Ranging Precision Analysis of Stonex X300 3D Laser Scannerd

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Abstract. This paper takes Stonex X300 3D laser scanners as a design scheme, tests ranging nominal and ranging precision of instrument and compares between calculating solution of Stonex X300 3D laser scanners and the measured distance of Leica TS30 total station. Experiment result shows ranging precision of 3D laser scanners is given on the basis of certain distances while ranging nominal is given on the basis of certain experiment conditions. In the process of collecting data in field surveying, it cannot completely reach its calibration value due to conditional limitation and ranging error in certain distance easily reaches nominal value. However, in terms of total station-scaled 3D laser scanners, it cannot reach too high differentiating ability. The farther the distance, the more difficult the discovery of target point. Ranging precision testing method in this paper has better reliability to be implemented and also has practical value for precision research in 3D terrain laser scanners.

1. Introduction

3D laser scanners technology has many technological advantages such as fast measurement, large data quantity, assuring precision and constantly automatic measurement. It has been used to obtain 3D coordinate information of the measured object surface. While this technology has been broadly applied in survey field, its application prospect is also very broad in protection and reconstruction of cultural relics, planning and management of urban design, processing manufacturing industry, medical health, defense industry and film-acrobatic making, etc. At present, the precision of 3D terrain laser scanners is mainly offered by manufacturer. Our country has not been standards or regulations in terms of 3D laser scanners measurement technology and there is not any professional institution for its technical detection and calibration. In addition, due to aging hardware of long-term usage in equipment, some factors including shock and abrasion of equipment will also affect precision so this status is not in favor of scientific and standardized management of surveying and mapping production. Therefore, this paper operates an experiment and it is significant to study and analyze the influence of different distances on measuring precision as well as the influence of different weathers on ranging precision.

2. Equipment and Its Precision Introduction

The involving equipments of precision test in this paper are Stonex X300 3D laser scanners of Guangzhou STONEX and high-precision TS30 total-station equipment of Leica Company in 2010.

Stonex X300 3D laser scanner is a 3D terrain laser scanner based on pulse-type which precisely measures and rapidly obtains amounts of geometrical 3D point cloud data under complex environment. There are three transmission ports in this scanner: GPS connector, high-speed USB port and Ethernet data transmission. Two industry cameras are set inside scanner with 1070 0000 pixels without peripheral cameras. Furthermore, scanner and photograph are operated under the same condition. It works below 10℃ and solves difficulty of most ineffective 3D laser scanners under subzero degrees. Main technological parameters from manufactures are shown in table 1.

Leica TS30 total-station instrument is the fourth generation high-precision intelligence total-station instrument and is also a super-high precision total station instrument. It redefines precision standard of total-station instrument with 0.5" angle measurement accuracy, 0.6mm+1ppm ranging precision and 3.5km measurement range, perfectly integrates functions such as angle measurement, distance measurement, automatic target recognition and fast tracking, and provides precision measurement with technical support. The high accuracy characteristic of this total station instrument completely satisfies accuracy evaluation requirement of 3D terrain laser scanner so it can be taken as reference and standard in ranging precision of Stonex X300.

Table 1. Main Parameters of Stonex X300 3D Laser Scanner

parameter	value
Visual scope	Level 360°（panorama vision） Vertical 180°（90°x 2）
Ranging scope	2-300m（80% reflectivity）
Scanning rate	>40，000 point/second
Angle resolution	Milliradian 0.37mrad
precision	±4 mm （50m distance）
Integration camera	The highest pixel 8560 0000 pixels
	Single image resolution 1070 0000 pixels
Data storage	Inner-set 32GB flash memory， which can expand to 64GB
Data transmission	Wi-Fi，USB port
Scanner control	Professional connecting intelligence cell-phone, wireless network interface of panel pc.

3. Experiment and Analysis of Ranging Precision

3.1. Basic Principle and Formula

For this smooth experiment, the layout of total station instrument, 3D laser scanner and target point are shown as figure 1. Since Stonex X300 3D laser scanner in experiment does not have matching function, it cannot know distance between facility center and target point. But the top of 3D laser scanner can connect a prism so that prism centers X and Y are the same to X and Y of 3D laser scanners. Difference value of value Z is a fixed value and experiment center takes this prism center as the center of laser scanner. In figure 1, total station facility is erected on C and 3D laser scanner is erected on B. There are prisms which are junction devices in 3D laser scanner and target points are pasted on A of a flat wall surface. (Figure 2.)

As is shown by figure 1, the measured distance between station C (total station instrument erection) and target point A is b while the distance between station C and prism (point B) 3D laser scanner is a with as horizontal angle. Distance from prism center to target point can be achieved by formula (1) because there is a constant difference value between prism Z coordinate and 3D laser scanner center Z. During data processing, Z coordinate value of 3D laser scanner will be ignored. The two-dimensional coordinate system distance from instrument center to target can be achieved by formula (2).

$$c = \sqrt{a^2 + b^2 - 2ad\,cos\,\gamma} \tag{1}$$

$$D = \sqrt{x^2 + y^2} \tag{2}$$

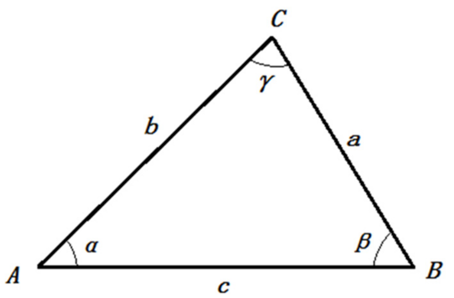

Figure 1. Layout of instrument and target points.

Figure 2. target point.

In order to eliminate influence of some artificial errors and fixed errors, observation in left and right will be applied. During distance measurement, two times observations adopt mean value in order to guarantee reality and reliability of experiment data. Measurement of controlling total station instrument will limit difference. Distance difference between two observations is ≤1mm and limited difference of horizontal value will be controlled in 3″ .

3.2. Scheme Design

Scheme one is to choose different measuring section distance. The farthest distance between instrument and target point selects 330m to analyze influence of different distances on ranging precision. Due to measuring distance difference, reflecting property of laser will also be the same so this leads that the same ground objects precision to observe different distances is also different during using 3D laser scanner to measure distance. Thus, choosing different distances for experiment and ranging precision will also be analyzed. Therefore, under precondition of conditional allowance in practical measurement, distance reflection surface with higher precision will be chosen as much as possible for field surveying. Laser scanner will be respectively erected from target point in 5m, 10m, 15m, 30m, 45m, 75m, 100m, 125m, 150m, 175m and 200m in distance for data collection. Then, total station instrument is used to measure distance and angle.

Scheme two is to do the same experiment under different weathers to analyze influence of different weathers on ranging precision. In practice, because of construction period, some constructions need to be urgently completed. Therefore, it will not be allowable to choose the best effect to measure on purpose. Even though it is snowing, raining or even smoggy, measuring error is large during measurement and ranging precision is not accurate. This scheme chooses to do experiment in foggy weather, compares and analyzes data under sunshine weather to finally get conclusion of surveying measurement in foggy day. The scheme discusses surveying measurement in good weather should be chosen as much as possible in order to improve data reliability.

3.3. Result Analysis

(1) In order to eliminate influence of some artificial errors and fixed errors during data measurement, total station instrument will adopt observation in left and in right in the process of angle measurement. During distance measurement, observations will get mean value for two times so as to guarantee reality and reliability of experiment data. Control total station instrument will limit errors. Two measured distances error is≤1mm and limited errors of horizontal angle are in 3″ . The measured data from total station instrument and AB distance according to formula (1) calculation are shown in table 2.

(2) Point cloud data (10 times observation target at the same location) from 3D laser scanner will be calculated through professional software Stonex 3D Reconstructor to get target point coordinate of

3D laser scanner default coordinate system and achieve distance from center to target point of 3D laser scanner through formula (2). The maximal value, the minimal value, the mean and mutual difference between the maximal value and the minimal value by 3D laser scanner are shown in table 3. In order to analyze stability of laser scanner ranging with distance change (5m to 200m), this paper also draws mutual difference line graph of the maximal value and the minimal value by laser scanner ranging. From this graph, with increase of distance, the difference value is larger and larger. However, it is not more than 4mm in general.

(3)Data of this simulating experiment total station instrument will be taken as true value to calculate difference value between the measured distance of 3D laser scanner and total station instrument. Data arrangement is shown in table 4 (result is until the fifth decimal place). According to histogram in table 4, difference value and absolute value of 3D laser scanner in this experiment increase with distance increases. In particular, error in 75m starts to rapidly increase and it reaches to the maximum in 175m.

Table 2. The measured distance of total station instrument

General distance	angle (° ′ ″)	Distance from CB instrument to prism（m）	Distance from CA instrument to target point（m）	Distance from prism to AB target point（m）
5m	74 07 46.5	4.41928	5.65525	6.15167
10m	83 40 37.4	3.62745	9.56660	9.85061
15m	135 57 37.3	7.11438	11.94765	17.76420
30m	160 10 11.8	20.23230	9.56710	29.41171
45m	155 09 41.8	21.66260	26.10445	46.65909
75m	163 23 14.6	50.75055	26.10710	76.13469
100m	169 19 40.4	23.68155	79.47075	102.83624
125m	173 37 15.2	47.05575	79.49880	126.37140
150m	171 53 1.25	68.78840	79.50175	148.16969
175m	177 13 11.2	110.23210	67.30650	177.48940
200m	179 57 50.15	102.88595	97.40810	200.29404

Table 3. Data Arrangement of 3D Laser Scanner (Unit: m)

General Distance	Maximal Value in distance	Minimal Value in Distance	Mean Value in Distance	Mutual Difference between the Maximal Value and the Minimal Value
5m	6.15332	6.14973	6.15081	0.00359
10m	9.85144	9.84601	9.84926	0.00543
15m	17.76399	17.75921	17.76213	0.00478
30m	29.41181	29.40663	29.40937	0.00518
45m	46.65993	46.65317	46.65581	0.00676
75m	76.12865	76.12204	76.12614	0.00661
100m	102.83011	102.82181	102.82585	0.00830
125m	126.35226	126.34617	126.35000	0.00609
150m	148.14480	148.13599	148.13910	0.00881
175m	177.47507	177.44937	177.45829	0.02570
200m	200.27802	200.24451	200.26773	0.03351

Figure3. Line Graph of Mutual Difference between the Maximal Value and the Minimal Value in Distance.

Table 4. The Measured Data Comparison of 3D Laser Scanner Total-station Instrument (unit: m)

Type			**RESULT**	**DATA**		
Total Station Instrument	6.15167	9.85061	17.76420	29.41171	46.65909	76.13469
Scanner	6.15081	9.84926	17.76213	29.40937	46.65581	76.12614
Difference Absolute Value	0.00086	0.00135	0.00207	0.00234	0.00328	0.00855
Total station instrument	102.83624	126.37140	148.16929	177.48940	200.29404	
scanner	102.82585	126.35000	147.13910	177.45829	200.26773	
Difference Absolute Value	0.01039	0.02140	0.03019	0.03111	0.02631	

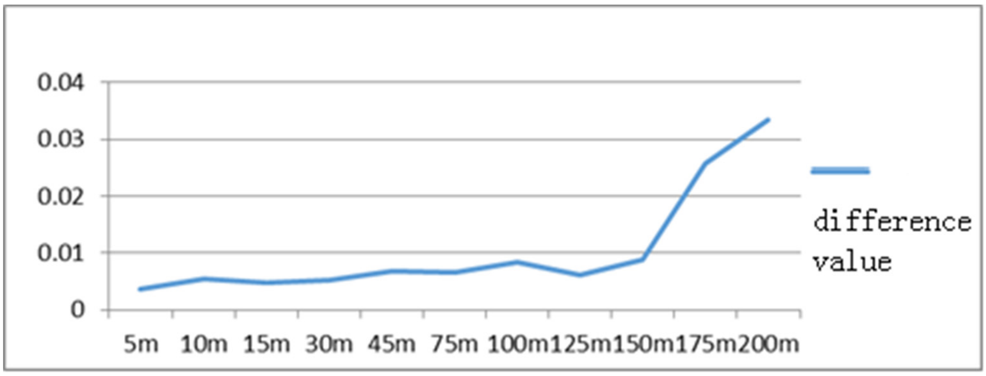

Figure3. Distributing histogram of difference absolute value

Table 5. Data comparison by 3D laser scanner and total station instrument

General Distance	Total Station Instrument	3D Laser Scanner	Difference Absolute Value
5m	5.31753	5.31638	0.00115
50m	50.25499	50.24927	0.00572
100m	100.97035	100.95145	0.01890
150m	151.08738	151.04996	0.03742

(4) For the same experiment under different weathers to analyze influence of different weathers on ranging precision, this paper repeats above experiment stages in foggy weather. Considering weather influence and other factors, observation station will be established at about 5m, 50m, 100m, 150m, 180m and 200m, and each observation station will be scanned 10 times. The measured "limited" distance under sunshine weather by instrument is 200m so the farthest distance will choose 200m in foggy day. Through calculating point cloud data, there is no effective point cloud data for instrument in 150m target distance. That is to say, laser which is emitted by 3D laser scanner is basically absorbed by surrounding environment as well as atmosphere and cannot return to instrument for storage. Some factors such as foggy day, atmosphere and refraction will seriously affect surveying measurement. Edge length which is measured by total station instrument and edge length which is measured by laser scanner are shown in table 5.

4. Conclusion

According to results and analysis of above experiment, these conclusions can be reached:

(1) Effective measurement range by Stonex X300 3D laser scanner under surveying environment (sunshine weather) is 200m and its effective measurement range under foggy measurement environment is 150m. Ranging nominal of this instrument is 300m but it cannot reach ranging nominal during surveying measurement.

(2) Scanning precision of 3D laser scanner will reduce with the increase of distance. The precision between 75m and 200m will dramatically decrease and difference absolute value at 175 meters is about 4 times at 75 meters.

(3) Even though general distances of experiment in foggy day are only 5m, 50m, 100m and 150m （effective point cloud data are very little at 150m, there are overlapping with sunshine data and this reflects ranging performance of instrument in bad weather measurement to some extent. Results show that the influence of foggy day on measurement result is serious so good weather should be chosen during surveying measurement and accuracy loss should decrease to the lowest as much as possible.

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