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Accuracy assessment of Terrestrial Laser Scanning (TLS), Airborne Light Detection and Ranging (LiDAR), and Interferometric Aperture Synthetic Radar (IfSAR) in agriculture

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Abstract

Terrestrial Laser Scanner (TLS) is one of the laser scanning technologies used in many applications nowadays. It produces very precise and fast measured 3D data acquisition of an object. This latest technology is very cost-effective and user-friendly. In this study, TLS was used to determine the Digital Elevation Model (DEMs) for Taman Sri Lambak, Kluang, Johor. The DEMS is utilized for the comparison of the, Airborne Light Detection and Ranging (LiDAR), Interferometric synthetic aperture radar (IfSAR), and TLS to ascertain the accuracy of these three different application in generating DEMs. The TLS data was filtered using Progressive Morphology algorithm using open source software, Airborne LiDAR Data Processing Tool (ALDPAT). Airborne LiDAR was filtered using TerraScan while IfSAR is already in raster data output. The DEM of TLS is generated by using Triangulate Irregular Network (TIN) in ArcMAP 10.2 to illustrate the differences of elevation between LiDAR, IfSAR, and TLS. From this assessment, TLS has better accuracy when compared to the benchmark obtained from Jabatan Ukur dan Pemetaan Malaysia (JUPEM) rather than LiDAR and IfSAR.

Keywords*:* terrestrial laser scanner (TLS), slope risk map, light detection and ranging (LiDAR), interferometric aperture synthetic radar (IfSAR)

INTRODUCTION

Terrestrial laser scanning (TLS) has become popular technique for surveying and mapping. Digital terrain models (DTMs) generates from TLS was used to evaluate the elevation of the models. It is essential to filter or remove out points that do not represents the terrain surface such as trees and grass especially at the steep slope to determine the terrain surface as precise as possible. Until recent, there are no specific tool and algorithm to filter TLS (Leslar.M et al., 2006). For Airborne LiDAR. Airborne LiDAR Data Processing Analysis Tool (ALDPAT) is a tool used to filter cloud points data. It contain of several techniques of filtering such as elevation threshold with expanded window filter (ETEW), Progressive Morphological(PM), Maximum Local slope, adaptive TIN filter (ATIN) and interactive Polynomial Fitting (IPF). Based on these techniques, PM is found to be the most suitable method to filter the data because it has all ability that meets the requirements of the good DEM where it performs well in removing building, bridge and vegetation on slope. PM also can filtered at steep slope area very well (Abdullah, 2012). After the filtering process, the DEMs for the study area will be generate to gain the elevation. Slope will be derived from the elevation for used in agricultural purposes. To determine the accuracy between TLS, airborne LiDAR, and IfSAR, statistical analysis was used.

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One of the problems in the plantation area is slope failure. Thus, to manage and monitor the slope failure, the most reliable way to create slope risk map is using LiDAR data. There are two types of LiDAR data namely airborne and terrestrial. Airborne LiDAR data is very expensive due to its high accuracy (10cm in Z direction) and massive data collection. In order to decrease the cost of purchasing airborne LiDAR data, IFSAR data can be one of the cheaper. But there are some problems when using IFSAR because the data is not as accurate as airborne LiDAR (50cm in Z direction). The main objective of this study is to evaluate the elevation accuracy of TLS, Airborne LiDAR, and IfSAR data. This study focus on comparison of the digital elevation model that derived from TLS, Airborne LiDAR, and IfSAR.

METHODOLOGY

Study area

The study area was located along the main road near agricultural area in the district of Kluang and in the state of Johor. It is about 3km long. The study area topography varies from flat surface to gentle slope and there are agriculture areas along the roadside. Figure 1 shows the study area in satellite image.

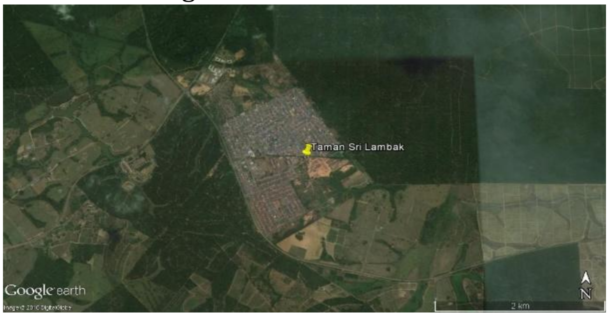


Figure 1. The study area on the satellite image. SPOT (Date:2/15/2015)

Data preparing and processing for TLS

Terrestrial Laser Scanning (TLS) is a fast method to capture and scan objects from its surrounding. It store data about its shape and also their physical characteristics. The advantage of this method is it can register huge numbers of point with high accuracy in a short period of time. During this research, FARO FOCUS 3Dx 130 laser scanner is used. The benefit of this equipment is it enables fast and accurate measurements of objects and building. Therefore, it will produce highly detailed 3D data for the study area. In addition, this equipment also has been integrated with GPS that will help in determine the coordinate of the equipment. Although in the bright sunlight, this equipment can well operate. This TLS works by projecting a laser beam onto an angled rotating mirror that reflects the beam to the object being scanned, while the entire unit rotates around a vertical axis. Thus the unit scans 360° in a horizontal plane and 320° in a vertical plane. Faro 3Dx130 has the distance accuracy up to ±2mm. It can scan about 130m from the scan point. It also can reduce the noise by 50%.

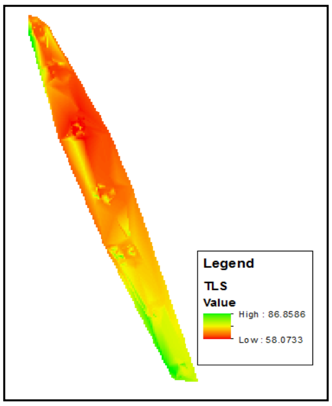
Processing of TLS data was done in the SCENE 3D software for registering the scan point. SCENE 3D laser scanner software is design specialized for the FARO Focus3D. SCENE processes and manages scanned data easily and efficiently by using automatic objects recognition as well as scan registration and positioning. This point-cloud software is extremely user-friendly, from simple measuring to 3D visualization to meshing and exporting into various point cloud formats. Once the data process complete, the commence evaluation and further processing can be done right away.

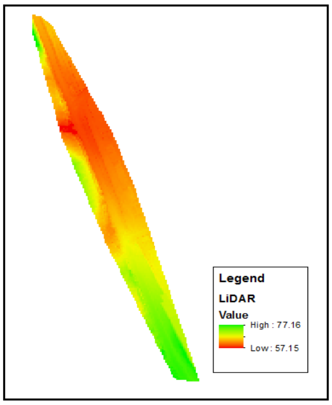
Digital elevation model

LiDAR is a commercial-processed data bought from a firm which provides services in surveying and mapping using LiDAR. The data is already filtered from ground and non-ground features. Thus it will show directly the elevation and slope for this area.

IfSAR is also commercial-processed data gained from a firm which provides services in this field. It contains DEM and Digital Surface Model (DSM) for this area. DEM is topographic model of the bare earth while DSM is a model of earth surface including terrain features, vegetation and buildings at the study area.

The DEMs were generated using Triangulate Irregular Network (TIN) in ArcMap 10.2.2. TIN is a digital data structure used in Geographical information System (GIS) as surface illustration in shape file format. TIN is a vector based that illustrate the physical land surface or bottom of the sea, made up of irregularly distributed modes and lines with three-dimensional coordinates (x,y,z). The advantage of TIN over a raster DTM in mapping and analysis is that the TIN point disperse variably, based on algorithms that determines which point is the most necessary for an accurate representation of terrain.





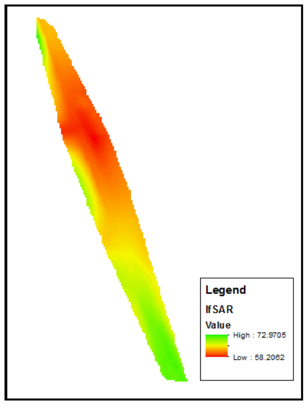


Figure 2. Shows the DEM created by TIN.

Accuracy assessment

The accuracy assessment plays an important role to determine the accurate method for creating DEMs. Then accuracy is calculated by comparing elevation data of TLS, LiDAR, and IfSAR with the benchmark from the JUPEM. The data is taken in the same x and y coordinates with the benchmark. The value of the elevation is taken to calculate the differences for the three data with benchmark.

Accuracy = |x-y| , where:

- x=the elevation value of benchmark.
- y= the elevation value of TLS, LiDAR, and IfSAR

Another set of assessment is by using root mean square error (RMSE). RMSE measures error were calculated between three data sets which is TLS,LiDAR, and IfSAR with the benchmark. The RMSE formula is as below:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \hat{x}_i)^2} \quad (1)$$

Where :
N= No. of data
Xi= Surveyed elevation value (LiDAR and IfSAR)
x̄i= TLS elevation value

RESULTS AND DISCUSSION

LiDAR data elevation accuracy is between 15cm -20cm (Hodgson et al, 2003)while IfSAR elevation accuracy is between 5m-10m (Orwig et al., 1995). It is clearly stated in the result that LiDAR data has higher accuracy compared to IfSAR. But, from this study, it was show that TLS is the most accurate among the LiDAR and IfSAR. Table 1 indicated the differences elevation of benchmark with TLS, LiDAR and IfSAR at 2 points. The TLS reading is 1.027m, followed by LiDAR 5.852 m, and IfSAR 7.013 m. It is show that TLS data is the nearest to the benchmark with differences about 1.027m. At point 2, TLS reading is 0.313m, LiDAR 12.04m, and IfSAR 12.075. From point 2, it also show that TLS has the least difference compared to the other. Thus it is prove that TLS data has the higher accuracy compare to the LiDAR and IfSAR. All the reading were compared at the same x-y coordinates.

Table 1. The differences elevation of benchmark between TLS, LiDAR and IfSAR

Points	TLS (m)	LIDAR (m)	IFSAR (m)
1	1.027	5.852	7.013
2	0.313	12.04	12.075

The graph in figure 3 show the elevation of TLS, LiDAR, and IfSAR in 30 different samples point. The graph shows the similarity between the data. From the graph, it show that there is a significant different between each data. The graph has been study in detailed and at every point, the elevation of TLS has huge different with LiDAR compare to IfSAR with LiDAR. There is no significant different between LiDAR and IfSAR data.

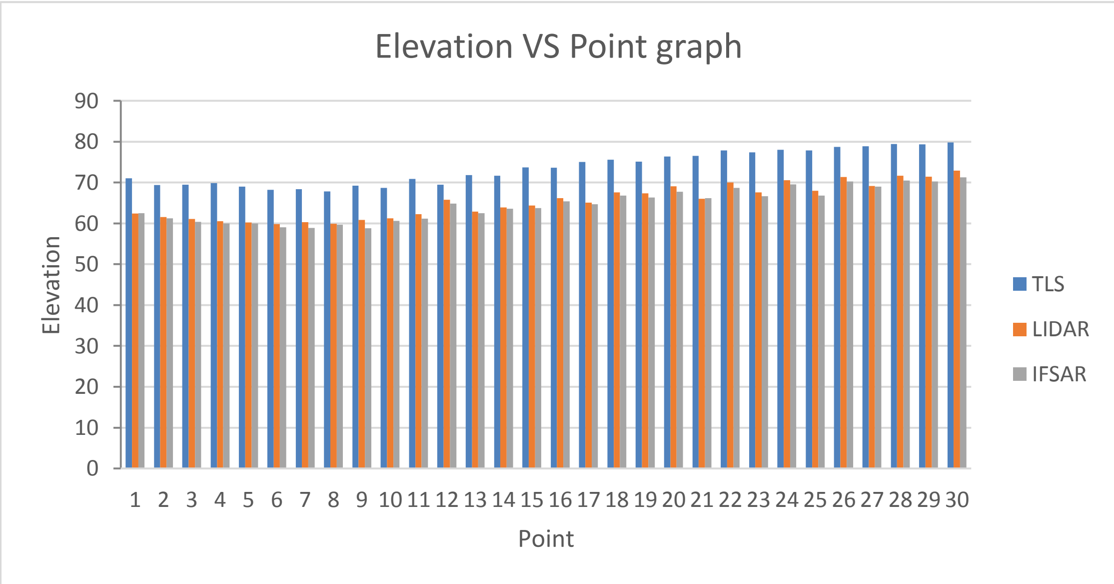


Figure 3. The elevation difference of TLS, LIDAR, and IfSAR at 30 different points.

Two BM from JUPEM was used as benchmark in the first comparison. From this assessment, it is found out that TLS give the most accurate measurement. Based on this result, TLS was selected as a benchmark for further assessment using RMSE.Table 2 shows the root mean square error of LIDAR and IfSAR. The RMSE value for TLS, LiDAR, and IfSAR are 8.334 m and 9.116 m respectively. LiDAR has the lowest RMSE value.

Table 1. RMSE value LiDAR and IfSAR.

RMSE LiDAR (m)	RMSE IfSAR (m)
8.334	9.116

Figure 6(a) show the error of IfSAR data when compare to LiDAR data. Green colour area indicates low error while red colour has higher error in the area. For intermediate error is shown yellow in colour while blue line is indicates as contour line with interval 5m. Figure 6(b) show the slope map for LiDAR data. Green colour area show the slope degree from 0° to 8°, yellow in colour area shows slope from 8° to 19°, while red colour shows slope between 19° to 74°. The area in top and bottom right circle figure 12 show the error and the area in top right and bottom circle in figure 6 show its slope. It is clearly shown that slope greater than 10° tendency to be the highest error as stated by National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. NOAA said that slopes greater than 10 degrees can often result in a higher error. Note that it is not only the local slope within a few pixels that matters, but also the general slope of the area for several tens or hundreds of meters around. A flat area near a steep slope may be good, but it may also have added error because of the generalized slope.

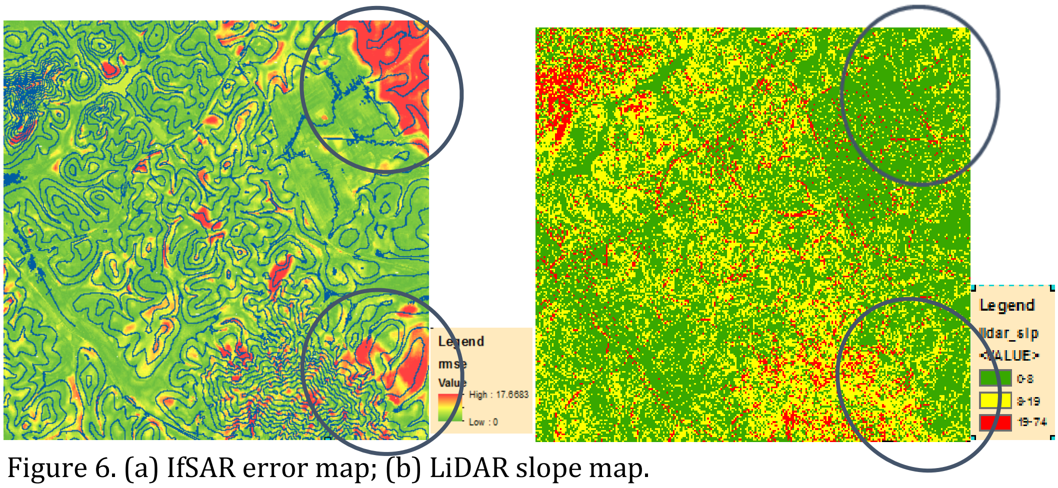


Figure 6. (a) IfSAR error map; (b) LiDAR slope map.

CONCLUSIONS

The following conclusions can be drawn from the study:

- Based on the results, it shows that TLS has better accuracy when compared to benchmark rather than LiDAR and IfSAR.
- TLS has the lowest RMSE value compared to LiDAR and IfSAR which is 1.695 m.
- Although it has better accuracy, this method is suitable for surveying in small area. TLS is fit to be used in agriculture due to significant accuracy compared to LiDAR and IfSAR.
- TLS and IfSAR data fusion can be used as feasibility study for a new area of research to see any improvement of accuracy.

Literature cited

Abdullah, A.F., Vojinovic, Z., Price, R.K., and Aziz, N.A.A. (2011), A methodology for processing raw LiDAR data to support urban flood modelling framework. J. Hydroinform. *14 (1),* 75-92.

Alkan, R. M., and Karsidag, G. (2012). Analysis of the Accuracy of Terrestrial Laser Scanning Measurements. FIG Working Week 2012 - Knowing to Manage the Territory, Protect the Environment, Evaluate the Cultural Heritage, (May 2012), 16.

Dowman, I. (2004). Integration of LIDAR and IFSAR for Mapping. Retrieved from http://discovery.ucl.ac.uk/55564/

Glira, P., Briese, C., Pfeifer, N., Dusik, J., Hilger, L., and Neugirg, F. (2014). Accuracy analysis of height difference models derived from terrestrial laser scanning point clouds. 16, 15987.

Hodgson, M.E., Jensen, J.R., Schmidt, L., Schill, S., and Davis, B. (2003). An evaluation of LIDAR- and IFSAR-derived digital elevation models in leaf-on conditions with USGS Level 1 and Level 2 DEMs. Remote Sens. Environ. *84(2),* 295–308. http://doi.org/10.1016/S0034-4257(02)00114-1

Holopainen, M., Kankare, V., Vastaranta, M., Liang, X., Lin, Y., Vaaja, M., and Alho, P. (2013). Tree mapping using airborne, terrestrial and mobile laser scanning - A case study in a heterogeneous urban forest. Urban Forest. Urban Green. *12(4),* 546–553. http://doi.org/10.1016/j.ufug.2013.06.002

Jamie, C., Keil, S., Kirk Waters, L. B., Brian, H., Rebecca, M., and J.H. (2012). Lidar 101 : An Introduction to Lidar Technology, Data, and Applications. NOAA Coastal Services Center, (November), 76.

Li, X., Baker, A.B., and Hutt, T. (2002). Accuracy of Airborne IfSAR mapping.

Orwig, L.P., Aronoff, A.D., Ibsen, P.M., Maney, H.D., O'Brien, J.D., and Holt, H.D. (1995). Wide-area terrain surveying with interferometric SAR. Remote Sens.Environ. *53(2)*, 97–108. http://doi.org/10.1016/0034-4257(95)00045-3

Riveiro, B., Morer, P., Arias, P., and De Arteaga, I. (2011). Terrestrial laser scanning and limit analysis of masonry arch bridges. Construct. Build. Mater. *25(4),* 1726–1735. http://doi.org/10.1016/j.conbuildmat.2010.11.094

Rock, R., and Park, S. (2007). an Introduction and Overview Presented by Keith Marcoe What is Lidar ?, 1–10.

Schmid, K.A., Hadley, B.C., and Wijekoon, N. (2011). Vertical Accuracy and Use of Topographic LIDAR Data in Coastal Marshes. J. Coastal Res. *275*, 116–132. http://doi.org/10.2112/JCOASTRES-D-10-00188.1

Seidel, D., Beyer, F., Hertel, D., Fleck, S., and Leuschner, C. (2011). 3D-laser scanning: A non-destructive method for studying above- ground biomass and growth of juvenile trees. Agric. Forest Meteor. *151(10),* 1305–1311. http://doi.org/10.1016/j.agrformet.2011.05.013

Thompson, G.W., Maune, D.F., and Llc, D. (n.d.). Issues and Answers in Quality Control of LIDAR DEMs.

Xie, L., Ying, Y., and Ying, T. (2009). Classification of tomatoes with different genotypes by visible and short-wave near-infrared spectroscopy with least-squares support vector machines and other chemometrics. J. Food Eng., 94, 34-39.

Zhao, J. W., Chen, Q. S., Huang, X. Y., and Fang, C. H. (2006). Qualitative identification of tea categories by near infrared spectroscopy and support vector machine. J. Pharm Biomed Anal. 41, 1198–1204.