structure, mainly due to the edge artifact noise caused by the laser spot diameter, superposition noise at the same location of multiple stations and long-distance laser ranging noise. When the noise is generated at the building boundary, it will have a certain influence on the cartography and line-taking of the internal staff.

In order to avoid the mapping error, Geomagic series point cloud post-processing software is used to fully automatically and high-precision denoising of the historical building point cloud data after the collocation and alignment are completed, so as to obtain more realistic and accurate point cloud data and improve the mapping accuracy, as shown in Figure 8.



(a) Before denoising (b) Automatic noise selection (c) After denoising

Fig 8. Point cloud denoising

The required elevation point clouds and section point clouds are cut out separately, and only the frontal visible point clouds are retained to avoid the interference of perspective point clouds during drawing.

2.3. Drawings of Plan, Elevation and Section

Import the processed point cloud data into AUTOCAD software for architectural drawings. The stitched scanned point cloud data and close-up photogrammetry data, in accordance with the rules and accuracy requirements for drawing ancient buildings, and with reference to the image data to draw two-dimensional drawings of plans, elevations, sections, etc., as shown in Figure 9 and Figure 10.

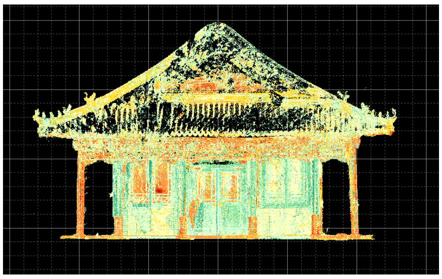


Fig 9. Elevation point cloud data

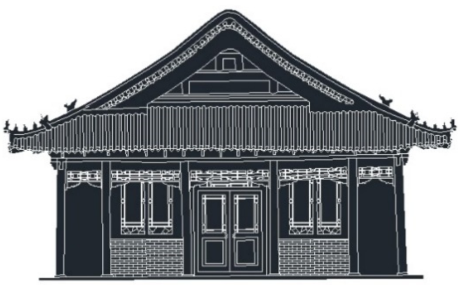


Fig 10. Drawing the elevation

2.4. Accuracy Rating

The use of a total station, rangefinder Baotu, Wulongtan, Daming Lake and moat within the length and width of some ancient buildings to verify the accuracy of the measurement results. For the building modeling simple, good access to the building, the direct use of the rangefinder to measure the length and width of the checked ancient buildings; for the building modeling complex, difficult access to the building, the use of the total station on the side of the measurement function to obtain the length and width of the checked ancient buildings.

A total of 280 ancient buildings were measured in the Tianxia First Spring scenic area and 175 buildings were selected for verification of the length and width dimensions, including 49 Baotu, 78 Daming Lake, 19 Wulongtan, 29 moats, 328 data of the above 175 buildings were checked and statistically analyzed, the maximum absolute value of the relative error of 1/769, the minimum absolute value of 1/3980, to meet the specification requirements Some of the statistics are shown in Table 3.

Table 3. Statistical table of building dimensional accuracy (partial)

Serial number	Length		Difference	Relative error (absolute value)
	Scanning data	*Checking data*		
1	38.015	37.985	0.030	1:1266
2	45.704	45.720	-0.016	1:2858
3	62.785	62.815	-0.030	1:2094
4	21.511	21.531	-0.020	1:1077
5	8.100	8.109	-0.009	1:901
6	60.716	60.733	-0.017	1:3573

[a] Unit: meter

3. Conclusion

Compared with traditional measurement, the use of 3D laser scanning technology can significantly improve the efficiency and quality of measurement results. According to the survey area environment, flexible selection of the appropriate 3D laser scanner can get more perfect point cloud information.

In this paper, we only study the application of ground-based 3D laser scanning technology in ancient buildings mapping, if we integrate airborne laser scanning technology to collect the top of ancient buildings, it is expected to get more abundant point cloud data.

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