Accuracy Assessment On Point Cloud Dataset from Terrestrial Laser Scanner with Different Objects Surface Properties

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Abstract. Terrestrial laser scanner is the instrument used for generating and receiving point cloud data from the ground either using tripod or handheld. This study focused on identifying the effect of different object surface properties in most standard building materials used towards the accuracy of point cloud captured using TLS that is important for guiding the observer before making measurement. Practically, all the captured data for each surface used the similar aspects in terms of resolution, quality, and point cloud distance using a single scan method. Next, all data processing were processed and computed using FARO Scene, ArcScene and AutoDesk Recap software that are capable to analyse through the reconstructed 3D model. It had been found that cement wall reacts better with the point clouds even the wood expected to give a good result as a few factors had given big impacts towards each of the object surfaces. The finding from this study had identified the reaction of the point clouds on each different object surfaces with various properties varies depending on the roughness, reflectivity strength, colors, textures and type of surfaces that became major indicator to determine accuracy of the distributions and arrangements of point clouds on each surface.

1. Introduction

In the concept, terrestrial Laser Scanner (TLS) systems potentially transfer the beam towards the object and received back the reflected signal from the scanned target. Most of the studies approved that terrestrial laser scanner intensity probable used widely in many applications. However, direct used of the original intensity data was not recommended as there were presence of environmental differences, inconsistency of scanned geometry, variety of radiometric system and other factors involved [6]. The technology of laser scanner is compatible for capturing also classifying a multiplex operation involving heavy equipment as it ability to provide automatic assessment to the observer on the time of operation [7].

This instrument able to capture in detail of the elements such as complicated structures, facades and many more that were incomplete, obstructed or not visible using other instruments as well as achieved high accurate data [4]. The previous study conducted indicates that the quality of the scan point using terrestrial laser scanner depends on four main aspects such as scan geometry, instrument mechanism, atmospheric conditions and the properties of the object surface. The particular scanning geometry
determine by the range and position of object or structures respective to the scanner position by the range between instrument and the object as well as the angle between the normal surface and incidence laser beam from the instrument [4]. This study is focused on the analyzing other aspects that affect the intensity and density of the 3D point cloud dataset using different object surface properties and comparing the measurements collected using terrestrial laser scanner with conventional method for verifying the fidelity of the scanned data achieved.

2. Methodology
The research methods for this study involved three main phases consist of preliminary study, data acquisition and processing as well as accuracy assessment. Figure 1 shows the general methodology for this study.

![General Research Methodology Flowchart](image)

**Figure 1. General Research Methodology Flowchart**

2.1 Study Area
The suitable location for conducting the study was chosen in order to fulfill all the requirements needed in this study. After all the measures taken, it had been made a decision to make the observation at Dewan Agong Tuanku Canselor (DATC) UiTM Shah Alam as the interior surface of the hall fulfill all the materials needed for this study. Figure 2 shows the interior structures and variety of surface materials inside the Dewan Agong Tuanku Canselor (DATC) UiTM Shah Alam.
2.2 Instrument and Equipment
In this study, data collection performed using FARO Focus X330 laser scanner for capturing point cloud data that able to scan up to 976,000 points/second with any object within 0.6-330m. The scan parameter during the data collection was ¼ resolution and 6x quality with point cloud distance of ± 5.000 mm per 8 m as distance between the surface and instrument was approximately 8m. All the observations for each surface using same parameter except for scan duration and the scan size. Besides, this study also performed with conventional data collection by using total station (OS 105-CM 0881).

2.3 Object Surface Properties
There were five types of object surfaces used as the test field in this study which surfaces that commonly exist in many buildings. Wood, aluminium, glass, cotton canvas fabric and cement wall surfaces had different characteristics that give various impact to the behaviour of the point clouds.

3. Result And Analysis

3.1 Scanned point clouds Dataset
In this phrase, each object surface properties gives different results depend on how the point clouds captured react on the surfaces.

3.1.1 Scanned point clouds for wood surface Wood surface has characteristics of having strong density and rough texture. It had been identified that the laser beam reflected pointedly from the surface to the instrument as well as reflect in systematically. The surface is dry and no moisture reacting on it making the point clouds reflected in constant direction. However, for this study, the reflectivity rate becomes slowly due to the rough surface, small holes on the surface make the point cloud penetrate into the hole, and not giving any data as it was reflected back. Figure 3 shows the 3-Dimensional view and the distribution of the point clouds reacting on the wood surface properties.
3.1.2 *Scanned point clouds for aluminium surface* As the aluminium surface has the most reflectivity rate among the others, the acceleration of the reflected point clouds is higher. Same with the wood surface, aluminium also has small holes on the surface as well as the surface has really smooth texture. The result achieved shows that not all the point clouds reflected back in constant direction and behaviour results in missing data that supposedly been captured. However, the point clouds able to penetrate into the small holes and reflected back the air conditioner box behind the aluminium surface thus results to wrong object surface real condition and appearance. The pale yellow shows the aluminium surface and the light grey shows the air conditioner box located behind the aluminium surface. Figure 4 shows the 3-Dimensional view and the distribution of the point clouds reacting on the aluminium surface.

![Figure 3. 3D view of wood surface scanned point clouds](image1)

![Figure 4. 3D view of aluminium surface scanned point clouds](image2)

3.1.3 *Scanned point clouds for glass surface* The glass surface gives the null results of overall scanned point clouds with bad surface appearance. This is because the point scattered in various directions before reaching the instrument as the laser beam scattered easily on glass surface. As the result, it can be identified that the most point clouds refracted into the glass surface and some of them reflected the objects behind the surface due to the transparency of the glass surface. The point clouds distributions were scattered on the entire surface and not giving good result in order to visualize the glass surface. Only the white area is the real glass surface but others were the object reflected from the behind of the glass surface such as stair platform, trees and building. Figure 5 shows the 3-Dimensional view and the point clouds distribution reacting on the glass surface.

![Figure 5. 3D view of glass surface scanned point clouds](image3)
3.1.4 **Scanned point clouds for cotton canvas surface** The result of scanned point clouds for the cotton canvas surface shows the point clouds had successfully given the data of the real surface appearance. The data captured able to cover the overall surface area in details as well as all the point clouds emitted reflected back to the instrument in constant manner. The point clouds were very reflective on this surface but the rate of speed for the reflected points to reach the instrument is slower due to the high absorption strength of the surface. Figure 6 shows the 3-Dimensional view and the point clouds distribution reacting on the cotton canvas surface.

3.1.5 **Scanned point clouds for cement wall surface** For the cement wall, the result shows the scanned point clouds also able to give the correct appearance of the object surface. The white color wall able to be detected by the point clouds and due to the rough surface makes the point cloud able to reflect in constant directions. The point clouds reflected back to the instrument in fast speed rate as the surface was oblique and the rough texture enable the point clouds to reach the surface and reflect back in systematic way. Even the light color surface is able to be captured by the point clouds as long as the surface is oblique and compact. Figure 7 shows the 3-Dimensional view and the distribution of the point clouds reacting on the cement wall surface.

![Figure 6. 3D view of cotton canvas surface scanned point clouds](image1)

![Figure 7. 3D view of cement wall surface scanned point clouds](image2)

3.2 **Density of point clouds Dataset**

From the finding, it was concluded that all the object surfaces give the different number of point clouds density. This is because different surface properties reflect the point clouds emitted differently. From the bar chart as shown in figure 9, the greatest number of point clouds is cotton canvas surface due to the property of the cotton canvas surface that were rough in texture and medium hard surface. The point cloud reflected in systematic way as the point clouds might not scattered from each other and reflected directly towards the scanner. The least dense surface dominated is by glass surface as the scanned point cloud results shows most of the point clouds scattered partly from each other. Due to the smooth and transparent surface, most of the point clouds reflected back to the scanner scattered and mostly did not reflect back to the scanner. Almost half of the point clouds penetrate into the glass surface and reflect point clouds from the surfaces behind the glass wall.

Number of point clouds on the wood, aluminium and cement wall surface is almost the same. This is because all these three surfaces had oblique and rough surface with different surface texture. However, for the aluminium surface some of the point clouds penetrate through the small hole on the aluminium surface and reflect back the point cloud for the air conditioner box that located behind the aluminium surface. As for the wood surface, the smooth surface enables point cloud to scatter before reflect back to scanner even though wood have rough texture. Cement wall had an oblique and rough surface and texture but due to the colour of the wall is white the point cloud unable to be identified as some of the point cloud become translucent. In short, it can be concluded that the different surfaces roughness, reflectivity, texture, surfaces and colours affect the number of reflected point clouds as well as determine on how the behaviour of the point cloud upon reaching the object surfaces. This statement is supported from the study by Che & Olsen, that indicates as laser pulses hit near perfect incidence on highly glossy surface makes the returns saturated that results to range walk which same
to the aluminium result as well as some objects would refract the laser beam same with the glass result thus makes the modelling difficult to be modelled [1]. Figure 8 shows the bar chart for the density of point clouds for each object surface properties.

![Densitiy of Point Clouds](image)

**Figure 8.** Density of point clouds for each object surfaces

3.3 **Accuracy of Target Lines Distance from Different Data Collection Method**

After all the data of target lines distance were measured for each object surfaces using different method tabulated and analyzed, a comparison is computed to identify the difference in term of distance measurement from two data collection method between point cloud datasets with Terrestrial Laser Scanner and conventional method with Total Station. In this study, two (2) datasets for each distance measurements have been collected. Thus, the measurement of distance between target line for each surface properties with using conventional measurement will be a reference as actual value for distance measurement from Terrestrial Laser Scanner. The results show most of the different distance measurement between two (2) data collection method is below than 15 cm. The lowest different is line a3 – a4 which is only 3.4 cm different and the highest different is line c1 – c2 which is 12.3 cm. This indicates that the aluminium surface gives a better result compared with the others surfaces due to several factors. Aluminium surface expose to sufficient light from the surrounding and the color of the surface was bright. Thus, when using the color intensity, it is easier to differentiate between the two separate panels to select correct point clouds before performing the distance measurement.

Next, the highest different with 12.3 cm and 11.9 cm differ to the total station measurement dominate by the line c1 – c2 and line r1 – r2. When conducting the study, these two object surfaces have been scanned with the same file because it’s were situated near to each other. However, this object surfaces location was at the highest level of the hall and there was no sufficient ceiling lamp that can cover the area. The environment is little bit dimmer and the color intensity unable to differentiate the color of the surface with other features. As example, target line c1 – c2 situated on the fabric block and when making the distance measurement, the snapping continuously snap the wrong block edges thus need to use free hand to avoid error. Unfortunately, the measurement still exceeding the expected tolerance due to the distortion of the model as the position of the instrument and the object surface were far from each other. In addition, the cement wall surface that situated above the cotton canvas surface facing the same situation as the object surface located near to the ceiling.

It can be analyzed that from the results obtained, the expected tolerance was below 10 cm for the different in distance measurement for both methods. Plus, the data collected from the total station must more than three datasets to obtain more accurate results. In this study, object edges used as the
reference mark while making the measurement and in order to achieve more compromising result, suitable reference mark must be used for enabling the mark to be invisible for both methods. In short, from this section all the measurements of target lines distance were acceptable and able to prove that the used of Terrestrial Laser Scanner able to replace the conventional data collection method in making measurement. Several factors might affect the scanned data from the TLS instrument but conventional method still been used in order to verify the measurement to ensure the integrity in data collection measurement and observation. Table 1 indicates the comparison of target lines distance from different data collection method.

| Type of surfaces       | Distance (m)          | Total station | TLS | Different (±) |
|------------------------|-----------------------|---------------|-----|---------------|
| Wood (Line w1-w2)      | 7.239                 | 7.175         |     | 0.064         |
| Wood (Line w3-w4)      | 2.464                 | 2.387         |     | 0.077         |
| Aluminum (Line a1-a2)  | 4.782                 | 4.712         |     | 0.070         |
| Aluminum (Line a3-a4)  | 2.383                 | 2.349         |     | 0.034         |
| Glass (Line g1-g2)     | 6.456                 | 6.384         |     | 0.072         |
| Glass (Line g3-g4)     | 2.004                 | 1.954         |     | 0.050         |
| Cotton canvas (Line c1-c2) | 5.274             | 5.151         |     | 0.123         |
| Cotton canvas (Line c3-c4) | 2.631             | 2.570         |     | 0.061         |
| Cement wall (Line r1-r2) | 3.697               | 3.578         |     | 0.119         |
| Cement wall (Line r3-r4) | 1.083               | 1.010         |     | 0.073         |

4. Conclusion
As the conclusion, this study had successfully performed accuracy assessment on the point cloud interval using Root Mean Square Error (RMSE) in order to compute which object surfaces had accurate point cloud distance with the actual value. The impact of the object surface properties towards the density of the point cloud dataset had been investigated and thus comparison for the measurement of target lines observed from different data collection method had been performed. From overall results, it had indicated that roughness, reflectivity strength, colors, texture and type of surfaces became major indicator to determine the reaction of the point clouds generated when reaching the surfaces. Coefficient of reflection which is ratio between reflected and incident energy for bright and smooth surfaces lies between 100% and 70% but when surfaces become darker and rougher it falls to 20% [2]. However, the factors of distance object surface to the scanner and inclination angle took major role for this study. As the target surfaces placed far away from the scanner and higher inclination angle, the point cloud moves away widely from each other thus affect the point clouds interval. Next, the point clouds scattering before reflected back to the scanner is important in order to achieve the same number of points generated with the points reflected. This situation depends on the object surface itself as reflective surfaces tend to scatter the points more compared to less reflective surfaces. Other than that, texture and sensory surfaces determined whether the point clouds will be bounced harder on the surface. Thus, interaction of the point clouds reacting on each target object surfaces give different result in point cloud distributions and arrangement as well as the overview of the scanned point cloud data. Lastly, since this study only perform single scanning method, the expected level of difference between the two data collection method unable to achieve. Even the
differences were in cm level, this study able to prove that the use of Terrestrial Laser Scanning for data measurement could substitute the conventional method.

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