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Ability of Terrestrial Laser Scanner Trimble TX5 in Cracks Monitoring at Different Ambient Conditions

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Abstract: Nowadays there are great progresses in surveying instruments, also in precise surveying works the reliability of these instruments must be checked to be used in ideal case. Requirement of high accuracy data in surveying applications needs calibration procedure as a standard routine for all surveying instruments specially when needed in the monitoring small cracks in important buildings. This is due to the assumption that all observed data are impaired with errors. Thus, this routine is also applicable to terrestrial laser scanner (TLS) to make it available for accurate surveying purposes. Here, in the current research paper, two calibration approaches were presented. These approaches are indoor and outdoor system calibration, with the intention to specifically identify the accuracy of the Trimble TX5 scanner with different resolutions in detecting the various widths of small cracks from 1 mm to 9 mm. This calibration has been processed using the 3D Laser Scanning Trimble TX5, a laptop and Scene software packages for data processing allowed us to compare the different crack widths and to evaluate the reliability and the accuracy of results. The calibration of data has been useful in order to identify and analyze over time, accuracy and it also gives us some elements about the validity of the technique for this kind of applications. Finally, this study shows the extraction of precise and reliable 3D metric information.

Key words: TLS · Resolution · Calibration · Target · Accuracy

INTRODUCTION

Terrestrial laser scanners (TLS) uses Light Detection and Ranging (LiDAR) technology to produce highly detailed 3D models for terrain surface, buildings, bridges, tunnels, electrical plants, oil plants and ……etc. However, their performance is highly dependent on the intended application and size of target to scan. These applications vary from forest management to monitoring of tunnels and other critical infrastructure [1]. Laser Scanning describes a method where a surface is sampled or scanned using laser technology. It analyzes a real-world or object environment to collect data on its shape and possibly its appearance. The collected data can then be used to construct digital, 2-D drawings or 3-D models useful for a wide variety of applications [2]. The advantage of laser scanning is the fact that it can record huge numbers of points with high accuracy in a relatively short period of time. It is like taking a photograph with depth information. Laser scanners are line-of-sight instruments, so to ensure complete coverage of a structure multiple scan positions are required [3]. Currently laser scanner technology can be divided into 2 categories: static and kinematic [4]. When the scanner is kept in a fixed position during the data acquisition, it is called static laser scanning. The advantages of using this method are the high precision and its relatively high point density. All static laser scanning can be seen as terrestrial laser scanning, however not all terrestrial laser scanning can be categorized as being static laser scanning [5].

In principle, 3D laser scanners work by sending a laser beam all over the field of view. Whenever the laser beam hits a reflective surface, it is reflected back into the direction of the scanner. To determine the position in space of the captured object, the Laser Scanner Photon uses polar coordinates which consist of the horizontal angle, the vertical angle and the measured distance relative to the Laser Scanner's position. The horizontal angle is given by the rotation angle of the laser scanner about its vertical axis, measured by an angle encoder [6].

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Fig. 1: Trimble TX5 3D Laser Scanning.

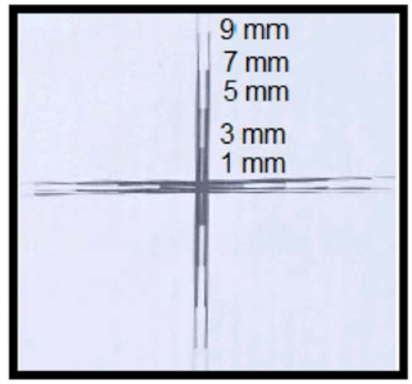

Fig. 2: The designed target (water proof paper sheet).

Fig. 3: Target location indoor.

The vertical angle is defined by the rotation angle of the reflecting mirror which deflects the laser beam on a circular track through the space. This angle is measured by a second angle encoder. The distance sensor measures the distance from the laser scanner to the hit object. In most cases either Phase Shift Measurement or Time of Flight Measurement (= Pulse Measurement) is used to determine the distance [7]. Additionally to the pure position in space, the Laser Scanner Photon determines the reflectivity of the captured surfaces by measuring the intensity of the received laser beam.

The Laser Scanner Calibration Procedure: There are many instruments available to carry out surveying work and all of them require calibration in order to produce accurate data. This requirement also goes to TLS instrument and it is a prerequisite for the extraction of precise and reliable 3D metric information from the point clouds [8]. A calibration has been established by using different input resolutions and ambient conditions [6]. 3D Laser Scanning System consists of Trimble TX5scanner (Fig. 1), a laptop, Scene Software and designed target is a (water proof paper sheet) contains five pairs of parallel lines with distances 1,3,5,7,9 mm between them (Fig. 2).

The Experiments: The calibration field includes two experiments: (1) Indoor (2) Outdoor:

Indoor

Measurements: One target is placed on a wall with distance (3.0 m) from the TLS (Fig. 3). Using different input resolution we get the following data as shown in (Table 1).

Resolution: The resulting scan resolution.it is rang the power of resolution from 1/1, up to 1/32.

Table 1: Illustrate the resolution and time.

Resolution	Time (hh: mm: ss)	Scan size (pt)	Mpts	Point distance (mm/10m)	Point distance (mm/3m)	Cases
1/32	0:02:03	1280 x 534	0.7	49.087	14.7261	Case 1
1/10	0:03:05	4096 x 1707	7.0	15.340	4.6020	Case 2
1/5	0:20:16	8192 x 3413	28.0	7.670	2.3010	Case 3
1/1	1:56:00	40960 x 17067	699.1	1.534	0.4602	Case 4

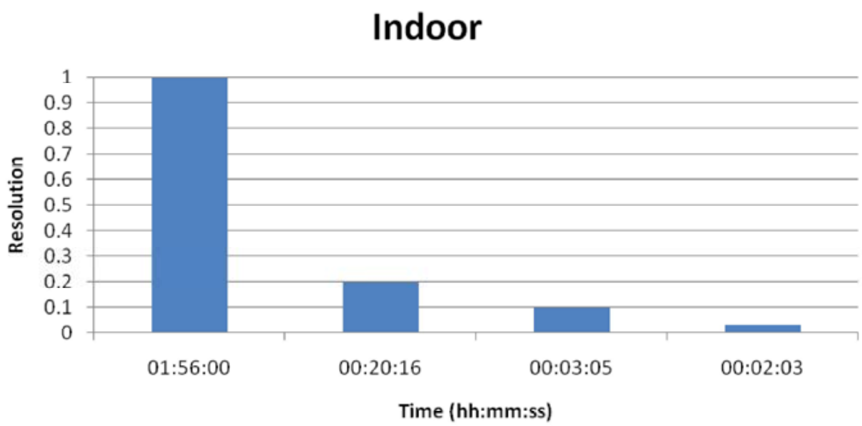

Fig. 4: Illustrate the resolution and time function.

Scan Size [P.t]: The resulting scan duration, vertical and horizontal scan points

Mpts: Resulting scan size in Mega points.

Point Distance [mm/10m]: Is the distance between the captured scan points in mm in a scan distance of 10 meters from the station to the target.

Also, Fig. 4 illustrates the relation between the used resolutions and the time consumed.

Observations Analysis:

Case 1: Nothing(recognize) appeared from target that was mentioned before the experiment took (00:02:03) the resolution intensitywas1/32, the M.P.T_S was 0.7 Mega points, the Point Distance is 14.7261mm in distance 3m (Fig. 5).

By auditing in the data of Case (1), it is noticed that:

- At low value of resolution (1/32) the taken was relatively short (00:02:03).
- The Point Distance is relatively large (14.7261mm) so the pair of parallel lines(on the target) of distance (9 mm) was not recognize
- At low value 0.7 Mega points due to short ofscan duration

Fig. 5: Illustrate the target with the parallel lines (Case 1).

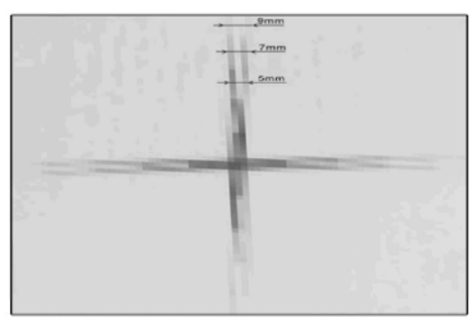

Fig. 6: Illustrate the target with the parallel lines (Case 2).

Case 2: It recognize that two pairs of parallel lines with distances 7,9 mm between them but not recognize the three pairs of parallel lines with distances 1,3,5 mm between them (Fig. 6).

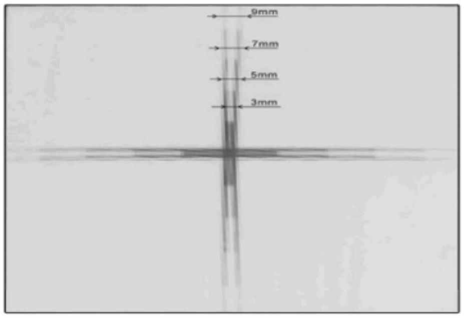

Fig. 7: Illustrate the target with the parallel lines (Case 3).

Fig. 8: Illustrate the target with the parallel lines (Case 4).

Fig. 9: Illustrate the target with the parallel lines outdoor.

By auditing in the data of Case (2), it is noticed that:

- At higher value of resolution (1/10) the taken was relatively short (00:03:05).
- The Point Distance equal (4.602 mm) so It recognize the two pair of parallel lines with distances 7,9 mm between them.
- At value equal 7.0 Mega points due to the scan duration (00:03:05).

Case 3: It recognize that three pairs of parallel lines with distances 5,7,9 mm between them but not recognize the two pairs of parallel lines with distances 1,3 mm between them (Fig.7).

By auditing in the data of Case (3), it is noticed that:

- At higher value of resolution (1/5) the taken was relatively short (00:20:16).
- The Point Distance equal (2.301mm) so It recognize the three pair of parallel lines with distances 5,7,9 mm between them
- At value equal 28 Mega points due to the scan duration (00:20:16)

Case 4: It recognize that all target five pairs of parallel lines with distances 1,3,5,7,9 mm between them the experiment took (01:56:00) the resolution intensity was 1/1, the $M.P.T_S$ was 699.1 Mega points, the Point Distance is 0.4602 mm at distance 3m (Fig. 8).

By auditing in the data of Case (4), it is noticed that:

- At higher value of resolution (1/1) the taken was relatively (01:56:00).
- The Point Distance equal 0.4602 mm) so it recognizes all pair of parallel lines with distances1, 3,5,7,9 mm between them.
- At value equal 699.1 Mega points due to the scan duration (01:56:00).

Outdoor:

Measurements: This experiment has been carried out at the Faculty of Engineering, Ain Shams University, Cairo, Egypt at the Public Works Department building three targets (water proof paper sheet) as described before is placed on a wall (Fig. 9) of the ground, first and second floor with average distances (22.0 m) from the scanner station.by Using different input resolution we get the following data as stated in Table 2.

Table 2: Illustrate the relation of resolution and time.

Resolution	Time (hh: mm: ss)	Scan size (pt)	Mpts	Point distance (mm/10m)	Point distance (mm/22 m)	cases
1/32	00:01:12	534 x 534	0.3	49.087	107.99	Case 1
1/16	00:01:29	1067 x 1067	1.1	24.544	54.00	Case 2
1/4	00:24:58	4267 x 4267	18.2	6.136	13.50	Case 3
1/1	01:36:00	17067 x 7067	291.3	1.534	3.37	Case 4

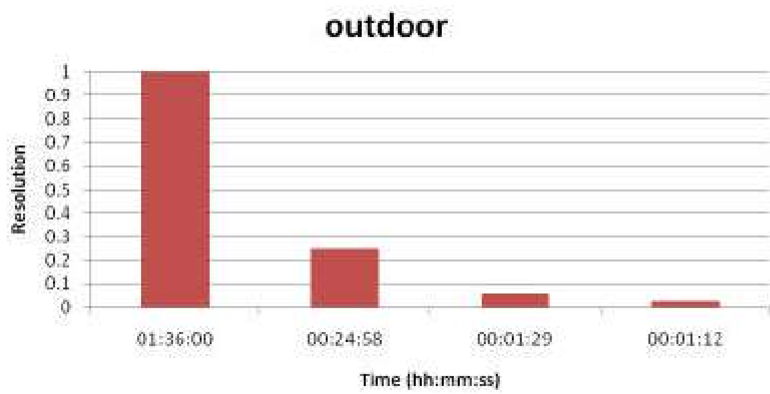

Fig. 10: Illustrate the resolution and time function.

Fig. 11: Illustrate the target with the parallel lines (Cases 1 to 3).

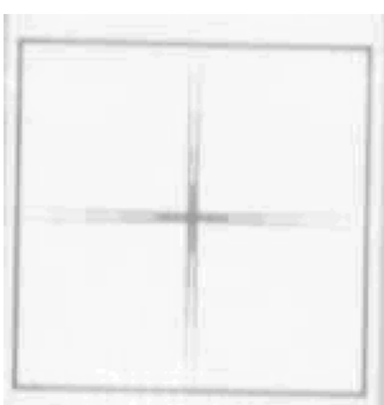

Fig. 12: Illustrate the target with clear three parallel lines (Case 4).

Observations Analysis:

Cases 1, 2 and 3: In these three cases no recognize a target the reason is the distance between the captured scan point of distance is (107.99 mm),(54.00 mm),(13.50 mm) on series as shown clearly from Fig. 11.

By auditing in the data of Cases (1, 2 and 3) outdoor, it is noticed that:

- The low value of resolution (1/32), (1/16), (1/4) the taken was relatively short time (00:01:12), (00:01:29), (00:24:58), respectively.
- The Point Distance is relatively large (107.99 mm), (54.00 mm), (13.50 mm) so the pair of parallel lines (on the target) was were not recognizing.
- At low value (0.3), (1.1), (18.2) Mega points due to short of scan duration.

Case 4: It recognize that target three pairs of parallel lines with distances 5, 7, 9 mm between them the experiment took (01:36:00) the resolution intensity was 1/1; the M.P.T_S was 291.3 Mega points, the Point Distances 3.37mm at distance 22 m (Fig. 12).

By auditing in the data of Case (4) outdoor, it is noticed that:

- At higher value of resolution (1/1) the taken was relatively (01:36:00).
- The Point Distance equal (3.37mm) so it recognize the pair of parallel lines with distances (5, 7,9mm) between them.

- At value equal (291.3) Mega points due to the scan duration (01:36:00).

CONCLUSION

Based on the data provided by TLS, this study developed the calibration techniques to determine and evaluate the accuracy of TLS measurement in monitoring small cracks in buildings. This is very crucial due to the requirement of high accuracy in surveying applications. There are two different calibration techniques that were performed based on: (1) indoor, (2) outdoor.

- The scanner should be placed in appropriate distance depends on the expected captured scanned building.
- For detecting minor cracks with periodic time you must be increase the resolution of the TLS then you expect the process will take longer time which gives higher number of points (Mpts) and better minor details.
- It is preferred to make the calculated point distance (by adjusting the scanner place from the target) to be smaller than the expected crack width to insure its appearance on the scanner.
- According to the previous experiments the selection of resolutions is very essential in scanning process as there no need for high resolution –long time – when the crack width is relatively large.

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