On the basic research of data analysis for Terrestrial Laser Scanner

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ABSTRACT: Since the 2000s, 3D laser (called Terrestrial Laser Scanner: TLS) surveying has been used in many scenes. It is used in very large fields. For example, there are construction field, civil engineering field, survey field, equipment management, asset management, preservation of natural heritage, inspection, reverse engineering, criminal investigation, analysis of accident scene, forest research, agriculture and media. The advent of 3D laser scanner has been said to be a technology that will great change the common sense of 3D measurement field. As mentioned above, 3D laser surveying system is very useful tool for design work and it has become popular around the surveying field of late years. However, the basic characteristics of the measurement data are not clear. Therefore, basic research for TLS was selected as a major theme. This research was conducted in collaboration with four surveying companies participating in the KIT Spatial Information Project. On the experiments has been used five 3D terrestrial laser scanners (FARO Focus S350, Leica C10 and Leica P50, TOPCON GLS-2000, RIEGL LMS-Z620). In this study, several other software and devices were also used. In order to coincidence the actual work and conditions, the experiment site was setting at the outside of the campus. The research was analyzed using point cloud data provided by surveying companies participating in the KIT spatial information project. On the analyzing process, taking value obtained by the total station as a true value, and compares it with the point cloud data. For example, comparing various values such as elevation and distance, and whether there is difference from the true value. Also, if there are differences, how to show the difference from the true value is considering. On the basic data analysis of point cloud data for TLS were just started and no clear results have been obtained at this time. By utilizing the results obtained in the research, our research will be contributing to the efficiency improvement of 3D laser surveying.

1. Introduction

In recent years, digitization of information has been established in all fields due to the demand for digitization of data. In addition, three-dimensional CAD as three-dimensional information is also generalized.
However, as these advanced technologies spread to surveying field, various problems were found. For example, it is difficult to get point cloud data of edge part like corner of building, it becomes difficult to make accurate measurement when the distance to the scanner is large. If there are traffic that passes the measurement area, it is impossible to obtain point cloud data that should be acquired. In addition, it was reported from the actual surveying site that securing the accuracy is difficult when performing laser measurement on grassland.
By investigating the characteristics of the laser scanner, it was found that, basic data analysis was necessary to improve the efficiency of surveying operations using the laser scanner.

2. RESERCH SUMMRY

The final target is to improve the efficiency of "survey using a terrestrial laser scanner". In this research, basic research was conducted to investigate the characteristics of the laser scanner. Using point cloud data acquired by multiple laser scanners with different companies and different performances, comparison by calculation of the least square plane and the comparison of elevation with the reference point were performed.
We examined the difference due to plane feature, the presence or absence of the difference with the elevation, and whether the difference or tendency appeared by the scanner.

3. OUTLINE OF EXPERIMENT

3.1 Equipment and software used in the experiment

The experiments were conducted using these equipment and software.

・3D laser scanner (5 models)
Table 1 shows the performance table of scanner.

Table.1 Performance table of scanner

Scanner	wavelength (nm)	Short distance measurement or Long distance measurement
A	1550	Short distance measurement
B	532	Long distance measurement
C	1550	Long distance measurement
D	Near infrared	Long distance measurement
E	1064	Long distance measurement

・Cloud Compare
This software is free software, and it can be used with point cloud data from laser scanner.
・MATLAB
MATLAB is well known as general-purpose software for mathematical analysis.

3.2 Place of experiments

The experiment was conducted on October 2017 and October 2018 in the Shiramine area of Hakusan City, Ishikawa Prefecture. The experiments on 2017 is an extensive measurement of the Shiramine area. The experiments on 2018 measured a narrower range than previous experiments in order to confirm the reproducibility of the point cloud data. The range measured by the five laser scanners in both the 2017 and 2018 experiments are the area surrounded by the red line in Figure 1. The point cloud data acquired within this area was compared with the plane formed by the point cloud data acquired by the scanner and with the elevation of the reference point SK8-1.

Fig.1 The experiment area (Shiramine of Hakusan City)

3.3 Using data

The data used for the analysis is point cloud data existing in the area of "2 m square centered on the reference point SK8-1" acquired in both the 2017 and 2018 experiments. When this point cloud data is visualized using Cloud Compare, it will be displayed as shown in Fig.2.


Fig.2 Capture of point cloud data

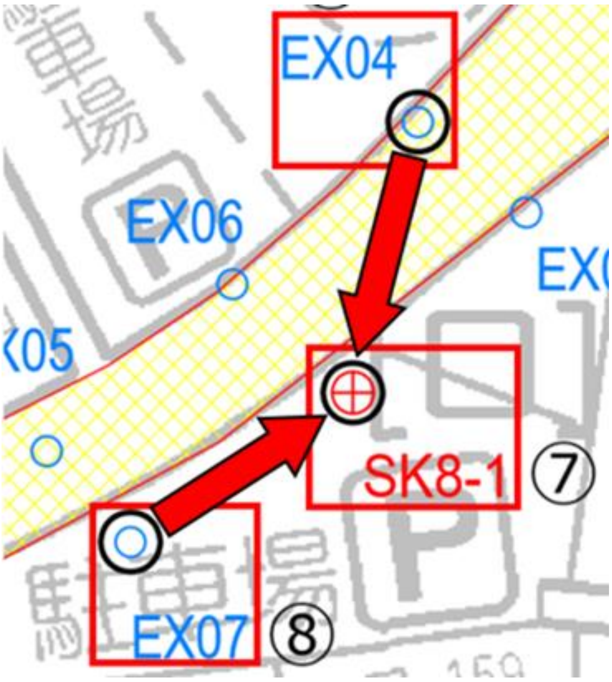

Fig.3 Placement of each point

EX04, EX06 and EX07 means control point in the Figure 3. First, on the EX04 experiment was conducted. At the same time, EX06, was conducted to confirm what kind of influence would occur if the target area were changed. Elevation values were calculated by changing the target range of analysis from 4 square meters, 1 square meter to 0.25 square meters.

Fig.4 Placement of control point EX06

3.4 Compare least square planes acquired by scanners

The plane determined from the acquired point cloud data can be considered as a pseudo ground surface obtained by the laser scanner. A plane in space can be obtained if the coordinates of three points are determined, however, in this research, point cloud data existing in "a range of 4 square meters centering on reference point SK 8-1" was extracted from many point clouds, it compared by calculating the least squares plane.

3.5 Least squares plane

The plane that minimizes the sum of the square distances to the point cloud is the least square plane, which is the "most probable plane of point cloud data".
From the calculation results, the equations of the least square plane calculated from point group data acquired by five types of scanners were compared for a range of 4 square meters centered on the reference point SK8-1. The coefficients of the two and three terms of the equation were found to be identical except in one place in all the calculation results. This study considered about the coefficient of first item of equation.

Table.2 Calculation result of least squares plane

Equation of Least Square Plane Observed from EX04 in 2017

A	0.013(x-19470.516)-0.027(y-48642.162)+0.999(z-501.012)=0
B	0.013(x-19470.508)-0.027(y-48642.162)+0.999(z-501.000)=0
D	0.013(x-19470.526)-0.026(y-48642.158)+0.999(z-501.010)=0
E	0.013(x-19470.493)-0.027(y-48642.133)+0.999(z-501.022)=0

Equation of Least Square Plane Observed from EX07 in 2017

A	0.012(x-19470.390)-0.028(y-48642.259)+0.999(z-501.013)=0
B	0.013(x-19470.396)-0.028(y-48642.266)+0.999(z-500.999)=0
D	0.011(x-19470.405)-0.028(y-48642.253)+0.999(z-501.012)=0
E	0.013(x-19470.395)-0.028(y-48642.248)+0.999(z-501.016)=0

Equation of Least Square Plane Observed from EX04 in 2018

A	0.013(x-19470.494)-0.027(y-48642.161)+0.999(z-501.019)=0
C	0.013(x-19470.509)-0.027(y-48642.160)+0.999(z-501.010)=0
D	0.014(x-19470.519)-0.027(y-48642.166)+0.999(z-501.018)=0
E	0.013(x-19470.488)-0.027(y-48642.161)+0.999(z-501.016)=0

Equation of Least Square Plane Observed from EX07 in 2018

A	0.013(x-19470.399)-0.028(y-48642.263)+0.999(z-501.016)=0
C	0.012(x-19470.411)-0.028(y-48642.272)+0.999(z-501.007)=0
D	0.011(x-19470.393)-0.028(y-48642.287)+0.999(z-501.007)=0
E	0.013(x-19470.398)-0.028(y-48642.249)+0.999(z-501.016)=0

The “least square plane acquired from the control point EX04 in 2017” and the “least square plane acquired from the control point EX07 in 2017” are combinations obtained by measuring the same reference point from different control points at the same time. On the measurement from EX04, the coefficients were the same for all four models, but in the measurement from EX07, small differences were founded for each model. Similarly, on the "least square plane obtained from the control point EX04 in 2018", the coefficients are almost the same for all four models, but on the "least square plane obtained from the control point EX07 in 2018" minor differences were seen.

“The least squares plane obtained from the control point EX04 in 2017” , “the least squares plane obtained from the control point EX04 in 2018” , “least square plane acquired from the control point EX07 in 2017” and the “least square plane acquired from the control point EX07 in 2018” are combinations obtained by measuring the same reference point from the same control point at different times. Comparing “the least squares plane obtained from the control point EX04 in 2017” and “the least squares plane obtained from the control point EX04 in 2018”, coefficient of first item was 0.013 in all cases except the one place. Similarly, comparing “the least squares plane obtained from the control point EX07 in 2017” and “the least squares plane obtained from the control point EX07 in 2018”, small differences in the coefficient values were confirmed, it was not constant.

From the above, it was found that when measured with different models, a few differences were recognized for each model depending on the measurement location. In addition, even when the observation time was different, it was found that if the measurement was performed from the same control point, the point cloud data tended to coincide, and the reproducibility of the data could be secured.

3.6 Comparison of elevation value to reference point SK8-1

In the comparison of elevation values, the elevations of the reference points measured by the total station were used as correct values. The elevation observed by the laser scanner was taken as “the value in the Z-axis direction of the center of gravity of the point cloud data”, and the elevation was compared with the elevation of reference point.

The following tables show the result of comparing the Z value of the point group center of gravity and the elevation (Table.3). These are shown "Comparison result with point cloud data which measured reference point SK8-1 from control point EX04 in 2017", "Comparison result with point cloud data which measured reference point SK8-1 from control point EX07 in 2017","Comparison result with point cloud data which measured reference point SK8-1 from control point EX04 in 2018" and "Comparison result with point cloud data which measured reference point SK8-1 from control point EX07 in 2018" respectively.

In addition, a graph of the difference obtained by each model is shown in Fig. 7.

Table.3 Comparison of elevation values

Comparison with data observed from EX04 in 2017

Scanner	Z value of center of gravity	True Z value	Difference (m)
A	501.012	501.003	0.009
B	501.000	501.003	−0.003
D	501.010	501.003	0.007
E	501.022	501.003	0.019

Comparison with data observed from EX07 in 2017

Scanner	Z value of center of gravity	True Z value	Difference (m)
A	501.013	501.003	0.010
B	500.999	501.003	−0.004
D	501.012	501.003	0.009
E	501.016	501.003	0.013

Comparison with data observed from EX04 in 2018

Scanner	Z value of center of gravity	True Z value	Difference (m)
A	501.019	501.003	0.016
C	501.010	501.003	0.007
D	501.018	501.003	0.015
E	501.016	501.003	0.013

Comparison with data observed from EX07 in 2018

Scanner	Z value of center of gravity	True Z value	Difference (m)
A	501.016	501.003	0.013
C	501.007	501.003	0.004
D	501.007	501.003	0.004
E	501.016	501.003	0.013

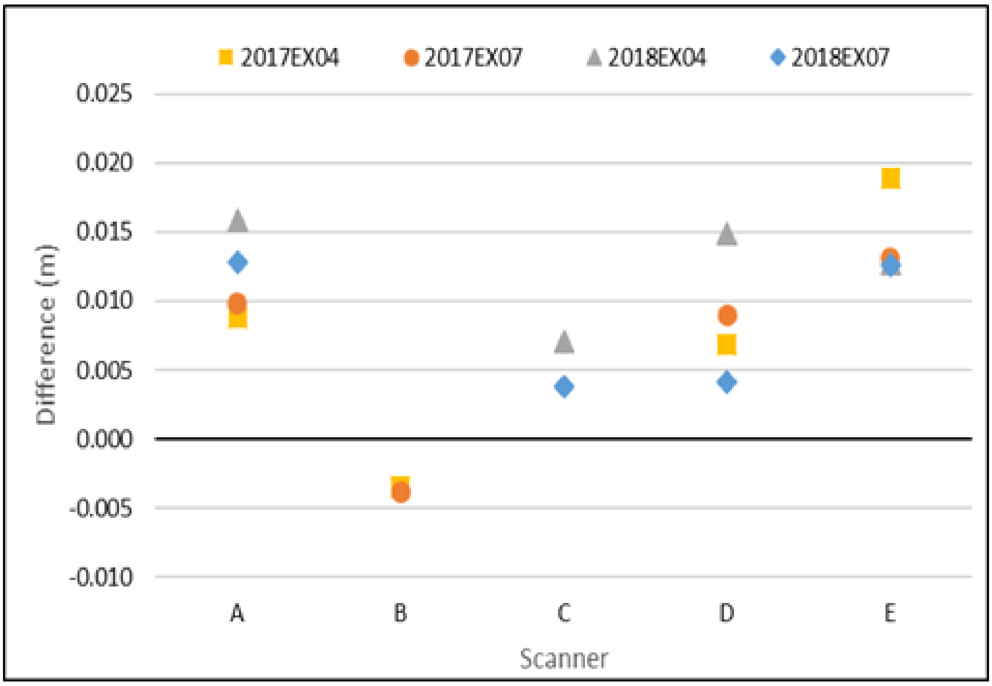

Fig.7 Difference from the true value to the reference point SK8-1

Based on the above results, it was found that 4 out of 5 models acquired higher values than the actual altitude. These results show a very important change unique to field experiments. Details will be explained in the next chapter.

3.7 Comparison of elevation values for control point EX06

In the comparison of the elevation value at the control point EX06, it was conducted with the elevation of the control point measured by the total station as the true value. The elevation observed by the laser scanner was taken as the “Z value of the center of gravity” and compared with the elevation of the control point, as in the case of the analysis at the reference point SK8-1. The elevation was compared while changing the range of point cloud data to 4 square meters, 1 m square meters, and 0.25 square meters when obtaining "Z value of center of gravity". Each results are shown from Fig. 8 to Fog.10.

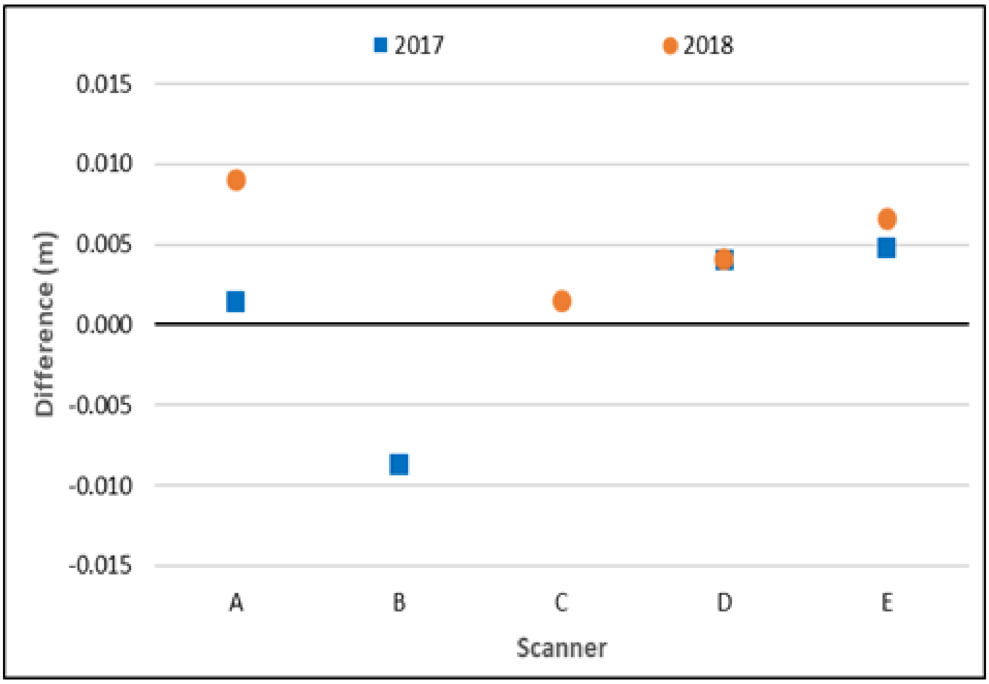

Fig.8 Difference with the true value for EX06 (4 square meters)

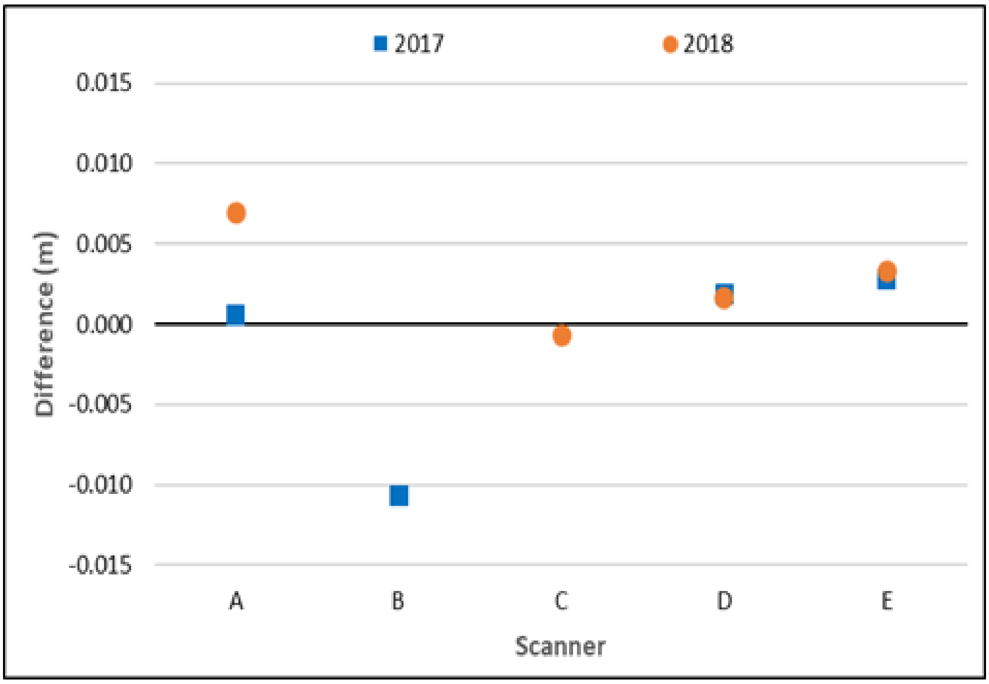

Fig.9 Difference with the true value for EX06 (1 square meters)

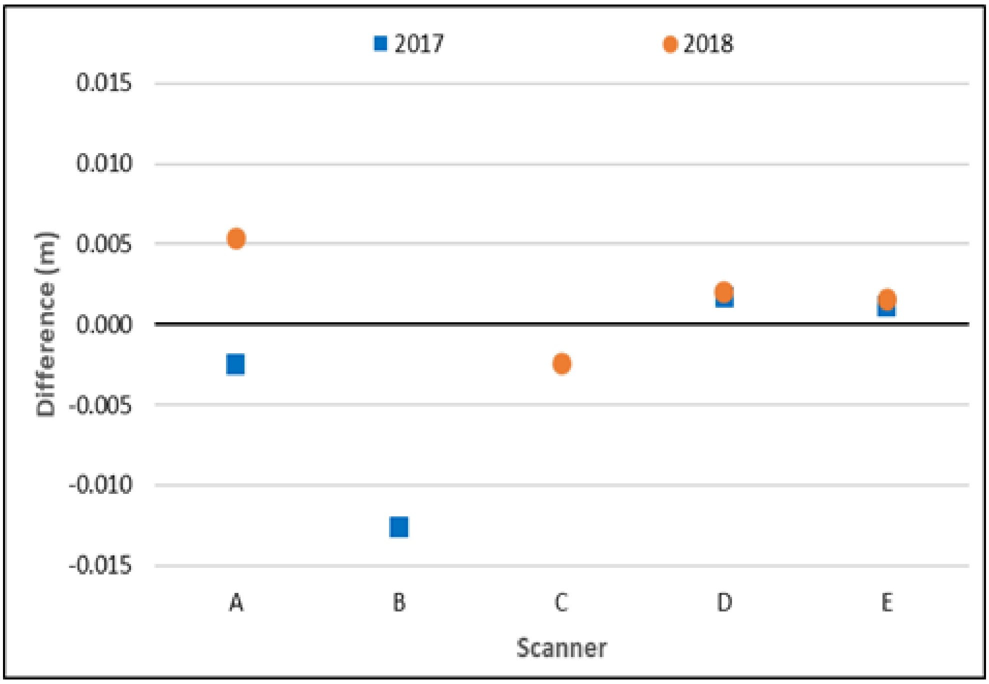

Fig.10 Difference with the true value for EX06 (0.25 square meters)

From the figures and tables, it was confirmed that the value of the difference decreases as the range is narrowed to 4 square meters, 1 square meter, and 0.25 square meters. The maximum positive difference areas obtained by 4 square meter was 9 mm. In addition, the positive difference for the 1 square meter analysis was up to 7 mm, it was small than that of 4 square meters. At 0.25 square meters, the difference in the positive direction decreased to 5 mm in the maximum.
On the other hand, for the negative difference, the largest difference obtained in the analysis of 4 square meter was -9 mm. In the case of a 1 square meter, the negative difference was a maximum of -11 mm, and for a 0.25 square meter, maximum of it was13 mm.
From mentioned above, the absolute value of the difference is not necessarily reduced (nearly 0), and it is considered that the observed value has generally moved in the negative direction.

4. Experimental result

As the target area narrowed, the positive difference between the true value measured by TS and point cloud data became smaller, and negative difference became larger. These variations are considered result of eliminating errors and noises included in the point cloud data. If it is correct thinking, the value of the center of gravity obtained is considered to approach the true value (the difference approaches 0). It is considered that there is another factor in the difference that has increased in the negative direction.
About the behavior of the point cloud obtained from a laser scanner has complex activity, many verifications need to be done in the future including model experiments.

5. Conclusion

The experiment was close to real work in the company. We are now planning a model experiment with finely defined topography and observation conditions, and we plan to analyze the effects of observation conditions and point cloud data acquisition.

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