KEMENTERIAN PENDIDIKAN TINGGI

JOJAPS

eISSN 2504-8457

POLITEKNIK MALAYSIA PORT DICKSON

Journal Online Jaringan COT POLIPD (JOJAPS)

Application of Terrestrial Laser Scanner for Three Dimensional as Built Building Model

Sr Che Ku Ahmad Fuad Bin Che Ku Abdullah MRISM [a]
Nurul Zaitul Syeema Binti Baharuddin [b]
Dr. Mohd Farid Bin Mohd Ariff [b]

ckfuad2419@gmail.com
[a] *Department Of Civil Engineering, Politeknik Sultan Haji Ahmad Shah, 25350 Kuantan, Pahang*
[b] *Photogrammetry And Laser Scanning Research Groups, Geoinformatics And Property Faculties, Universiti Teknologi Malaysia, 81310, Johor Bahru, Johor*

Abstract

Laser Scanner technology is become an option in the process of collecting data nowadays. The improvement in the study of spatial data acquisition technology using laser scanning enable more efficient acquisition of three dimensional (3D) of data collection in surveying work. This study is to determine the application of Terrestrial Laser Scanner (TLS) in making the three dimensional (3D) of building model. The term of as-built is referring to the actual state of a built building at any time during its life cycle, particularly during its service life (Son *et al.*, 2015). TLS is more efficient, accurate, save time and save labor cost. Conventional method in data acquisition need more expert labor, time consuming which lead extra cost. The TLS instrument present the data in points cloud form with a lot of information such as x, y, z value, intensities, and in RGB colors. The 3D model which generated from point clouds data can give more in visualization of the scanning object. This 3D model are suitable for 3D city model work, topographic model, forestry mapping, 3D monument and others.

Key-word: - Terrestrial Laser Scanner (TLS), as built building, points cloud, 3D model.

1. Introduction

In recent years, the technology in data acquisition is focusing on about the accuracy, save time and less cost. Conventional method is still applicable but this scanning process can provides better facilities. This study takes advantage of technologies where using TLS in data acquisition as well as generating as-built buildings in 3D models. Also it can be applied for others modelling purposes.

Nowadays, the data acquisition involves the measurement of big area and large object for example 3D city model, forestry mapping, as-built, Building Information Management (BIM) and other. The main advantages of TLS is a method that is quick and fast in collecting data, and be able to observe a large region in 3D (Zogg, 2008). The laser scanner instrument such as Leica C10 The Leica ScanStation C10 does full dome scans up to 10x faster – now, less than 2 minutes for a typical room (www.leica-geosystems.com). It also conducts general 360º and focused areas scans faster, can be set up & moved faster, lets users locate targets, register & geo-reference faster and lets users check scan results faster. The use of TLS in measurement and data collection was very good because it has a promising technique and potential to acceptable as a new measurement technology (Schulz, 2007)

The laser scanning technology has started with the development of 3D laser scanning during the 20th century in order to achieve the accuracy of the reconstruction of the surface of objects or places (Ebrahim, 2011). The data obtained from TLS is high accuracy and widely used to generate 3D modelling.

Latest TLS not only generate 3D data, even now are able to capture four-dimensions (4D) data which is 3D space data plus time (Kromer *et al.*, 2015), since the reflected laser beam can detect the amplitude or intensity of the laser beam. TLS is a 'ground-based' instrument used to scan various object from small monument until to the very large building. The laser scanner technology is a quickly tool of scanning an object by recording the shape and surface to visualize the object in RGB points cloud information (Lerma *et al.,* 2014). Three main types of methods for Terrestrial Laser Scanner are Time of Flight (TOF), Phase Shift and Triangulation Based System (Schulz, 2007). However, Phase Shift and Triangulation Based system rarely used in Terrestrial Laser Scanner compared with the Time of Flight (TOF) method.

The conventional method is still used on measurement and mapping but is rarely to perform in 3D model. As-built plans are normally required by the construction management for the purpose of monitoring the progress of work and the payment of claims. The TLS technology can encourage surveyor to collecting data and perform the data in 3D model In short time and the 3D model can give better information with good visualization. In addition, it is sometimes difficult to detect and record changes based on decisions made during construction time and thus can produce a final product that deviates from the state as designed. This study will conducted for the purpose of implementing new technology in the as-built work process and also can be used as a database that for further study whether to review the construction work which has been completed, for the in-future development and construction work and for future reference in case of any accident or disaster.

This study is conducted to generate 3D model of as-built building details from point cloud provided by TLS. Then to determination the accuracy of as-built model by comparing it to the existing as-design. Therefore, the method of data collection using TLS and how to generate the 3D model of the building in LOD3 needs to be determined and studied to get good results. As for this study, Leica ScanStation C10 is used in data acquisition on field. Leica ScanStation C10 represents the most capabilities and best value packed into a single laser scanner instrument. It is includes scanner, auto-adjusting camera, battery, tilt sensor, data storage, and plummet laser on the instrument. Then cloud data from the TLS tool will be processed using the Cyclone software for registration purposes. It will then be displayed in the form of RGB data model or point cloud intensity.

To generate the data in 3D model, SketchUp Pro 2016 software is choose because it is very user friendly and suitable to use for points cloud data in generate 3D model. To ensure that the results obtained meet the required accuracy, quantitative accuracy assessment of dimensional measurement data of the building was carried out. Thus, hypothesis test results obtained are shown in the chapter of results and analysis. UTM Eco-Home on the campus of UTM Johor Bahru as shown in Figure 1.1 is selected as the study location. Based on Office of Corporate Affair of UTM, the construction of house on the concept of "Sustainable Development". The building has two levels which located 3 bedrooms, a hall, kitchen and bathroom. To generate the building in 3D modelling, collecting data using conventional method is not suitable. Leica C10 is the selected instrument for data collecting purpose. TLS can produce 3D data in point cloud format. Then the Cyclone software is used for processing stage. Point cloud format is used to generate the 3D detail model of building in a LOD3 by referring to CityGML standard. The advantage of using cloud data from TLS is that it can provide very accurate data and able to accurately describe the object. Many previous studies use cloud data to produce 3D models for many purposes such as 3D mapping, object analysis, and for documentation purposes.

Figure 1: UTM Eco-home building (www.news.utm.my)

2. Methodology

The methodology is developed related to the activities carried out by the work design, data acquisition and data processing. The methodology are divided into four phases of workflow consisting of:

Phase I : Literature study
Phase II : Data acquisition
Phase III : Data Processing
Phase IV : Analysis

The flowchart in Figure 2 shows the overall methodology of the study with the four phases that framing the flowchart. These phases are specified to accomplish the study requirements and objectives of the study. The first phase would cover the literature study which are include as-built study, level of details, TLS and 3D modelling. The second phase is data acquisition which cover the field works using TLS and Total station for comparison. In processing phase show the step on generating 3D modelling and also 2D plan as the control. Finally, the analysis phase is to analyse the comparative measurement.

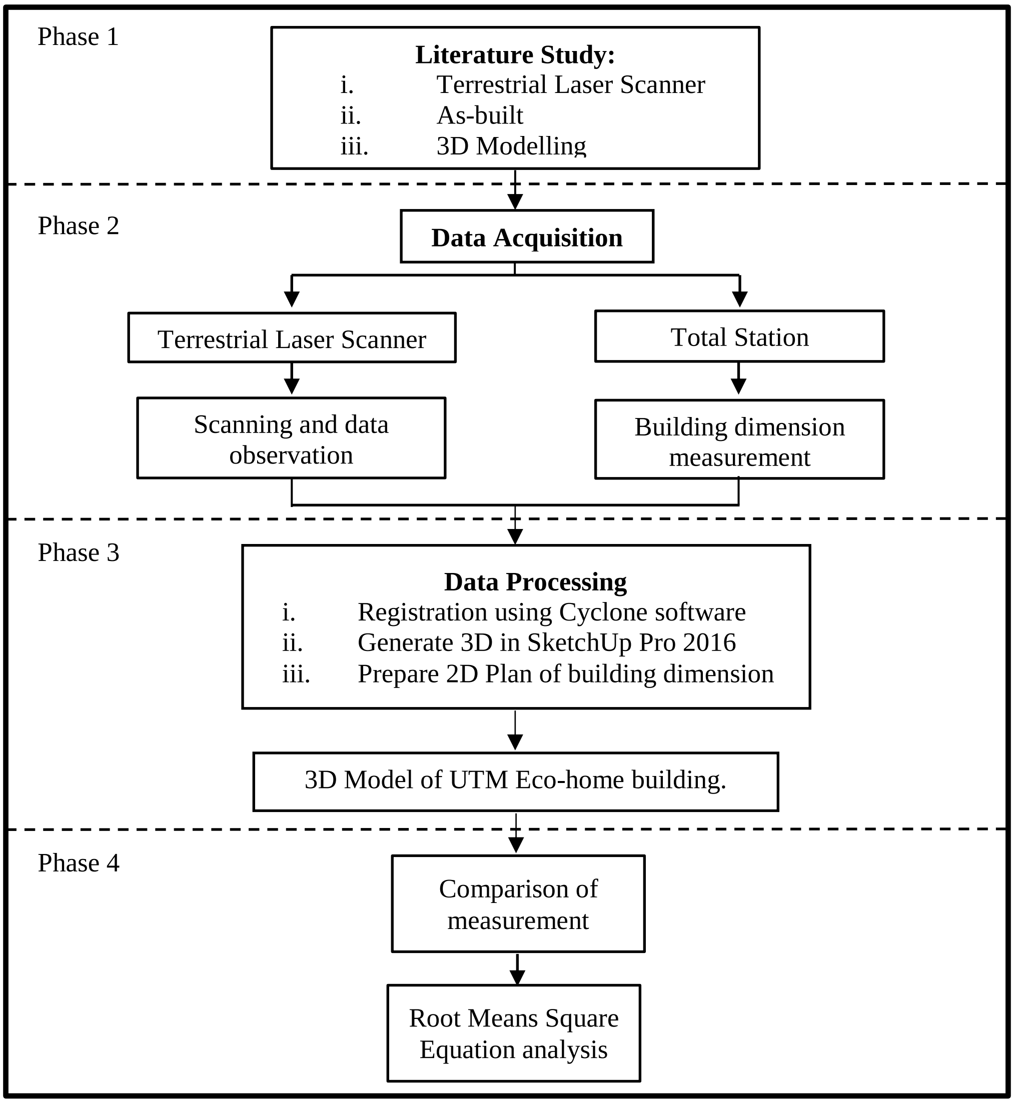


Figure 2: Methodology workflow

Literature study is conducted to gain a better understanding and to get an idea of the study. This includes studies on the equipment used, the appropriate software and work processes in this study. The topics covered are the purposes of as-built survey, the use of TLS tools, the effectiveness of Level of Details (LOD3) and generating 3D models of as-built buildings. The term of as-built is referring to the actual state of a built building at any time during its life cycle, particularly during its service life (Son *et al.*, 2015). The 3D as-built data which is acquired from field work on construction site can used to establish the geometric properties for building façade. Currently, as-built data obtained also needed for management purposes while projects under construction, after completion of the project, and for the operation and maintenance phase related to civil engineering. As an example of the studies conducted, the progress of the construction activities will be compared with the 3D model 'as-built' data obtained from the construction site along with design information contained on the building layout plan information. (Pettee, 2005).

In visualization purposes, this 3D as-built model generated visual presentation is referring to the facade of the building based on the Level of Detail (LOD3) which as recommended by City Geographic Mark-Up Language (CityGML). Recently, the Open Geospatial Consortium (OGC) has been established to determine the CityGML 3D city model in the five LOD. It has categorized the 3D model from the LOD0 to LOD4 for efficiency in the visualization (OGC, 2012). Figure 3 shows the building structure in formed from LOD1 to LOD4. Each LOD would represent 3D visualization of model building which can be categorized according to the strength of each model. To produce this 3D model, data observation method requires a special method and equipment. Therefore, observations using laser scanners have been selected.

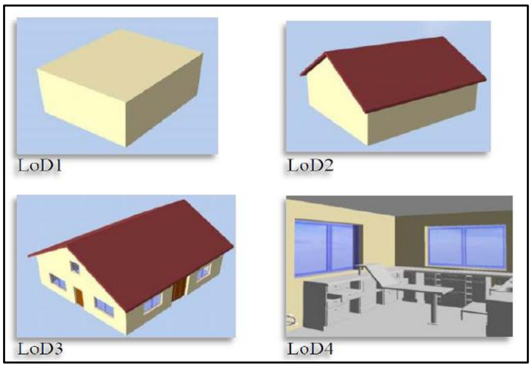


Figure 3: Level of Detail for 3D Building Model (Fan & Meng, 2012).

3. Data Acquisition

Data collection process is done using Leica ScanStation C10. This TLS tool needs to be set around the scanning area to scan the entire façade of the object. Five TLS's stations were selected for data acquisition work where the location of this station is covered the study object. Ten spherical target was used in this study as a reference target for five laser scanning stations established. At least five of the same targets can be observed by each adjacent station. Observations on the same reference target are required for the registration process later.

Each station observations only show a certain view by station. In order to incorporate all five stations of different views of the observed data, overlapping spherical target targets are used to combine all these stations in the registration process where Cyclone software is applied. It is intended to merge all data acquisition where it will cover all Eco-home building façade in one view. Figure 4 shows the cloud point data depiction obtained from the TLS C10 tool as well as the spherical target in its position.

In order to obtain accurate measurements of the object observed, the measurement of building dimension were carried out using Topcon Total Station ES-105. Topcon total station is used as a validation of the accuracy of the distance measurement at every dimension of the building where it will be compared with TLS data acquisition and also on 3D model generation. In addition, it is also needed in the process of data analysis.

Figure 4: The point cloud data of Eco-home building façade with spherical target on site obtained using TLS

i)

ii)

Figure 5: i) Leica ScanStation C10 scanner (www.leica-geosystems.com/hds, 2016)
ii) Topcon Total Station ES-105 that was used in this study (www.topconpositioning.com, 2016)

Figure 6: The spherical target

4. Data processing

Data processing is done because the data must be unified into single display from five stations with different view. To facilitate data processing, raw data needs to be combined using the spherical target method. Sphere targets are used in the field and are also used during the registration process in Cyclone software. Target used need to be marked and defined their registration number or id. To ensure data is accurate and unite, id constraints should be reviewed for accuracy checking. Figure 8 indicates the accuracy of the registration process is able to achieve up to millimetre accuracy.

This integration is obtained by using a constraint system, which can be the partner of the same object or the overlapping data points that exist between the two scans. The registration process to calculate the optimum alignment of the whole transformation for each scanning component is recorded, so that the constrained object is aligned as closely as possible in the resulting scan. After done with registration processes, data cleaning is needed to be done for removing any unwanted data as noise.

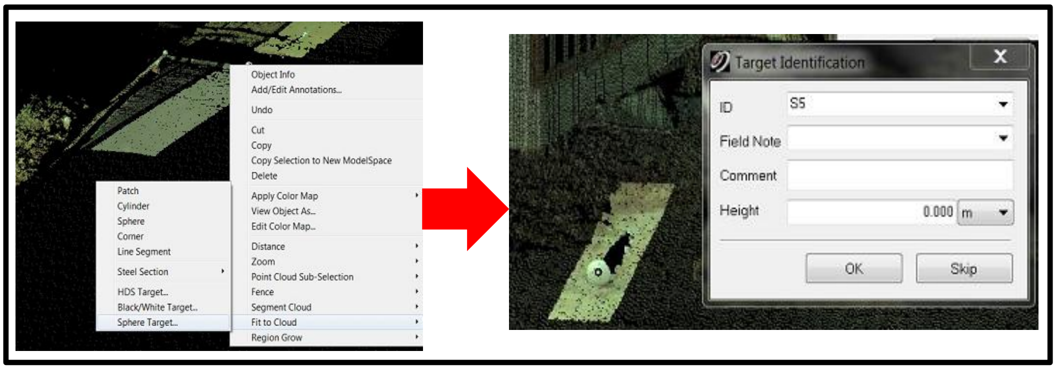
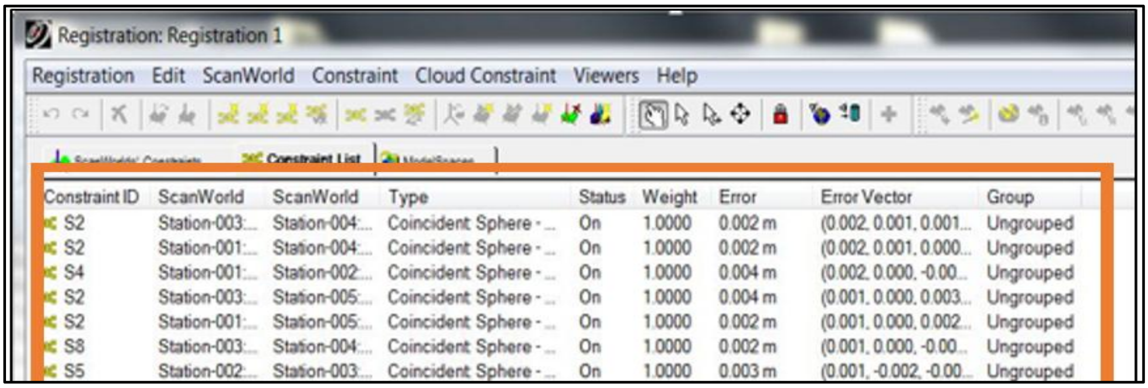


Figure 7: The registration process using spherical target for 2 scanning station.



Constraint ID	ScanWorld	ScanWorld	Type	Status	Weight	Error	Error Vector	Group
S2	Station-003:...	Station-004:...	Coincident Sphere - ...	On	1.0000	0.002 m	(0.002, 0.001, 0.001...	Ungrouped
S2	Station-001:...	Station-004:...	Coincident Sphere - ...	On	1.0000	0.002 m	(0.002, 0.001, 0.000...	Ungrouped
S4	Station-001:...	Station-002:...	Coincident Sphere - ...	On	1.0000	0.004 m	(0.002, 0.000, -0.00...	Ungrouped
S2	Station-003:...	Station-005:...	Coincident Sphere - ...	On	1.0000	0.004 m	(0.001, 0.000, 0.003...	Ungrouped
S2	Station-001:...	Station-005:...	Coincident Sphere - ...	On	1.0000	0.002 m	(0.001, 0.000, 0.002...	Ungrouped
S8	Station-003:...	Station-004:...	Coincident Sphere - ...	On	1.0000	0.002 m	(0.001, 0.000, -0.00...	Ungrouped
S5	Station-002:...	Station-003:...	Coincident Sphere - ...	On	1.0000	0.003 m	(0.001, -0.002, -0.00...	Ungrouped

Figure 8: Accuracy constraints obtained on the registration process.

4.1 Generated 3D Modelling

3D modelling work is done using SketchUp software. SketchUp software is used because it has good facilities for utilizing point cloud data from other software. SketchUp also has the ability to bear millions of point cloud data very well. Data from Cyclone is downloaded directly to SketchUp for modelling process. The modelling process was started by selecting and creating control points axis, X, Y and Z as the references axis. Next, the process of building the 3D model continues until it reaches the desired level of LOD3 as shown in Figure 9. LOD3 is selected for 3D modelling finishing as it is sufficient to shows the details of the model and building facade.

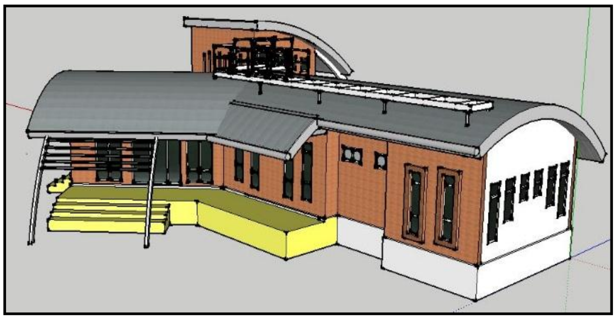


Figure 9: The appearance of Eco-home building Surface model generated using SketchUp

5. Data Analysis

The analysis is carried out to check the accuracy of the 3D model building results. Thus, generated Eco-home building model is compared to the existing layout plan and the conventional method to examine the resulting differences. The comparison is performed by measuring the difference of measurement distance on the dimensions of the building.

5.1 Data Comparison

As the verification process, a 3D model generated in LOD3 is measured and compared with the Layout Plan. It is also compared to building dimensions for direct measurements using Total Station. The Total Station tool is used as a benchmark for the process of measuring the dimensions of the study building as it proved to be an accurate tool in measurement. Measurement data used for comparison procedure is shown in Table 1.

Comparison between this three measurement shows that the layout plan give the poor measurement value. The best result is to comparing distance measurement between 3D building models with the total station method as shown in Table 2. The highest value of comparison is 0.05 meter. While the lowest value of comparison is 0.004 meter. From comparison value between 3D building model and total station method, the conclusion shows that there is no significant different for distance measurement between it. The resulting range is small.

Table 1: Building dimension measurement from provided layout plan, 3D model, and total station as reference.

Structure		Layout plan	3D Model	Total Station /reference
Wall	a	2.700	2.720	2.711
	b	17.100	17.450	17.436
	c	5.800	5.910	5.900
	d	3.500	3.630	3.635
	e	0.670	0.680	0.684
	f	3.000	2.820	2.852
	g	0.670	0.680	0.684
	h	6.000	6.060	6.064
	i	6.600	6.770	6.742
	j	4.700	4.900	4.887
	k	4.800	4.770	4.758
	l	2.700	2.754	2.711
Window	Window width 2	0.500	0.520	0.500
	Window width 1A	0.500	0.540	0.500
	Window width 5	2.850	2.800	2.900
	Window width 4A	3.350	3.130	3.140
	Window width 4C	1.164	1.160	1.120
Door	Door width 2	0.900	0.920	0.900
	Sliding Door width 1	3.200	3.290	3.260
	Sliding Door width 2	2.100	2.180	2.130

Through the calculation of the residual value, it can be extended to the calculation of the sample mean, standard deviation of the sample and the variance of the sample. This calculation serves to check and prove the accuracy of the measured data. The range comparison is done between the 3D model dataset and the reference dataset using Total Station. These comparisons are listed in the Table 2. Table 2 shows the distance review between the reference dataset and 3D model dataset. The range differences between both measurements are shown as a residual on the table.

Table 2: Comparison between the 3D model dataset and the reference dataset to calculate the residual.

Bil	Code	Distance measurements: Total Station/ Reference	Distance measurements: 3D Model	Residual (X)
1	a	2.711	2.720	0.0090
2	*b*	17.436	17.450	0.0140
3	c	5.900	5.910	0.0100
4	d	3.635	3.630	-0.0050
5	e	0.684	0.680	-0.0040
6	f	2.852	2.820	-0.0320
7	g	0.684	0.680	-0.0040
8	h	6.064	6.060	-0.0040
9	i	6.742	6.770	0.0280
10	j	4.887	4.900	0.0130
11	k	4.758	4.770	0.0120
12	l	2.711	2.754	0.0435
13	Window width 2	0.500	0.520	0.0200
14	Window width 1A	0.500	0.540	0.0400
15	Window width 5	2.900	2.800	-0.1000
16	Window width 4A	3.140	3.130	-0.0100
17	Window width 4C	1.120	1.160	0.0400
18	Door width 2	0.900	0.920	0.0200
19	Sliding Door width 1	3.260	3.290	0.0300
20	Sliding Door width 2	2.130	2.180	0.0500

Based on the findings, the differences ratio between each dataset can be referred to the resulting graph as shown in Figure 10. The graph is obtained according to the observations within twenty measurements taken on the dimensions of building. In conclusion of the resulting graph, it turns out that the difference in distance resulting range is very small and insignificant.

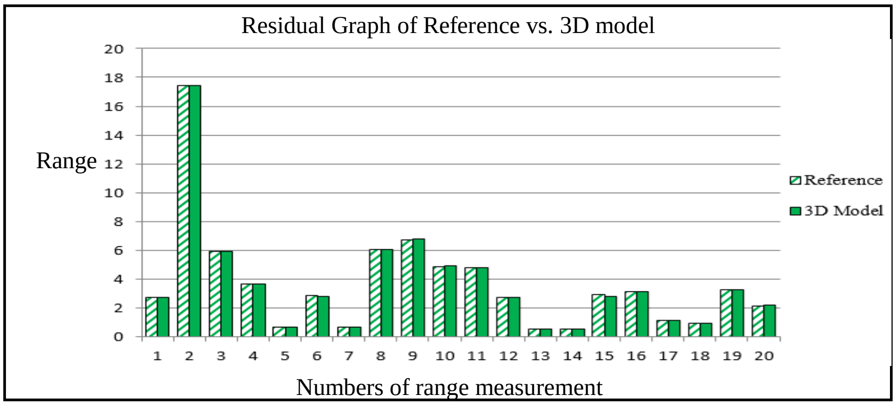
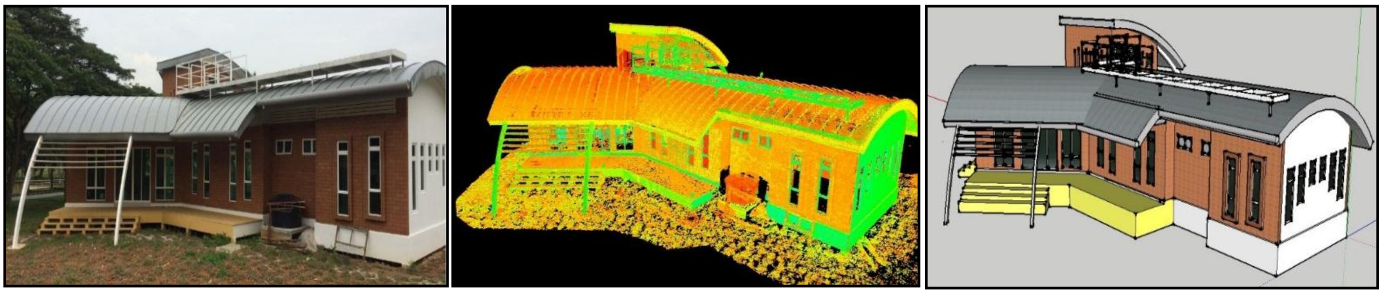


Figure 10: The graph shows the less noticeable distance between the 3D model dataset and reference dataset.

From the table and graph obtained, the next matter to determine the accuracy of the dataset be conducted by getting the Standard Deviation and Variance of the sample. The lower the value of standard deviations means that the most of the numbers are very close to the average. While highest standard deviation means that the numbers are spread out from the average number. To obtain the roots mean square error (RMSE), the value is calculated by dividing the total number of standard deviation over twenty readings taken. From the result, RMSE for 3D model comparing with reference data are 0.033m. This value is acceptable. Therefore, it can be concluded that the 3D model generated from TLS data is very suitable to be used based on desired level requirements LOD3. As a result, the 3D building model was successfully produced as shown in Figure 11, where (i) shows the real object UTM EcoHome building, (ii) display model in the form of point cloud data processed in Cyclone software, and (iii) the final result of 3D building model in Sketchup software.



i)Real object *ii) Point cloud from Cyclone* *iii) 3D model generated using SketchUp*

Figure 11: The appearance of Eco-home building in various style.

6. Conclusion And Recommendation

From this study, the measurement or surveying work can be easily done in future using the laser scanner technology and absolutely it can save time, reduce work cost and gives accuracy in the measurement process. The laser scanner technology also can encourage and motivated surveyor to finish up their surveying job also in data collecting for large area with these advantages. As a recommendation, 3D building models can be generated in LOD4 for interior detailing in future. Also it can try to integrate TLS data clouds with other point clouds data such as from LiDAR, Mobile Laser Scanner and Handheld Laser Scanner.

References

Alkan, R. M., and Karsidag, G. (2012). *Analysis of the accuracy of terrestrial laser scanning measurements.* Paper presented at the FIG Working Week.

BEM, B. o. E. M. (2005). *A Guide to Engineering Practice for M & E Engineers*. Malaysia: BEM Retrieved from http://www.bem.org.my/v3/pdf/circulars/Guide%20M&E.pdf.

Biljecki, F. I. L. I. P., Ledoux, H. U. G. O., & Stoter, J. E. (2014). Redefining the level of detail for 3D models. *GIM International: the worldwide magazine for geomatics 28 (November), 2014*.

Ebrahim, M. A.-B. (2011). 3D Laser Scanners: History, Applications, and Future. 100. doi: 10.13140/2.1.3331.3284

Fan, H., and Meng, L. (2009). *Automatic derivation of different levels of detail for 3D buildings modelled by CityGML.* Paper presented at the 24th International Cartography Conference, Santiago, Chile.

Gröger, G., and Plümer, L. (2012). CityGML–Interoperable semantic 3D city models. *ISPRS Journal of Photogrammetry and Remote Sensing, 71*, 12-33.

Kromer, R. A., Abellán, A., Hutchinson, D. J., Lato, M., Edwards, T., & Jaboyedoff, M. (2015). A 4D filtering and calibration technique for small-scale point cloud change detection with a terrestrial laser scanner. *Remote Sensing, 7*(10), 13029-13052.

Leica ScanStation C10 – The all-in-one laser scanner for any application, from http://leica-geosystems.com/products/laser-scanners/scanners/leica-scanstation-c10

Lerma, J., and García-San-Miguel, D. (2014). Self-calibration of terrestrial laser scanners: selection of the best geometric additional parameters. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2(5), 219.

Office of Corporate Affair, U. (2016). UTM bina rumah pintar lestari - UTM Eco-Home. Retrieved 12/12/2016, 2016, from http://www.news.utm.my/2016/12/utm-bina-rumah-pintar-lestari-utm-eco-home/

Schulz, T. (2007). *Calibration of a terrestrial laser scanner for engineering geodesy.* Technical University of Berlin.

Sadikin, H., Hernandi, A., Saptari, A. Y., & Puspa, A. (2015). The Study of Terrestrial Laser Scanning (TLS) Survey for Three–Dimensional (3D) Building Documentation. *FIG Working Week*, 1-18.

Salacha, A., Markiewicza, J. S., & Zawieskaa, D. (2016). Integration of Point Clouds from Terrestrial Laser Scanning and Image-Based Matching for Generating High-Resolution Orthoimages. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 399-404.