

Effect of Target Properties on Terrestrial Laser Scanning Intensity Data

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Abstract—Terrestrial laser Scanning (TLS) intensity data are influenced by many factors. In this paper, the influence of target surface properties on TLS intensity data is considered. Experiments were carried out with standard reflector, some different color plates and selected building facades of various kind of material. Through the research on the intensity quality, we can conclude that the target reflectance characteristics at the laser wavelength determine its intensity value. Two correlations, that is, intensity value and range accuracy, intensity value and its standard deviation are not the same for different targets. Color has a great impact on the intensity of scanned point data. The white, yellow, cyan and green plates have large intensity with a better reflectivity at green laser, while red and black have small intensity with worse reflectivity.

Keywords—Terrestrial Laser Scanning, target surface properties, intensity data, point cloud, effect analysis

I. INTRODUCTION

Terrestrial laser scanning (TLS) is a well-known surveying technology and has already been used over a decade. In contrast to traditional technology of single point positional surveying, TLS can offer millions of densely spaced points, called “point clouds”. For each point, the 3D coordinates (X, Y, Z) and the intensity value (I) are recorded. Intensity is defined as the ratio of strength of reflected light to that of emitted light.

In the past, laser intensity information was abandoned because of its large noise. But recently, a number of researchers gradually pay more attentions to the usage of intensity information. This is because the progress in laser technology and the subsequent advent of suitable sensors in TLS. Several publications about the usage of laser intensity have been found [1-4]. The intensity data are usually combined with 3D data for object classification and matching purposes. Results show that the intensity value is a functional for classification, but we all know the intensity values used in these papers are the original recorded values. The raw intensity data are influenced by many factors, such as instrument mechanism, environmental conditions, target surface properties and scan geometry. In order to improve the application reliability of laser point intensity information, radiometric aspects should be also investigated together with geometric parameters.

Previous publications have less information about the performance of TLS intensity data. Clark et al. (2004) tested the effect of colors on range accuracy with standard color patches, but did not concern its effect on intensity data. Bucksch et al. (2007) investigated the effect of five grey patches on the intensity quality, but the experiment samples were few. Based on the related literatures, this paper will investigate the effect of target properties on TLS intensity data. In order to obtain some reliable results, test samples with planar plates of different materials, including targets of defined reflectivity, common color patches and building materials, were scanned at varying distances and angles to the scanner. In each case the resultant point cloud was analyzed to examine the effect of different materials on intensity data.

II. EXPERIMENT DESCRIPTION

A. Test configuration

1) Laser scanner

For the purpose of this research, the instrument used was a 532nm ScanStation C10 terrestrial laser scanner. The scanner is a pulsed scanner using the time of flight to measure range. The main technical specifications of this scanner are listed in Table 1.

TABLE I. MAIN TECHNICAL SPECIFICATIONS OF SCANSTATION C10 SCANNER

System Performance	
Accuracy of single measurement	
Position	6mm
Distance	4mm
Angle (horizontal/vertical)	60urad / 60urad (12" / 12")
Laser Scanning System	
Range	300 m @ 90%; 134 m @ 18% albedo
Scan rate	Up to 50,000 points/sec
Field-of-view	360°×270°

2) Sample frame

In order to obtain the scanned point cloud of different samples easily in each case, a sample frame was made with the size of 30cm×30cm. During the scanning experiment, each sample was placed in the sample frame fixed on a theodolite base. The base had leveling bubble and horizontal circle, which could control scanning state.

B. Test samples

For the completion of this research, three series of samples were selected. The first test series were the targets of defined reflectivity (Lambertian reflector, reflectivity: 35%, 55%). Furthermore, eight common color patches (red, yellow, green, cyan, blue, white, grey, and black) were selected. In addition, six building materials (wood, brick, concrete, asphalt, marble and granite) were chosen. All samples were planar plates with the size of 30cm ×30cm.

C. Measurement setup

Experiments were carried out outdoor on the relatively flat ground. The scanner and a Total Station (TL) were placed at a distance of about 80 meters. Sample frame was placed between them, facing the scanner. Three devices were adjusted at the same height. With regard to the distance between sample frame and scanner, the experiments were designed to three different setups.

Ex1: The sample frame was placed at about 10 meters from the TLS. All samples were rotated around vertical axis in step of 10° (related 0° to 80°).

Ex2: The sample frame was placed at about 30 meters from the TLS. All samples were rotated around vertical axis in step of 10° (related 0° to 80°).

Ex3: The sample frame was placed at about 70 meters from the TLS, facing the scanner which implies that the scanning angles were never larger than about 3 degree.

As the sample frame device was not very accurate in practice, the real orientation of the plate with respect to the scanner at a certain orientation setting was reconstructed from the point cloud data.

III. DATA PROCESSING

According to the experimental setup above mentioned, each dataset was obtained in each case. The points were selected manually from the resulting point cloud of each scanning ensuring that all spurious points and floating points were eliminated. The scanned data were exported in an ASCII files (PTS format), which contain 3D coordinates together with the intensity value of each point.

As the scanned data were exported to .PTS format, the intensity value of each point was ranged from -2047 to +2048. Based on the general requirements of visualization of the output image, all intensity values were transformed linearly to 0 -255 as an 8 bit grayscale.

Terrestrial laser scanners allow millions of points to be recorded in a few minutes, but it is difficult for them to obtain 3D coordinates of a certain point. Usually we use sphere or plane target to solve the problem. In this experiment the samples we used are all plane, so the 3D coordinates of each sample at one position can be used for plane fitting in order to fit planes to the data and determine the plane accuracy, and the precision index of each scan can be acquired.

After each plane was fitted, three statistical parameters, i.e. plane fitting accuracy σ_p , average intensity \bar{I} of all points on the fitted plane and its standard deviation σ_I could be

calculated. The plane fitting accuracy σ_p is also used to stand for the range accuracy of the sample at each specific position. Mean intensity \bar{I} and its standard deviation σ_I stands for the sample intensity value and the intensity quality respectively at that position.

IV. RESULTS

According to the data processing procedure, three statistical parameters of different targets in each case were calculated and displayed by graphs and tables. In order to analyze the results easily, the distance and the incidence angle at each position were used to stand for the scanning station, not having their actual meanings.

A. Analysis of the targets of standard reflector

To the targets of standard reflector, the intensity values of targets at each position are shown in Fig.1. There is a clear tendency of decreasing values of intensity as the incidence angle is increasing. In Fig. 1, we can also see that the intensity lines of 55% reflector are above those of 35% reflector. In other words, the intensity values of 55% reflector are always greater than those of 35% reflector when the two targets are scanned at the same position. This means when two targets have the same heterogeneity, the target with high reflectance provides the high intensity value.

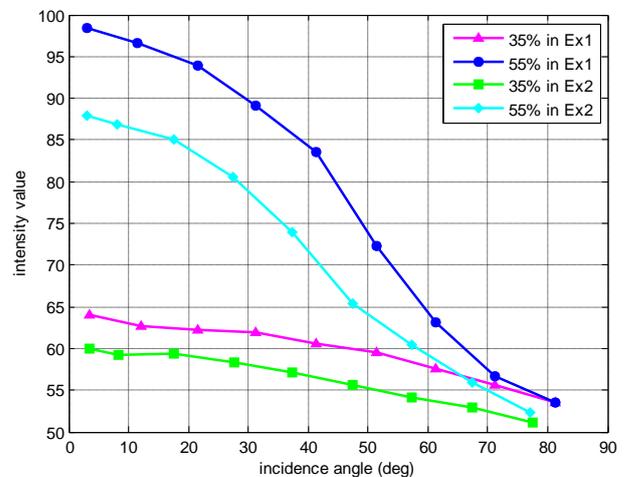


Figure 1. Intensity value in dependence on incidence angle in Ex1 and Ex2 (reflectivity 35%, 55%)

For standard target, it is obvious that the target properties not only determine the target intensity value, but also affect the range accuracy and the standard deviation of intensity value. Fig. 2 shows the range accuracy values of two standard reflectors at each position in Ex1 and Ex2. At the same scanning position, the range accuracy value of 35% target is higher than that of 55% target, except at one scanning state. That is, the 35% target has worse range accuracy than 55% target. We can also see the similar phenomenon in Fig. 3, namely, the standard deviation of mean intensity of 55% reflector is less than that value of 35% reflector when they are scanned at the same position. High reflectivity causes high intensity quality, while Low reflectivity causes low intensity

quality. These experiment results of standard targets match with our expectations very well.

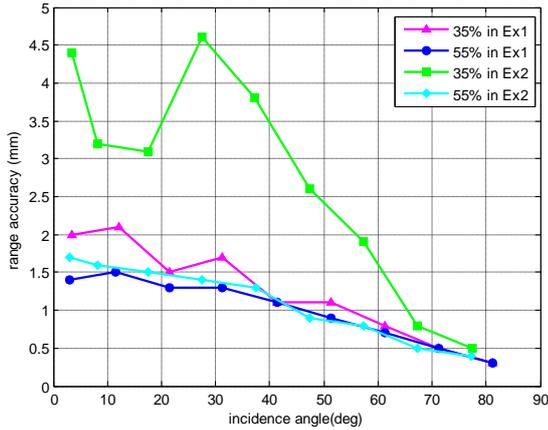


Figure 2. Range accuracy σ_P [mm] in dependence on incidence angle in Ex1 and Ex2 (reflectivity 35%, 55%)

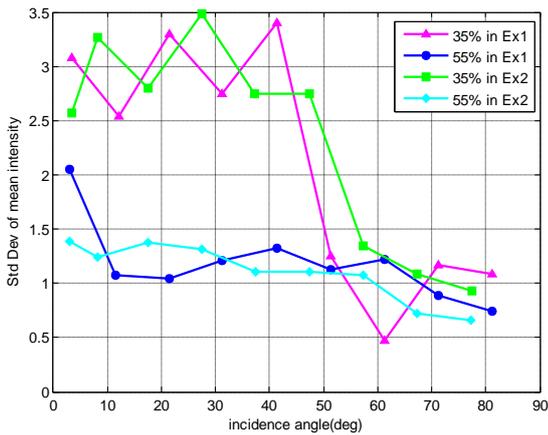


Figure 3. Standard deviation of mean intensity σ_I in dependence on incidence angle in Ex1 and Ex2 (reflectivity 35%, 55%)

B. Analysis of common color

The effect of target's color on the point quality is major depended on the color reflective properties with respected to the laser wavelength. Fig.4 illustrates the variation of intensity value with color at each incidence angle. The intensity lines are plotted sequentially from top to bottom except the state of small incidence angle. Yellow, cyan, green and white have high intensity value, while blue, grey, red and black have low intensity value. These results are consistent with the spectral reflectance in green band.

Due to the fact that the selected colors are not standard materials, the results in range accuracy and the standard deviation of intensity value are not consistent with the general expectation. Though the order of range accuracy is not strictly corresponding with that of intensity value one another, the range accuracy is also related to the color reflectivity. Yellow, cyan and green color patches have relatively high range accuracy, while the range accuracy of red and that of blue color patches are low (Fig. 5). Fig. 6 shows the relationship between intensity value and its related standard deviation σ_I .

These lines in Fig.6 intersect each other and no law can describe the relationship.

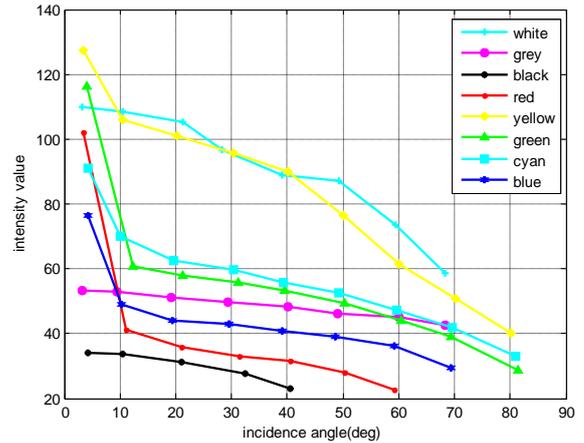


Fig. 4 Intensity value in dependence on incidence angle in Ex2 (all color samples are included)

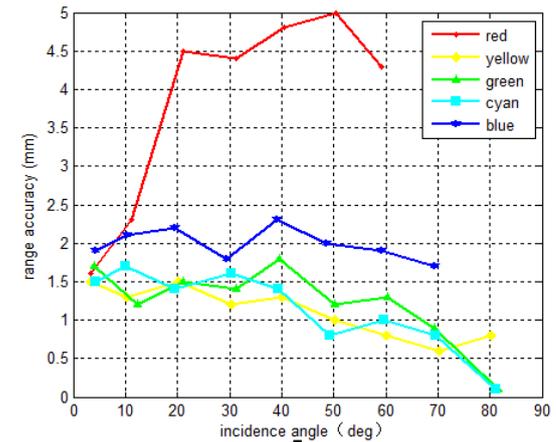


Figure 5. Range accuracy σ_P [mm] in dependence on incidence angle in Ex2 (red, yellow, green, cyan, and blue are included)

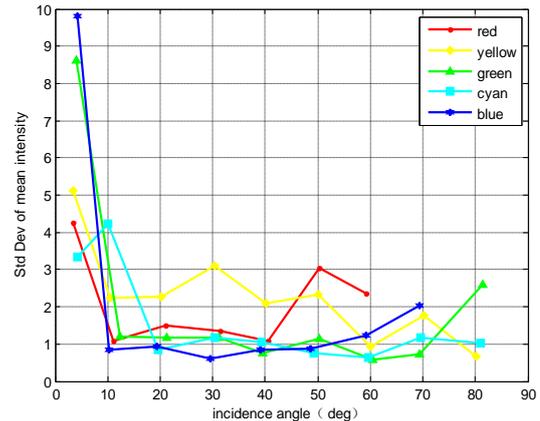


Figure 6. Standard deviation of mean intensity σ_I in dependence on incidence angle in Ex2 (red, yellow, green, cyan, and blue are included)

C. Analysis of building materials

With the complexity and heterogeneity of the selected building materials, there will be no point or obvious errors in some scanning cases. Here only some reliable scanned data are researched. Table 2 lists the statistical parameters calculated from reliable scanned data.

TABLE II. DESCRIPTIVE STATISTICS FOR BUILDING MATERIALS AT SOME SCANNING POSITIONS IN EX1, EX2 AND EX3

Position	Parameters	wood	brick	concrete	asphalt	marble	granite
10m 0°	Mean intensity	107.05	49.57	87.31	42.53	84.83	62.35
	Range accuracy (mm)	3.4	4.5	2.8	3.6	3.8	2.3
	Std Dev of mean intensity	4.22	1.74	3.11	1.49	5.49	1.48
10m 40°	Mean intensity	83.45	48.10	77.86	39.47	62.83	58.6
	Range accuracy (mm)	4.7	2.5	5.6	3.1	3.5	1.6
	Std Dev of mean intensity	4.42	1.59	3.61	1.49	1.78	1.59
10m 70°	Mean intensity	56.64	45.3	61.46	39.12	54.17	50.73
	Range accuracy (mm)	1.4	0.7	0.4	2.3	2.5	0.4
	Std Dev of mean intensity	1.42	1.47	0.95	1.44	1.46	1.35
30m 10°	Mean intensity	94.80	46.54	74.13	39.19	67.22	57.57
	Range accuracy (mm)	4.3	2.4	4.1	4.0	4.0	3.5
	Std Dev of mean intensity	5.48	1.59	4.38	0.87	4.78	1.20
30m 50°	Mean intensity	61.70	44.81	61.95	37.26	56.62	52.90
	Range accuracy (mm)	4.2	1.4	3.3	3.5	1.5	2.7
	Std Dev of mean intensity	1.48	1.53	1.05	2.18	1.81	1.10
70m 0°	Mean intensity	53.19	36.54	47.70	25.81	47.08	42.63
	Range accuracy (mm)	1.5	3.6	4	3.5	2.9	1.9
	Std Dev of mean intensity	1.30	1.82	1.04	3.19	1.24	0.97

From Table 2, we can draw some conclusions. For any scanning position, there is a regular pattern of the intensity values of six building materials. Wood has the highest intensity value, followed by concrete, granite, marble and asphalt. Although the intensity value of wood is the highest, its intensity fluctuation is also the biggest, from 107.05 to 53.19; on the contrary, the intensity fluctuation of asphalt with the lowest intensity value is little, from 42.53 to 25.81.

The two correlations, i.e. intensity value and range accuracy, intensity value and its related standard deviation, are uncertain. Granite has middle intensity value with the highest data quality in range accuracy and the standard deviation of mean intensity; however wood has the highest intensity value with relatively poor data quality.

V. CONCLUSION AND FUTURE WORKS

This paper investigates TLS intensity data dependence on target properties from two target aspects of material and color. From the data obtained it is evident that the target reflectivity with respect to the laser wavelength determines its intensity value for all samples. As for the two kinds of relationship, namely intensity value and range accuracy, intensity value and its standard deviation, are different to different feature targets. For the target with surface homogeneity, the intensity value is inversely proportional to the range measurement accuracy and its standard deviation. But for the common materials with surface heterogeneity, there is no rule can be founded in the two relationships. Color has a great impact on TLS intensity data. The colors with high reflectivity at the laser wavelength have higher intensity values.

The results of this paper provide a basis for the subsequent applications of intensity data, but these are not sufficient for understanding the target intensity characteristic. In further studies, we would analyze the effect of other factors on TLS intensity data and study the calibration method of intensity data.

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REFERENCES

- [1] H. Hasegawa, "Evaluations of LIDAR reflectance amplitude sensitivity towards land cover conditions," *Bulletin of the Geographical Survey Institute*, Vol. 53, pp. 43-50, 2006.
- [2] S. Kaasalainen, H. Kaartinen, and A. Kukko, "Snow cover change detection with laser scanning range and brightness measurements," *EARSeL eProc*, vol. 7, pp. 133-141, 2008.
- [3] J. N. Liu, and X. H. Zhang, "Classification of laser scanning altimetry data using laser intensity," *Geomatics and Information Science of Wuhan University*, vol. 30, pp. 189-193, 2005.
- [4] L. Huang, X. S. Lu, and Y. Liang, "Building Facade Extraction and Classification Using Laser Scanning Intensity," *Geomatics and Information Science of Wuhan University*, vol. 34, pp. 195-198, 2009.
- [5] J. Clark, and S. Robson, "Accuracy of measurements made with CYRAX 2500 laser scanner against surfaces of known colour," *IAPRS, XXXV (B5)*, 2004, pp. 1031-1036.
- [6] A. Bucksch, R. Lindenbergh, and J. van Ree, "Error budget of terrestrial laser scanning: influence of the intensity remission on the scan quality," *Proc. in the GeoSiberia*, Novosibirsk, Russia, 2007.