COMPARISON OF WORKING EFFICIENCY OF TERRESTRIAL LASER SCANNER IN DAY AND NIGHT CONDITIONS

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KEY WORDS: Laser scanning, range, illumination, 3D modelling

ABSTRACT:

Terrestrial Laser Scanning is a popular and widely used technique to scan existing objects, document historical sites and items, and remodel them if and when needed. Their ability to collect thousands of point data per second makes them an invaluable tool in many areas from engineering to historical reconstruction. There are many scanners in the market with different technical specifications. One main technical specification of laser scanners is range and illumination. In this study, it is tested to be determined the optimal working times of a laser scanner and the scanners consistency with its specifications sheet. In order to conduct this work, series of GNSS measurements in Istanbul Technical University have been carried out, connected to the national reference network, to determine precise positions of target points and the scanner, which makes possible to define a precise distance between the scanner and targets. Those ground surveys has been used for calibration and registration purposes. Two different scan campaigns conducted at 12am and 11pm to compare working efficiency of laser scanner in different illumination conditions and targets are measured with a handheld spectro-radiometer in order to determine their reflective characteristics. The obtained results are compared and their accuracies have been analysed.

1. INTRODUCTION

Terrestrial Laser Scanning (TLS) is becoming a more popular topic in Geomatics with its applicability and wide area of use. Studies show that measurement method of laser scanner (time of flight, phase measurement or optical triangulation laser radar) has significant importance in the accuracy and quality of the scan therefore appropriate type of scanner should be chosen specifically for the purpose of the scan (Schulz et. al., 2004). Also the scanned material and material of the targets effect the scanning quality and accuracy because of the differences in intensity and surface reflectivity (Voegtle et. al., 2008). In this study two different scans has been conducted to determine the effect of environmental lighting (mainly solar illumination). Scans have been carried out during mid-day and night conditions at the same spot with same targets. The obtained results has been compared according to obtained detail level (according to the amount of points obtained from a specific target) and intensity values of the same objects between two different scans.

2. LASER SCANNING FUNDAMENTALS

Böhler and Marbs, described Laser Scanning as; Measuring horizontal and vertical angles distances to an object using a systematic pattern either by using phase difference or time of flight method (2002). It is also stated that the range acquisition is performed by deflecting a strongly collimated laser energy in different directions (Pfeifer et. al. 2007).

Along with the distance and horizontal and vertical angles intensity values which consist of the optical power of the backscattered echo of the emitted signal (Pfeifer et. al. 2007) are also measured and stored within the point data and also used in colour mapping in the most basic form of data (Point Cloud). The intensity values are subject to change according to the distance between the scanner and the target water content of the target and atmospheric conditions (Pesci, 2008).

2.1 Terrestrial Scanner Types

Laser scanners differ by many criteria and there are no “one size fits all”. Therefore laser scanners in the market can be categorised; by their areas of use or their measurement systems and/or according to other many parameters. In this study Terrestrial Laser Scanners will be categorised according to their distance measurement methods which is important for this project. Two widely used method for distance measurement in laser scanning is Time of Flight (ToF) and Phase measurement (Pm). In a very general sense ToF method provides longer ranges and higher speeds but sacrifices accuracy for the range while Pm method provides more accurate results in distance measurement but lacks the range of ToF method (Table 1).

Measurement System	Range [m]	Range accuracy [mm]	Manufacturers (examples)
Time of flight	~ 1000	> 10	Mensi, Riegl, Cyra, Callidus
Phase measurement	< 100	< 10	Zoller+Froehlich, IQSun
Optical triangulation, Laser radar	< 10	< 1	Minolta, Leica

Table 1. Classifications of laser scanners (Schulz, 2004)

The Scanner that has been used for this study is a Leica Scan Station C-10 which uses time of flight method with a 532nm visible green pulse laser. Further technical specifications are given in Table 2.

doi:10.5194/isprsarchives-XL-7-W2-19-2013

System Performance	
Accuracy of single measurement	
Position (1-50m)	6 mm
Distance	4 mm
Angle (horizontal/vertical)	60 µrad / 60 µrad (12" / 12")
Modeled surface precision/noise	2 mm
Target acquisition	2 mm std. deviation
Dual-axis compensator	Selectable on/off, resolution 1", dynamic range +/- 5', accuracy 1.5"
Laser Scanning System	
Type	Pulsed; proprietary microchip
Color	Green, wavelength = 532 nm visible
Laser Class	3R (IEC 60825-1)
Range	300 m @ 90%; 134 m @ 18% albedo (minimum range 0.1 m)
Scan rate Up to	50,000 points/sec, maximum instantaneous rate
Scan resolution	
Spot size	From 0 – 50 m: 4.5 mm (FWHH-based); 7 mm (Gaussian-based)
Point spacing	Fully selectable horizontal and vertical; <1 mm minimum spacing, through full range; single point dwell capacity
Field-of-View	
Horizontal	360° (maximum)
Vertical	270° (maximum)
Aiming/Sighting	Parallax-free, integrated zoom video

Table 2. Technical Spesifications of Leica Scan Station C-10 (Leica, 2011)

2.2 Time of Flight Method

ToF method (or pulse based method) is a commonly used range finding method in engineering applications, because of its range advantage and data collection speed advantage over phase method (Caltrans, 2011)

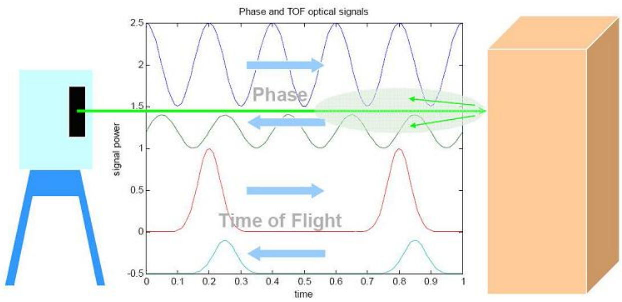

Figure 1: Working principle of phase based and time-of-flight laser scanners (Image courtesy of the UC Davis AHMCT Research Center: http://www.ahmct.ucdavis.edu)

By using this method instruments can obtain ranges up to 1000 meters and acquire 50000 points per second. In the most basic sense time of flight instrument consist of series of sensors that detect outgoing and incoming "pulses" and high precision stopwatches to detect the time intervals between outgoing and incoming signal and by using the speed of light to determine the range.

3. METHODOLOGY

Two different measurements has been carried out at two different time of the day (midday and night) to carry out this test in order to determine whether a difference in range and detail acquisition of the TLS dependant to solar illumination, The test area has been chosen so that it includes vegetation, manmade objects and terrain features in İstanbul Technical University campus (Figure 2).

Figure 2: Overview of the day time scan and the area with image overlay

Existence of distant characteristic objects has been taken into account for detail comparison. Another benchmark used for comparison were the targets (Leica 6 inch Targets) (Figure 3).

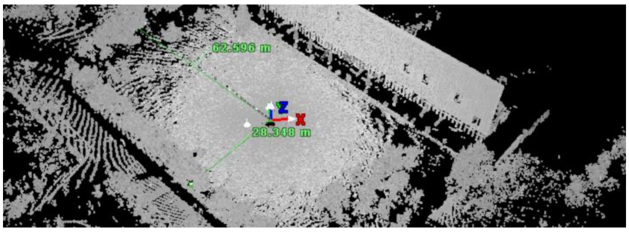

Figure 3: Position of the targets

The Reflectance of targets has been measured (changing between 0.0 to 1.0) with a spectro-radiometer and reflectance results are obtained relative to a white reference (Figure 4).

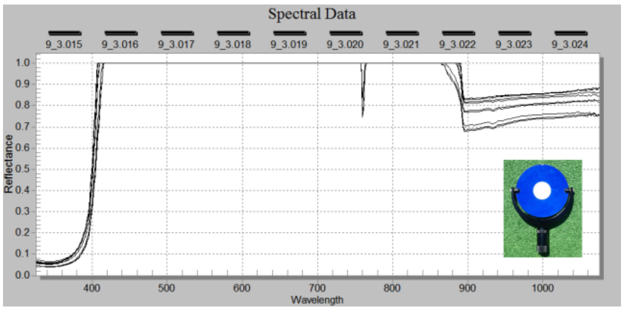

Figure 4: Reflectance chart of target

The intensity values of the targets have been listed in order to help to compare the referenced targets with reflectance values (Table 3.)

Intensity	
-1144	1904
1898	-1144
1895	1898
-1231	1895
1856	-1231
1906	1856
1911	1906
1910	1911
1894	1910
1905	1894
1910	1905
-519	1910
704	-519
1908	704
1894	1908
1908	1894
1909	1908
1913	1909
1911	1913
-1136	1911
1904	-1136
1901	1904
Average = 1318.568	

Table 3: Intensity values of the target surface

The Scans are carried out in high resolution which amounts to approximately 25 million points in a single scan session. The same object in two different scans has been compared to analyse detail difference between two sessions and the amount of detail points on the objects has been analysed and compared to determine if there is any reduction in detail level between day and night conditions (Figure 5)

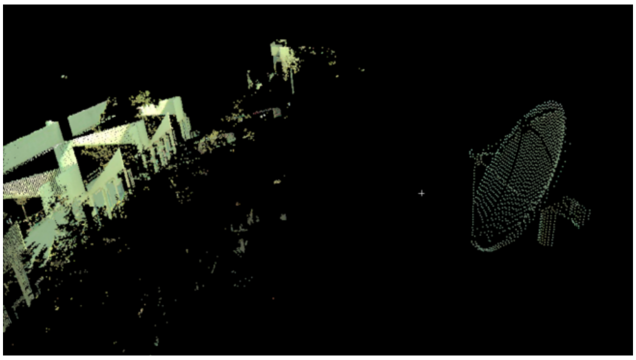

Figure 5: Satellite dish as a sample object

The farthest characteristic object (satellite dish) has been chosen to compare in order to determine if there is any loss in detail between day and night scans.

4. RESULTS

The detail count of the same object in two different lighting condition resulted that there is only %0.002 difference in detail at an object approximately 90 meters far (Figure 6).

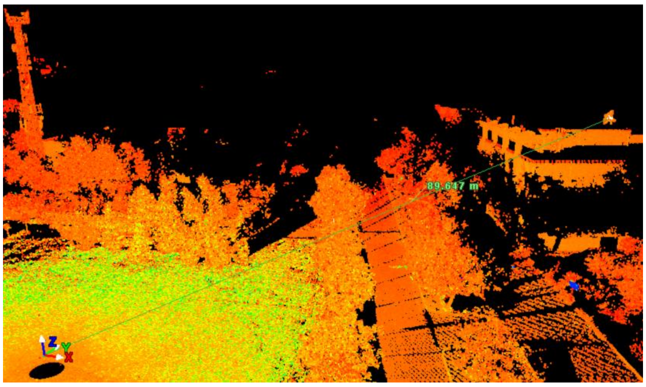

Figure 6: Distance from scanner to satellite dish

The model of satellite dish created from scans in daylight conditions consisted of 1474 points while the model obtained from night measurements consisted of 1471 points. Furthermore the average intensity of the target surface has not shown any significant change between day and night.

5. CONCLUSION

Laser scanners are versatile tools for obtaining large amounts of point data in high speeds and they can be considered weather independent up to a certain point (this independence is subject to specifications of the instruments). According to the information gathered from the scan sessions and detailed comparisons of separated models of the characteristic objects has shown that there is no significant change in detail and maximum scanning distance of the scanner according to solar illumination. The study can be expanded by using a more complex test network with suitable targets (i.e. Lambertian Targets) and more detailed reflectance measurements.

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