Evaluating the Distance Impact to the Scanning Topographic Object with the 3D Point Cloud Resolution

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Abstract. FARO 3D Terrestrial Laser Scanner (TLS) system was used to evaluate the impact of distance on scanning the topographic, building or structure object due to the lack of knowledge on the impact of the distance toward the resolution of the image produced by the terrestrial laser scanner. There is a lot of high-rise building that need to be monitored from time to time to prevent unwanted catastrophe from accruing in a good plan city. This study aimed to investigate the accuracy of point cloud produced by the laser scanner by scanning the object at a different distance are performed, especially to find a suitable distance for optimum accuracy. The main fieldwork activity involved is the selection of the most appropriate position for setting up the TLS at three different distance which is 30m, 40m and 50m from the building. The chosen position must cover the same area view to make sure the image can be used to compare with each other in term of accuracy. Before scanning the selected side of the building, several targets were placed on the building as it is necessary to tie the building to control points on the ground that have been acquired with Real-Time Kinematic (RTK) Global Positioning System (GPS). The image processing is done by following the flow of the scanning using Scene software to link the target with 3D coordinate and generate a point cloud. The accuracy of the 3D image captured at three different distance generated by the Scene software is compared to evaluate the impact of distances on accuracy. It can be suggested that distance selected for the experiment is reliable for high accuracy measurement in monitoring of structural movement.

1. Introduction

TLS is a fast and point rich measurement technique possible to capture millions point in a very short time, it capable of measuring distance of an object and record it as an image that can be processed to display the point cloud and link with coordinates system [1] [2] [3] [4] [5] [6] [7]. The operation is based on a laser beam being sent in form of phase or pulse the reflections is recorded by receiver to get the distance of the points from TLS based on the time travel. Beside that the returning to the beam carries information such as colour and angle of the specific point of the building. With this, the angle and distance to the object being scanned can be determined through computerised calculation. The TLS derived output is the point cloud with coordinates x, y, z and Set of pictures of measurement [8] [9]. TLS calculations were carried out in order to achieve an accurate three-dimensional model of the object and appropriate applications for any user, that is a three-dimensional model in the context of a point cloud enabling observations to be taken out, creating cross-sections and visualisations of the object, and surveying sketches such as projections, cross-sections and views created from the recorded point cloud,
vector models of structure, manufacturing and engineering facilities, and models of objects with unusual shapes[10] as conducted in Malaysia [15][16].

However, software plays an important role in producing results that provide true coordinates on the image based on coordinate on the ground. The software choices during data processing make an impact the model produces from scanning activities that Can be used and vice versa which is accessible together with the downstream modelling and visualisation tools. The choice of software affects frameworks that can generate how effective the procedures are and the types of models and plans that can be generated. The selection of tools will contribute to the work that can be performed efficiently. Different and possibly several cloud points [11] need to be scanned to obtain total performance of the scenario. Point clouds describing topography that can be generated from laser scanning, image correlation, radargrammetry, Synthetic Aperture Radar (SAR) tomography, time of flight cameras (ToF cameras) and Multi-beam Echo Sounding (MBES). There is no convention for describing a point cloud size. For example, a picture may have a traditional sampling distance of points over the topographical region, rather than it can be described as of interest. This sampling interval depends on the collection process and the device can be as low as a couple centimetres such as from terrestrial laser scanning, but as big as numerous hundreds of meters. Topographic points clouds can cover wider areas, from a few tens of meters to a whole world [12].

2. Methodology
This section introduces about all the work process which all the steps required for this study. The methodology that involved in this project include determining the instrument relevant for data capturing, selection of site, reconnaissance at the site, establishment of control point with RTK GPS, capturing data with TLS, data processing, result analysis and conclusion. Figure 1 show the methodology involved in the study. First, a building with enough space to establish observation position (ground control points) at 30m, 40m and 50m from the building, at that point 3D coordinates is determined as a reference coordinates for TLS data observation on the building. Six points were selected on the building as control points on the building, where they going to get 3D coordinates after processing, the coordinates of this points will be compared between the three different observation station.

![Figure 1. Methodology of the study](image-url)
2.1 Positioning Control Point Location

The establishment of the control points on the ground and building is the most important task before the scanning of the building. The quality of the ground control point is paramount to make sure the TLS will provide high quality coordinates on the building. Six (6) control point have been marked on the building and three on the ground. Static GPS observation is conducted on 4 main ground control points which later will be used as reference for RTK GPS observation on for TLS station. The static observation involving one-hour period for 4 each main station. Figure 2 below show that the ground control point observed using RTK GPS technique that will position the TLS.

![Figure 2. Ground Control Point](image)

2.2 Scanning the Building

In this study, terrestrial laser scanner instrument was used as the main instrument to obtain the point cloud on the building. Using the laser scan technique, the image and point cloud data will be recorded and later assigned with coordinates value based on the TLS position. The observation is conducted with resolution specification on three different distance which is 30-meter, 40-meter, and 50-meter. The setting for of the resolution is 1/1 and the quality is 4x which the highest. The following are the procedure for TLS observation:

- First, setting the instrument at the first station and followed by the configuration of TLS.
- The observation will be carried by scanning the whole building for 5 minutes to get general overview of the target object.
- After scan the whole building observer require to select the angle or area required for observation.
- Set the time for observation on the TLS. All observation for this terrestrial laser scanner is based on constant high resolution and quality of observation. First observation was conducted at the first station which is 30 meters from the building.
- Then, after the observation finished, transfer TLS to second station and third station. Repeat the steps i to iv at all station as shown at Figure 3.

![Figure 3. The position of TLS relative to building.](image)
2.3 GPS Observation for TLS Station

GPS observation is conducted to determine the coordinate of the TLS observation station. For this data collection, MyRTKnet method is used to obtain the coordinate of the station which come with real-time corrections, its capable reach up to centimetre level accuracy. The coordinate is in Easting, Northing and Height of the station as X, Y and Z. Real Time Kinematic (RTK) is a technique used to get the precision of position data derived from satellite-based positioning systems. Procedure of GPS Rapid Static:
- Make sure the roaming receiver is connected to master receiver and the configuration of parameter is correctly set.
- Check the antenna height.
- Record the data in 10 observations at least for each 3 epochs.

2.4 Processing TLS Data

There were several benefits of using laser scanning technology compared other traditional terrestrial surveying techniques. Laser scanning enabled the structure and surrounding site to be recorded in detail with relative ease and speed. FARO SCENE is an important tool for 3D laser scanning that can help to process and manage scan data more efficiently. After the end of the scanning, the data was imported from the scanner SD card into the Faro Scene processing software. The processing is possible after TLS data scanning is completed, and the model of building faced is ready to be generated. TLS capable of capturing point details on the building in a very close interval to rebuild the building in 3D model. The very first step consisted of automatic filtration based on the "Stray" filter to remove the so-called stray (faulty) points. Stray filter eliminates scan points resulted from hitting virtual surfaces with a laser spot or reaching no target at all, e.g. the sky [13]. There are many stages needed to be carried out throughout the compilation of the scenario show in Figure 4.

![Figure 4. Flow of Process using Scene Software.](image_url)

Terrestrial laser scanners (TLS) are electronic tachometers that perform reflectorless distance measurements. The basic version of a terrestrial laser scanner has a transmitter, a spinning mirror, an optical telescope, a detector, and a recorder. The transmitter creates a laser beam that enters the revolving mirror system [14]. The registration technique is a core element in integration of multi-platform, multi-angle, and multi-temporal remote sensing data captured by TLS. The control points on the target of the building should be assigned in scene software as reference coordinate to calculate the possible coordinate of the other feature captured by laser scan. By registering the image using the survey point on the building all the point cloud on the image has their coordinate system that can be evaluate root means square errors, weather it acceptable or beyond the allowable error in surveying field.
3. Result and Analysis

3.1 Real Time Kinematic (RTK)

This practical task will involve 3 station which is 30m, 40m and 50m. Each meter collects 10 observations for each 3 epochs. The tolerance between reference coordinate is 0.03 for Easting and Northing and 0.06 for the height. Table 1 below show the table of RTK calculation.

| Table 1. Station 1 Epoch 1 |
|-----------------------------|
| No. Observe | 1 | 2 | 3 |
| Easting (E) | -2184.9010 | -2184.9906 | -2184.9906 |
| Northing (N) | 7.5260 | 7.5300 | 7.5300 |
| Height (H) | 0.003 | 0.013 | 0.013 |

| Table 2. Station 1 Epoch 2 |
|-----------------------------|
| No. Observe | 1 | 2 | 3 |
| Easting (E) | -2184.9010 | -2184.9906 | -2184.9906 |
| Northing (N) | 7.5260 | 7.5300 | 7.5300 |
| Height (H) | 0.003 | 0.013 | 0.013 |

| Table 3. Station 1 Epoch 3 |
|-----------------------------|
| No. Observe | 1 | 2 | 3 |
| Easting (E) | -2184.9010 | -2184.9906 | -2184.9906 |
| Northing (N) | 7.5260 | 7.5300 | 7.5300 |
| Height (H) | 0.003 | 0.013 | 0.013 |

| Table 4. Station 1 Epoch 1 |
|-----------------------------|
| No. Observe | 1 | 2 | 3 |
| Easting (E) | -2184.9010 | -2184.9906 | -2184.9906 |
| Northing (N) | 7.5260 | 7.5300 | 7.5300 |
| Height (H) | 0.003 | 0.013 | 0.013 |

| Table 5. Station 2 Epoch 2 |
|-----------------------------|
| No. Observe | 1 | 2 | 3 |
| Easting (E) | -2185.7480 | -2185.7370 | -2185.7370 |
| Northing (N) | 7.5040 | 7.5080 | 7.5080 |
| Height (H) | 0.057 | 0.057 | 0.057 |

| Table 6. Station 2 Epoch 3 |
|-----------------------------|
| No. Observe | 1 | 2 | 3 |
| Easting (E) | -2185.7480 | -2185.7370 | -2185.7370 |
| Northing (N) | 7.5040 | 7.5080 | 7.5080 |
| Height (H) | 0.057 | 0.057 | 0.057 |

Means

RMS (m) 0.003 0.003 0.003
RTK is used for applications that require higher accuracies because RTK can position them to the centimetres in real time. In this practical, the data are collected by 3 epochs at every station Ground Control Point. Every epoch has 10 readings taken and one reading takes 5 seconds to complete. Besides that, height of RTK collect in Ellipsoidal Height and it should get the true height which is Orthometric Height. Formula for the calculation is $H = h - N$ where $H$ is Orthometric Height, $h$ is Ellipsoidal Height and $N$ is Geoid Height. For the RMS data observation in three decimal place and the residual value not more than three times of RMS value.

Based on the data observation, the observation is under the criteria which is at a good quality. Rejection of data are required to verify the condition of data whether good or bad. The results are under allowable RMS because of the data that have been collected fulfill the accuracy that have been stated.

### 3.2 Generated Image from TLS Observation

There are 3 types of distance of terrestrial laser scanned that used to observe which is 30m, 40m and 50m (Figure 5, Figure 6, Figure 7). Based on the output image that show on those figures, the observation is made with the highest setting of quality and resolution which is 1/1 for the resolution setting and 4x for the quality setting but by different distances. It clearly shows that the farther the distance is taken, the shorter the time taken to observe with specific angular want to observe regardless of whether the higher the quality and resolution of the data taken.
3.3 Point Cloud of Scanned Data

This Terrestrial Laser Scanner by using Faro instrument, the data scanned for the point cloud are 122,000 points per second at submillimetre accuracy. As stated on the Table 11 even though the rate of scanning is the same the size of points cloud is different as distance from target changed. Points cloud will increase in size when the instrument moves away from the target causing the number of the points reduced in relation that the time consume for the scanning change accordingly at the same resolution and quality of scan setting set before scanning operation.

| Distance (Meter) | Time Taken (Minute) | Point Cloud       |
|------------------|---------------------|-------------------|
| 30               | 34                  | 34,686,721        |
| 40               | 36.15               | 35,561,048        |
| 50               | 26                  | 18,799,424        |
3.4 Comparison of Control Point Coordinate Between Different Distance.

Laser scanning is a prosperous spatial data acquisition method with using electromagnetic wave to measure distance from transmitter to the points on the object. It is applicable for measurement volumes below 1m³ up to areas of hundreds and thousands of km². It falls well within the realm of photogrammetry where every single point captured at submillimetre at a very rapid rate to build a large number of point cloud with x and y coordinates plus distance from transmitter. Laser scanner uses laser light to measure distances from the sensor to the object in a systematic pattern. The distance measurement aspect, i.e. the ranging, relies on laser light for performing that measurement based on the measurement an arbitrary coordinates system is established for the image until the image register to local coordinates system during the processing of the image in scene software.

There are commonly two different principles can be used to measure the distance between sensor system and target points at a different resolution depending on the frequency of the laser wave. They differ in accuracy, but all have their justification for a certain range of distance from the target and frequency. The largest ranges can be probed using the pulse round trip time measurement principle, obtaining mm-accuracy. Short distances, e.g. up to 100m, can be measured faster and more accurate with the phased based measurement technique. Shorter distances, e.g. up to 2m, can be measured with even higher precision, e.g. accuracy better than ±1mm, with triangulation. The following are comparison local coordinates of the control points on the building made between Easting, Northing and Height of the target.

| No. of Target | Distance (Meter) | Difference (Meter) |
|---------------|------------------|--------------------|
| 30            | 40               | 50                 |
| A1            | -2180.023        | -2189.018          | 0.0059   |
| A2            | -2195.133        | -2195.132          | 0.0006   |
| A3            | -2201.084        | -2201.087          | 0.0012   |
| A4            | -2189.097        | -2189.098          | 0.0009   |
| A5            | -2195.002        | -2195.005          | 0.0018   |
| A6            | -2201.102        | -2201.102          | 0.0006   |

| No. of Target | Distance (Meter) | Difference (Meter) |
|---------------|------------------|--------------------|
| 30            | 40               | 50                 |
| A1            | -6734.327        | -6734.327          | 0.0037   |
| A2            | -6734.368        | -6734.361          | 0.0026   |
| A3            | -6734.417        | -6734.417          | 0.0005   |
| A4            | -6734.352        | -6734.350          | 0.0006   |
| A5            | -6734.393        | -6734.394          | 0.0005   |

| No. of Target | Distance (Meter) | Difference (Meter) |
|---------------|------------------|--------------------|
| 30            | 40               | 50                 |
| A1            | 18.6594          | 18.6519            | 0.0075   |
| A2            | 18.6404          | 18.642             | 0.0016   |
| A3            | 18.6605          | 18.6593            | 0.0002   |
| A4            | 15.4053          | 15.4072            | 0.0006   |
| A5            | 15.4731          | 15.4728            | 0.0002   |
| A6            | 15.4547          | 15.4528            | 0.0012   |

Based on the tables 12, 13 and 14 above showed that the comparison of height value for observation from 30m compared with 40 meters station, the minimum and highest difference are 0.0002 mm and 0.002 mm. But for 30 meters compared to 50 meter, the minimum and highest difference are 0.0003 mm and 0.002 mm. Finally, the difference between 40 meters and 50 meters are 0.0003 mm and 0.002 mm respectively. It shows, most of the accuracy analysis of 30 meter until 40 meters are accurate, meaning all of them suitable distance that can be used to do the scanning with a very highest accuracy.

4. Conclusion

Based on this study, it can be inferred that distance selected for the experiment is reliable for high accuracy measurement in monitoring of structural movement. It means that the 30m, 40m and 50m produce a high-resolution point cloud but of course as the scanner move away further from object the resolution decrease together with scanning time and number of point cloud but it still in millimeter.
accuracy that required by surveyor for high accuracy survey job. Through this study, concept of laser scanner data capturing at different distance, processing scanned scene and the analysis achievable coordinate accuracy on the image capture using TLS has been properly evaluated. The distance between station and targeted object needs to be measured to make the point cloud produced during data acquisition fail with the resolution that can provide an equal accuracy. If the distance is too far from the target and has the possibility of reducing resolution and accuracy the station needs to be relocate to a closer position to an equal resolution for the whole image when it jointed to gather.

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