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High resolution survey for topographic surveying

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Abstract. In this decade, terrestrial laser scanner (TLS) is getting popular in many fields such as reconstruction, monitoring, surveying, as-built of facilities, archaeology, and topographic surveying. This is due the high speed in data collection which is about 50,000 to 1,000,000 three-dimensional (3D) points per second at high accuracy. The main advantage of 3D representation for the data is that it is more approximate to the real world. Therefore, the aim of this paper is to show the use of High-Definition Surveying (HDS), also known as 3D laser scanning for topographic survey. This research investigates the effectiveness of using terrestrial laser scanning system for topographic survey by carrying out field test in Universiti Teknologi Malaysia (UTM), Skudai, Johor. The 3D laser scanner used in this study is a Leica ScanStation C10. Data acquisition was carried out by applying the traversing method. In this study, the result for the topographic survey is under 1st class survey. At the completion of this study, a standard of procedure was proposed for topographic data acquisition using laser scanning systems. This proposed procedure serves as a guideline for users who wish to utilize laser scanning system in topographic survey fully.

1. Introduction

Topography refers to the natural features, relief and man-made features which exist on the surface of the Earth. All of these are represented in the topographic map by applying cartographic rules. The difference between planimetric map and topographic map is the additional of contour lines on topographic map. The most common techniques used for topographic surveying are using total station, aerial photogrammetry, Global Positioning System (GPS) and remote sensing technique which use satellite imageries. Since mid-2000, TLS is getting popular for topographic surveying [1-3]. This is because this technology is capable of collecting up to a million highly accurate point clouds per second. At the same time, TLS also decreases the turnaround time and the data has high level of completeness. Currently, most of the researchers who are using this technology for topographic survey only provide their outputs in virtual 3D visualization (softcopy) forms instead of hardcopy maps [2], [4], [5]. Besides this, TLS is also involved in many engineering fields such as construction [6], monitoring [7], as-built of facilities [8], archaeology [9] and other applications.

Therefore, TLS was chosen as the geomatic tool for topographic surveying in this study. The aim of this study is to investigate the capability of this technology for capturing and producing topographic data. This is carried out by using the same method as applied to the total station which utilises the backsight and foresight target for traversing. In this case, the HDS targets provided by the vendor were used. After completing the data collection, Leica Cyclone 7.3 software was used to register and georeference the individual set of scans into a single geometric space based on a desired coordinate system. This is because the set of point clouds obtained at individual scan station are not joined together but referring to an arbitrary polar coordinate system of the instrument. After that, the unwanted data such as noise, vegetation and building were filtered using ALDPAT software before

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generating the Digital Terrain Model (DTM) and the contour map in Surfer 8 software. At the same time, Cyclone II Topo software was used to digitize the topographic features. Lastly, the topographic plan was produced using AutoCAD 2011 software. The detail of the workflow for the data collection and data processing is discussed in section 3 and 4 respectively.

2. Study area

The main entrance of Universiti Teknologi Malaysia (UTM) was chosen as the study area for this investigation as shown in figure 1. The traverse loop is highlighted in blue polygon. The main man-made features found in this test area are helipad, UTM main gate, two blocks of hostel, one building belonging to the Faculty of Built Environment, open space parking lots, half of the UTM lake, a guard house and two roads. The total size of the area is about 70754 metre squares (m^2). This area was chosen because it covers most of the important elements for topographic mapping, such as building, water body, road, slope, bridge, and vegetation. Furthermore, there is a geodetic monument within the area which is used for establishing the mapping coordinate datum.

Figure 1. Location of study area discussed in this paper.

3. Techniques used for data collection

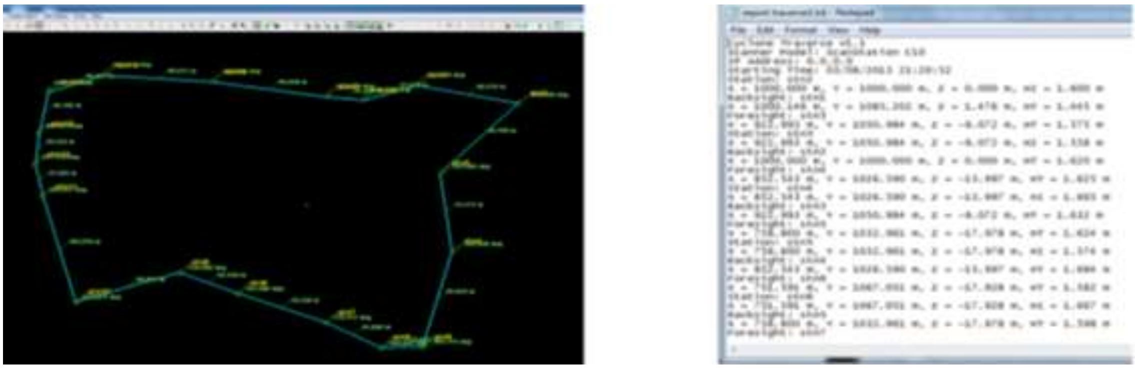
Data collection was carried out by using the traversing method for both TLS and total station. A total of 18 scan stations were set up to completely cover the study area. The 6” (15.24cm) HDS targets provided by the developer were used in this data collection for back station and fore station. First of all, the laser scanner Leica ScanStation C10 needs to be set on a tripod and followed by levelling and centering the instrument. This step is important because the instrument must be levelled correctly and plumbed directly over the top of the traverse mark or station on the ground in order to minimize the error in measurement. After setting out the TLS, bearing and coordinates of the back station were set in order to define the fore station. The line of sight for both back station and fore station with the instrument is required. In this study, the 3D point clouds were collected using medium resolution mode (0.1m of point spacing for both horizontal and vertical spacing at the range of 100m). Each scan took around 7 minutes and 10 minutes additional for capturing image (RGB value). At the same time, the Field-of-View (FOV) of scanner set to 360° for horizontal and 270° for the vertical axes. Moreover, the ideal distance between the scanner and surrounding features is not to exceed 200m. All of these steps were repeated for the rest of the stations until the traverse loop is closed. On the other hand, total station Topcon GTS 325 was also used to carry out topographic survey for that area occupying the same traverse stations. The time spent for completing the survey the area was 2 days for TLS and 3 days for the total station because of the batteries power and weather constraint.

3.1. The 3D laser scanner Leica ScanStation C10

Leica ScanStation C10 is categorized as Time-of-Flight (TOF) scanner which offers an optimal range of 300m [10]. This kind of scanner measure the distance between the scanned object and scanner by calculating the total time travelled (Δt) from emission of laser pulse and the detection of the laser which was reflected back from the object. That is (Δt) times the speed of light (c) and divides the product by 2. Besides this, the nominal scanning rate of this scanner is 50,000 points per second. The accuracy of the single measurement for this instrument is 4mm for distance and 12” for angle. The maximum FOV for this scanner is 360° for horizontal and 270° for vertical axes with the help of Smart X-Mirror design. Furthermore, the integrated high resolution digital camera in the scanner also provides ability to record the intensity value for point cloud. In addition, the total station-like interface and on-board graphic colour touch screen display also allow users onsite data viewing. Moreover, this scanner also has internal memory storage of 80 Gigabytes which is ideal for large area surveying.

4. Data processing

The raw data collected using TLS was directly transferred from the scanner to computer using a data cable. After that, the database for this project was created in Leica Cyclone software. Then, the sequence of the scan station and corresponding instrument height were entered correctly in the Cyclone Traverse Editor. The traverse was verified once all the essential information was entered. After verification of the traverse, the traverse loop was displayed graphically (figure 2a) and a report on the traverse loop was generated (figure 2b). From the report generated in Cyclone, the result shows that the linear misclosure is 1:66541 which means the survey is a 1st class survey.



(a) **(b)**

Figure 2. (a) Graphic of traverse loop and (b) traverse report generated in Cyclone software.

Then, this is followed by process of point cloud registration. The process of registration is to transform all the individual scans into a single dataset using 6 parameters of rigid-body transformation [11]. After finished registration, the process of georeferencing is carried out with 3 control points. The process of georeferencing is to transform the polar coordinate system which is the instrument coordinate system into geodetic coordinate system [11]. After that, Model Space of the data was created as shown in figure 3.

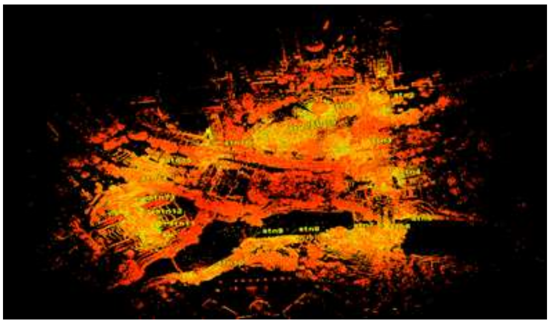


Figure 3 Registered point clouds.

The topographic features were digitized in Cyclone II Topo software by assigning appropriate code for each type of features as shown in figure 4. This step could be enhanced by using segmentation method based on the geometry of the features [5]. At the same time, the registered point cloud was imported into ALDPAT software in order to filter out the unwanted data such as man-made features and vegetation using Polynomial Filter. After that, the DTM (figure 5a) and the contour map were generated using software Surfer 8 (figure 5b) respectively. Then, both digitized topographic features and the contour map were exported in .dwg format in order to produce topographic plan in AutoCAD 2011 software.

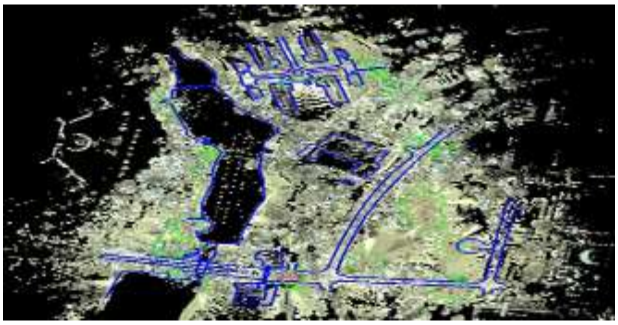
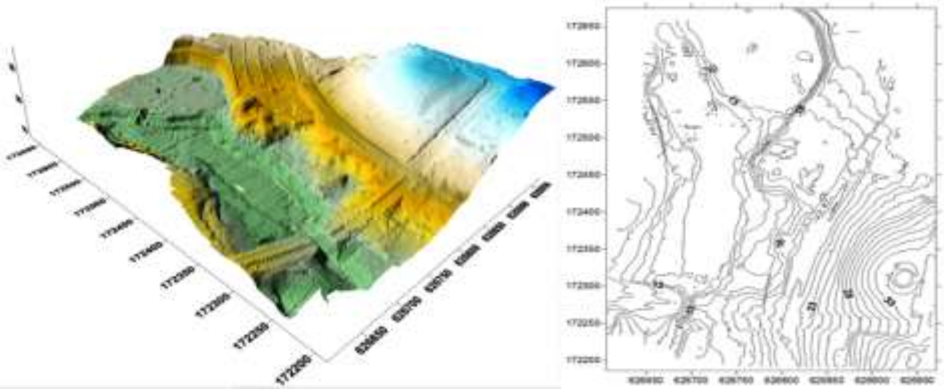


Figure 4. Digitizing of topographic features in Cyclone II Topo (blue clour).



(a) **(b)**

Figure 5. Generated (a) DTM and (b) contour map using Surfer 8 software.

5. Result and analysis

The final output of this study is a 2D topographic plan as shown in figure 6. The scale of the generated plan is at 1:1000 which is under the category of large scale. The standard of procedure of using TLS for topographic survey is proposed through this study as shown in figure 7.

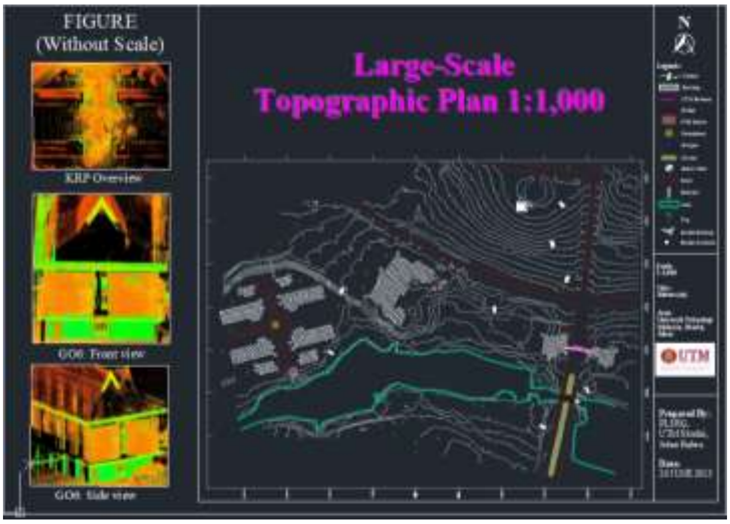


Figure 6. Generated 2D topographic plan.

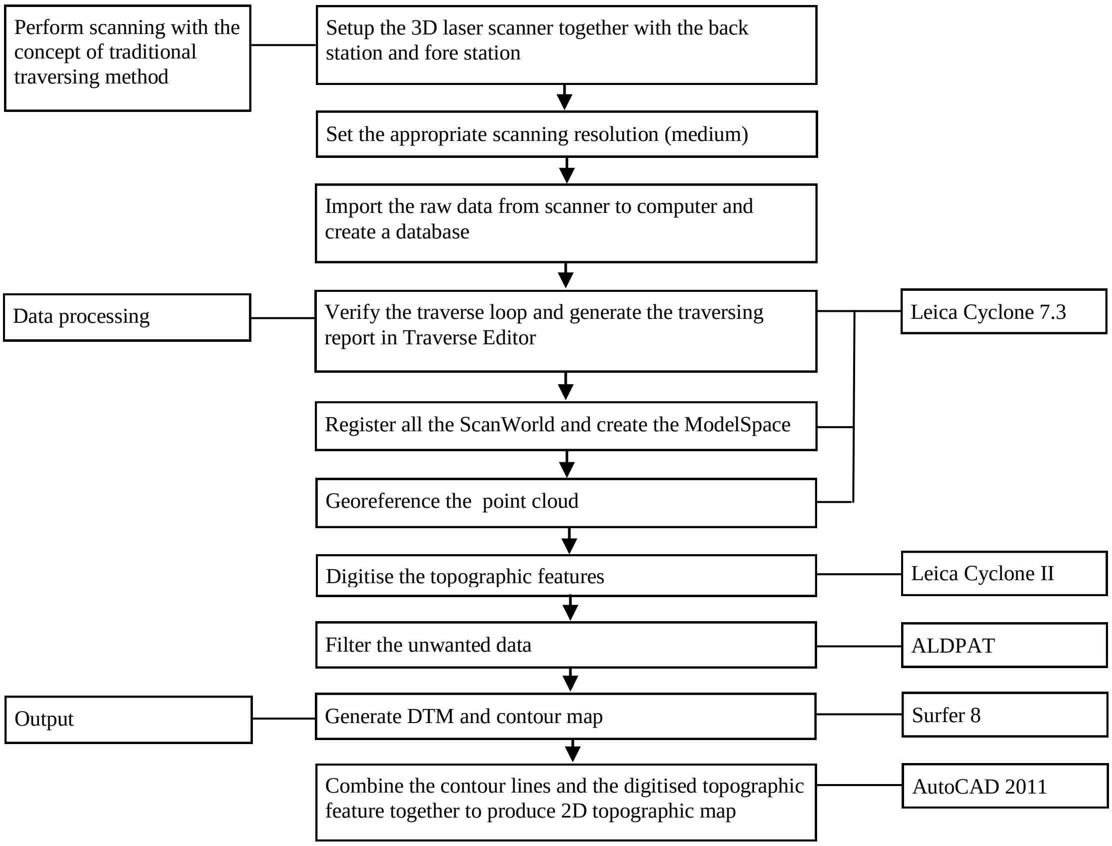
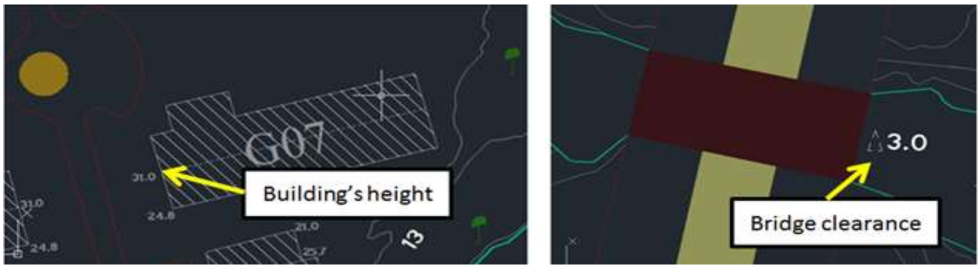


Figure 7. The proposed standard of procedure.

The main difference between this 2D topographic plan with ordinary 2D topographic plan is the additional information for building which were height of the building and height of bridge clearance as shown in figure 8a figure 8b respectively. In other words, the information provided in this plan is in 2.5D. The information of building's height can be displayed without having the problem of data obstruction as can be found in 2.5D plan presentation. According to Penninga [12], the 3D volume features (building) are 'glued' the on top or below of the Triangulated Irregular Network (TIN). Hence, this method of presentation is more appropriate in the display of 2.5D data for printing the hardcopy 2D topographic plan. Hardcopy printing is still popular because hardcopy plan is more convenient for most of the user (e.g. surveyor) for bringing the plan to the survey site.



(a) **(b)**

Figure 8. Data presentation for (a) building's height and (b) bridge clearance

Last but not least, this topographic plan was validated by comparing the length of the building measured by TLS method with the measurement obtained from total station. One of the hostel buildings is selected randomly for validation. The difference between the measurements is 6.13cm. This discrepancy is still acceptable for topographic mapping requirement [13].

6. Conclusion

In conclusion, this study has shown that TLS is capable to provide the same result as traditional topographic survey using total station. At the same time, the time spent for data collection on site is much shorter by using TLS, thus supporting the concept of rapid mapping [4]. Besides that, the richness of the data also can be used in future for modeling for example 3D City Modelling. For future work, this research will continue with mapping larger area by combining the aerial photos acquired using Unmanned Aerial Vehicle in order to cover the area which hardly scanned by TLS. In addition, a more appropriate filtering algorithm is needed for generating a higher quality DTM.

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