



THREE DIMENSIONAL ASSET DOCUMENTATION USING TERRESTRIAL LASER SCANNER TECHNOLOGY

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ABSTRACT

Asset documentation is a detailed record or inventory of the properties located within a room or a building. It is important to record the assets in case of property loss happen inside the premise especially when that premise caught fire, earthquake, robbery and others. The instrument used in this study is Faro Laser Scanner Photon 120/20. The object of the study is the computer room of Photogrammetry Lab, Faculty of Geoinformation and Real Estate. The final output of this study is the 3D model of the assets available inside the building. Before 3D model can be formed, the scanned data which is in the form of point cloud generated from the laser scanner have to be registered and georeferenced in order to combine the scans. The combine scans is the representation of the whole area of work surveyed from every scan points. These processes use Faro Scene, software that comes together with the laser scanner. By introducing this method, large scale asset documentation such as for factories and schools would be very beneficial rather than conventional method. The next process is to model the point cloud using AutoCAD 2011. Every item available on the room such as desks, chairs, cubicles, computers, whiteboard, projectors and cupboard are modeled and each of these items was inserted with attributes so that we can know the information of each items.

Keywords: Terrestrial Laser Scanning, Three Dimensional Model, Asset Documentation, AutoCAD 2011

1.0 INTRODUCTION

Nowadays, 3D models are widely used in a variety of field. This application includes asset management, environmental modeling, reverse engineering, city planning, cultural heritage, and also piping (Aminuddin, 2010). 3D modeling is also a new way for data presentation as a final product of measuring and surveying technique. The 3D model can also be turned into a digital asset by associating it with critical information related to the physical asset and storing the 3D model and the associations in a database for retrieval and management of the digital asset.

Laser scanning technology and digital close-range photogrammetry are two types of technology that can produce 3D model. The main difference between these two technologies is that the equipment that is used and the work procedure. Close range photogrammetry is a visual method where the camera orientations need to be solved first before capturing an image (Ordóñez et al., 2010). Meanwhile, like most of surveying devices, TLS need to be calibrated periodically (Santala and Joala, 2010).

The 3D laser scanner is also called an active remote sensing system because no additional personnel are needed to hold a ranging pole or to place targets for measuring surfaces, which are not practical if the survey has to be done on hazardous areas such as landfall sites. Other advantages of laser scanning are better quality of the results in terms of accuracy and precision of final result, survey can be done by only a man (one-man survey), no interference with construction and operations activities and simple and easy equipment operating and data processing (Nur Adlina, 2010). As for this study, the 3D model is produced by Faro Photon 120/20 Laser Scanner and Faro Scene Laser Scanner Software.

Asset documentation has undergone changes which is parallel with technological advancement. However, people still relate asset documentation with the conventional recording method. This method is called recording and filing system. This system operates by a person who will record any utilities such as switches, fans, lights, wiring system and others that are available on a building using check-form. Besides determining the utilities available on a room, the area and volume of the room is also determined using basic equipment such as measuring tape. Area and volume are important criteria of choosing a suitable type of lights and fans. This system is very simple to execute that even schoolboys can take this job. Furthermore, this system only needs measuring tape, paper and pen which can be considered cheap.

Year by year, technology advancement is introduced in this job. Then comes electronic recording system complete with internet access. Asset documentation has made use of the introduction of Personal Digital Assistant (PDA) where recording data can be stored and send directly to the office. For area and volume measuring, distance meter (Distomat) have been used to determine the building or room dimension. It uses laser technology to measure lengths from a certain distance. However, this method is considered as tedious when it comes to large scale building with lots of room to be recorded.

Therefore, the idea of using terrestrial laser scanner has been considered in order to achieve better accuracy and precision, as this equipment had started to gain popularity among surveyors. By using laser scanner, there will be no more worries about items miscount and recording error as the data captured using laser scanner is stored to the computer that is linked to the scanner. The data collected using scanners are called point clouds. Point clouds are formed when laser hits the scanned surface and these points can be in millions. Therefore, these points can later become 3D model using CAD software.

Laser scanning method can also determine the area and volume of a scanned object once it has been modeled. It provides more accurate area and volume value than the value from conventional method. Besides, the data captured using this method covers the whole area and there will be no need to come back to the site when there is miscount error because the scanned environment can be viewed again back in the office.

2.0 TERRESTRIAL LASER SCANNER (TLS)

TLS is an active imaging device that can rapidly acquire a dense set of three-dimensional (3D) points on a large object or surface (Lichti et al., 2000). The TLS is a surveying instrument that massively captures coordinates of ground points in 3D with high velocity and accuracy. TLS

began to be used in the 1990s for mobile robot navigation (Singh and West, 1991), in the construction of metric scale 3D models, such as sculptures (Beraldin et al., 2000) and industrial applications (Sequeira et al., 2003).

There are three types of laser scanner systems which are time of flight, triangulation and phase shift measurement system (Anne, 2009).

Time of flight measurement system has a laser diode that sends a pulsed laser beam to the scanned object. Referring to **Figure 1**, the pulse reflected by the surfaces and part of the light will return to the receiver. The time that light travel from laser diode to the object surface and back is calculated. Therefore, the distance to object using assumed speed of light can be calculated from the time that the beam travels. (Boehler et al., 2001).

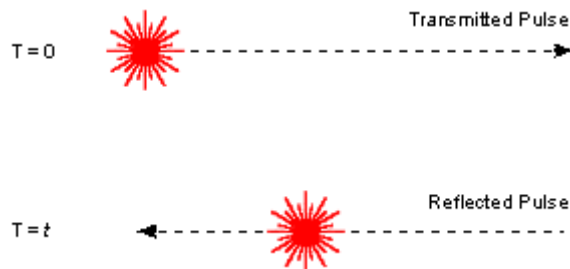


Figure 1: Time of flight measurement system

Meanwhile, triangulation system is an active system that uses laser light to probe the environment. From **Figure 2**, a light spot or stripe is projected onto an object surface and the position of the spot on the object is recorded by one or more charged couple device (CCD) camera. The distance can be determined from the object to the instrument geometrically by recorded angle and the base length.

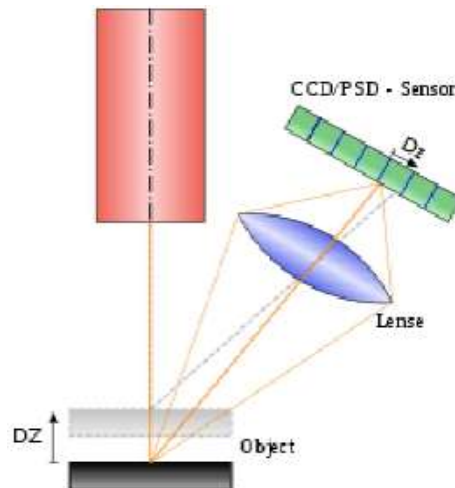


Figure 2: Triangulation measuring system

Phase shift measurement is a technique for measuring distances that uses a laser beam with sinusoidal modulated optical power being sent to a target. A reflected beam is monitored, and the phase of the power modulation is compared with the emitted beam as shown in **Figure 3**. A continuous wave laser is used as the carrier for a signal modulated onto it, typically using amplitude modulation. The phase of the emitted and the received signal is compared (Nur Adlina, 2009). The relation between phase differences, $\Delta\phi$ given in radians and the one way range, r is:

$$r = \Delta\phi / (2.\pi).\lambda/2 + \lambda/2.n$$

Where λ is the wavelength in meter and n is the unknown number of full wavelength between the sensor system and the reflecting object surface (Anne, 2009).

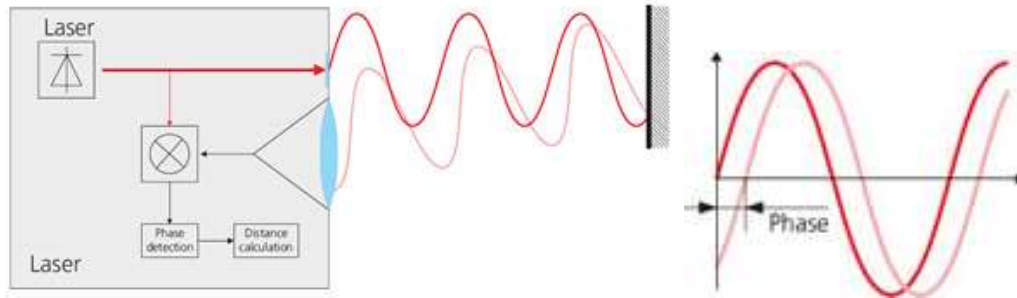


Figure 3: Phase shift measuring system

Laser scanning method can produce points cloud with very high precision within a short period of time (Nur Adlina, 2010). There are two types of laser scanning instruments. One is airborne laser scanner while the other is terrestrial laser scanner. As the airborne laser is located inside the airplane, on the contrary, the terrestrial laser scanner is used at the ground in order to get the measurement. This research is only focused on terrestrial laser scanner.

A laser scanner is also called an active remote sensing system since there are no personnel needed to hold a range pole or to place a target for measuring surfaces. To get detailed and accurate 3D models of object or structures, combination of a pulsed laser with high speed scanning optics is needed (Lemmens and Huevel, 2001). It can be categorized by the principle of the distance measurement system (Anne, 2009). This system correlates to both the range and resulting accuracy of the system. The three system are, time of flight, phase shift measurement as well as triangulation.

2.1 Faro Photon 120/20 Laser Scanner

Faro Photon 120/20 Laser Scanner, shown in **Figure 4** is used to capture the data in this study. It is developed by Faro Technologies Inc. This laser scanner is a portable non-contact measurement system to accurately capture 3D data. The system rotates 360 degrees and measures everything within its line of sight up to 120 meters away. With a scan rate of 976 000

points per seconds and an accuracy of up to ± 2 millimeters, it can be used in a wide range of industries. This scanner is use together with Faro Scene 4.6 laser scanner software, has automatic scan registration and automatic color adjustment (Faro Technologies, 2009).



Figure 4: Faro Photon 120/20

Table 1: Specifications of Faro Photon 120/20 Laser Scanner

Range	0.6 - 120 m
Unambiguity Interval	153.49 m
Distance Error at 25m and 84% Reflectivity	2 mm
Typical Resolution	8,000 x 3,500
Typical Duration	233 seconds
Max. Resolution	470,000 x 16,384
Measurement Rate	up to 976,000 points/sec
Laser Power	20.0 mW
Wave Length	785 nm
Vertical Field of View	320°
Horizontal Field of View	360°
Weight	14.5 kg
Data Storage	Integrated hard disc or via Ethernet connection

2.2 Faro Scene

Faro Scene software is specifically designed for the Faro Laser Scanner. It is simple and easy to learn user interface with tabbed windows, the new dockable structure view, well-structured menus and tool bars allow user to use Faro Scene with less learning effort and provide more efficiency at the same time. Faro Scene processes and manages scanned data efficiently and easily by using the automatic object recognition, scan registration and positioning. This software can also colorize scans. The software is user friendly and generates high-quality data in seconds.

Scan projects can now be published on a web server by the push of a button. The new SCENE Web-Share feature allows for easy access of the laser scans with a standard internet browser. This software can be supported by latest operating system especially Windows 7 both in 32 bit and 64 bit system. It has an efficient workflow through the original data acquisition to the finished project. Faro Scene can be integrated with other software, especially with other Faro software such as Faro Cloud, AutoCAD-related software and other software similar to AutoCAD. Some important tools featured in this software are measurement tools, object fitting as well as 2D and 3D visualization.

In order to use FARO Scene seamlessly, these are the recommended hardware specifications. A scan with 30 million scan points takes up approximately 400 MB when loaded in full resolution. Therefore, the computer should have at least 1 GB of main memory. Meanwhile, the mouse that will be used should have 2 buttons and a scroll wheel. Then, the graphics card should support OpenGL and have its own memory. Lastly, the network card is required for licensing FARO Scene (Faro Technologies, 2009).

3.0 METHODOLOGY

3.1 Project Design and Preliminary Works

Before doing the scan, preliminary works are done. Therefore, site visit was done in order to decide on where to establish the scan stations and scan targets as in **Figure 5** and **Figure 6**. Note that in Figure 5 the scan stations are indicated by circular-shaped figure. It is because the laser emitted from the scanner did not cover the area under the equipment.

It is very crucial to plan the location of the scan stations in order to ensure that the object and also the spherical target are visible and clearly seen from the various stations. Three stations were established to cover from all dimensions around the room in the scanning sessions. The scan stations established must be more than one in order to cover the whole area of the computer room. Hence, the spherical scan target should be used wisely as a link between these stations. Digital cameras can also come in handy in order to capture the images of the room so that we can refer the scanned objects with the objects in the real world (Suhaib, 2009).

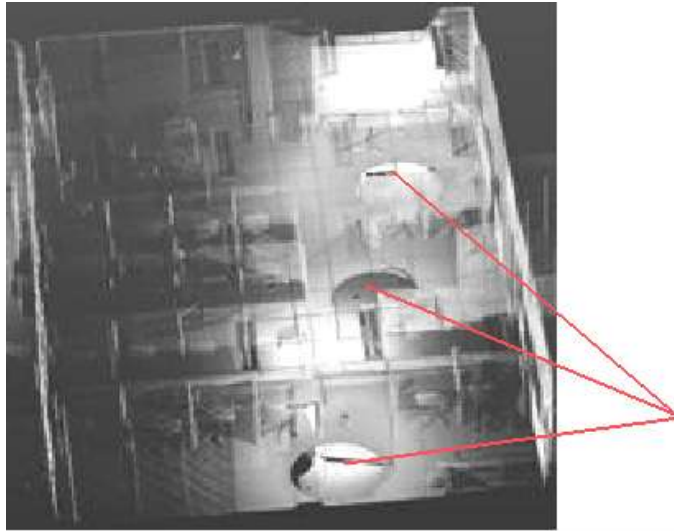


Figure 5: Locations of scan stations established at the computer room



Figure 6: Locations of scan targets around the computer room

3.2 Scanning Task

The scanner is set up using carbon fiber tripod where the battery used is mounted on top of it and the scanner with its tribrach is placed above the battery. Establish cable connection as shown in **Figure 7** (Faro Technologies, 2009). Switch on the external operating PC and when the PC is ready, switch on the power for the scanner by using the switch on the battery pack. The data capturing procedure was shown in **Figure 8**.

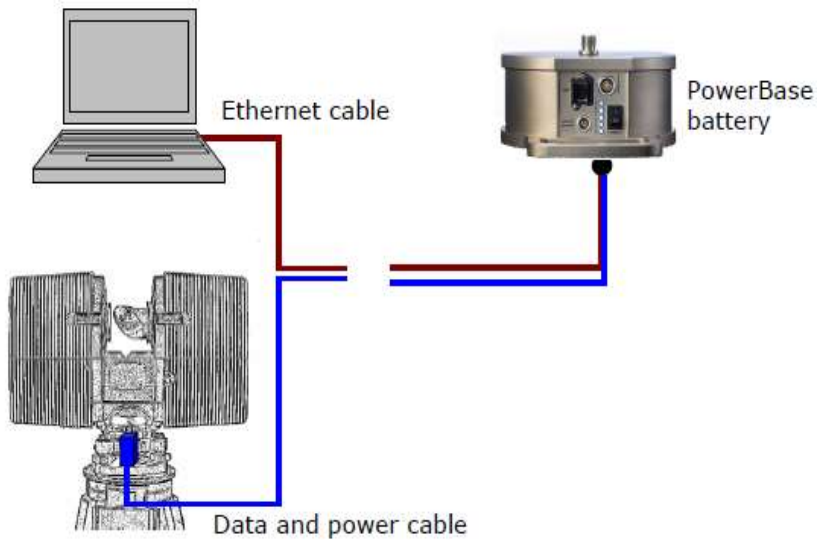


Figure 7: Connection between scanner-laptop-battery

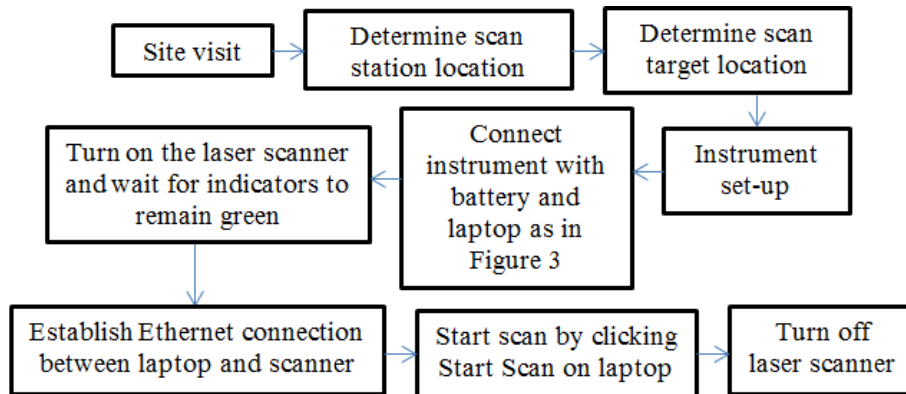


Figure 8: Data capturing procedure

Start the scanner by pushing the On/Off button. This will start the boot procedure of the internal PC, which will be indicated by the PC LED turning to red for a moment and then flashing in green. When the PC is ready, the PC LED will remain green, while the Motor LED will be flashing in green till the initial parameter transfer is finished. When the base unit and the mirror unit are ready, the Motor LED will stop flashing and remain green (**Figure 9**).

The next step is to establish an Ethernet connection between laptop and scanner. Select the scanner used by left click on the scanner’s name as displayed in **Figure 10**. Open the context menu with a right-click to connect to the scanner. The status icon will change to “Connected” as shown in Figure after the connection has been established and the Start Scan will become activated.

For this study, the scan resolution of $\frac{1}{4}$ was used for scanning. The expected scan time and file size were depend on the resolution, noise compression ratio and scan range chosen. The

higher the degree of resolution selected the result on scan time and file size would be longer and bigger (Ong and Cheong, 2010).

In the very first scan after the scanner has been switched on, the scanner starts turning counter clockwise for a brief moment. Then it stops and starts scanning in clockwise motion. All consecutive scans are then taken without the initial counter clockwise motion. On completion of the scan the scanner rotates counter clockwise back into its initial position.

After scanning is complete, lock the laser by turning the key to the off position. Use the On/Off button on the scanner (pressing it for at least 5 seconds) or the FARO Record Software to shut down the scanner. The PC and the motor LED will be flashing green during the shutdown and the Laser and the Motor LED will be switched off. After the shutdown is finished, the PC LED will be off and then switch off the power supply of the scanner

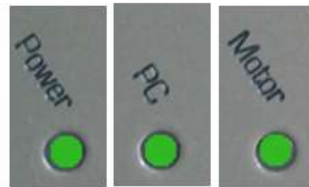


Figure 9: Power, PC and Motor LED indicators

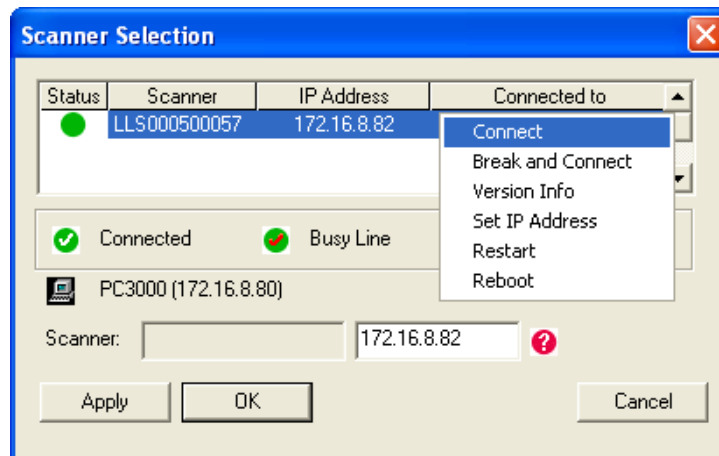


Figure 10: Establishing Ethernet connection

3.3 Scan Registration

Figure 11 shows the procedure of data processing using Faro Scene. The first step is to import files from laser scanner. There will be three files that need to be imported since there are three scan stations that have been established. After the files have been loaded, images as in **Figure 12** will appear.

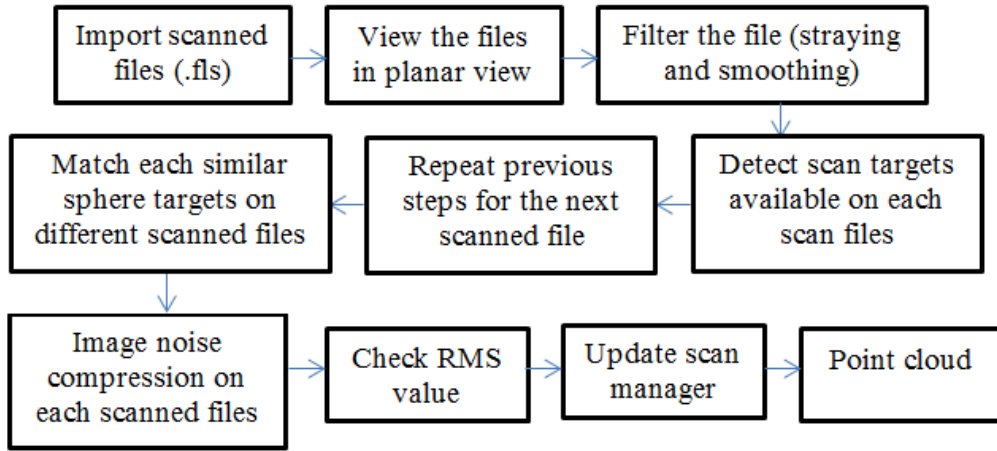


Figure 11: Data processing procedure

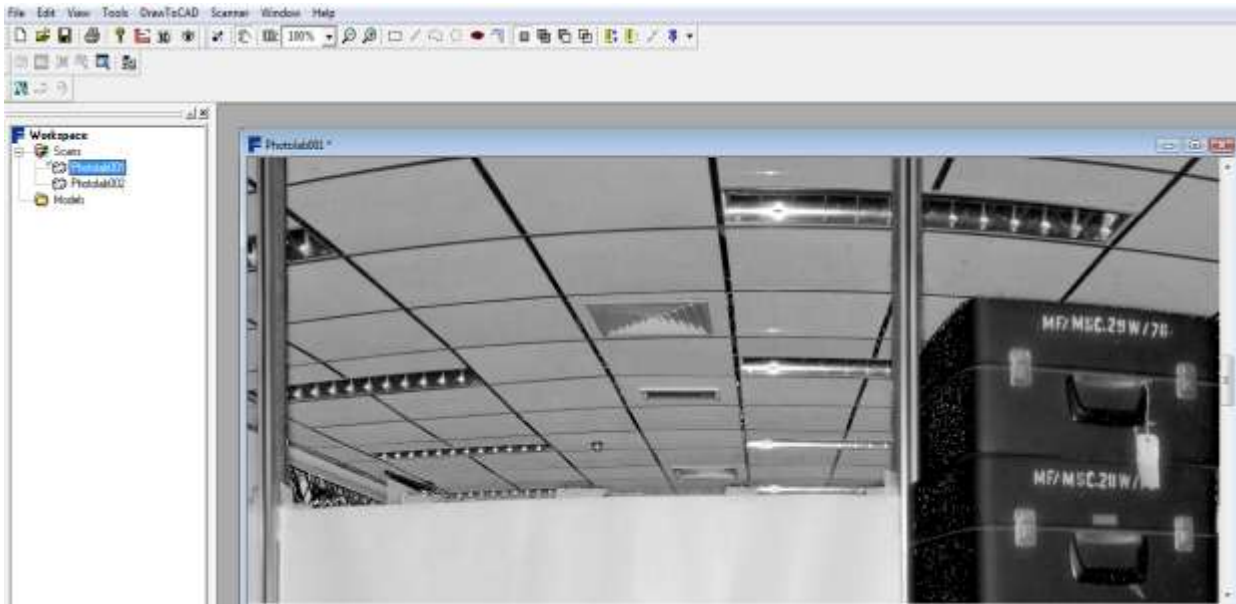


Figure 12: Display of a scanned image after loading complete

These sphere targets were used in scan registration where it will detect the same spheres that have been used in different scan stations. Besides spheres, other flat plane such as wall or floor can be used as reference for scan registration as long as the planes are detected on two or more different scan stations. This process is called plane registration. The spheres will automatically be named based on the same spheres detected on the previous scan station shown in **Figure 13**. If the sphere name is not the same but it's the same physically, then it needs to be renamed. There will be sphere that is detected only on one scan station and undetected on other stations. Therefore, the sphere can be deleted or just ignore but it is recommended to be deleted if there are a lot of spheres involved in a particular scan.



Figure 13: Spheres detected on a scan station

Then, select the whole image of a scan station by dragging the mouse and the image will turn yellow indicating that the image has already selected. Next, right click on selected image, then select New Scan. An option will appear. On the options, select noise compression 2:1 to make the image more compressed. Then click OK. Subsequently, check the root mean square (RMS) value displayed in **Figure 14** which must be less than 0.005 on each scan station. If the RMS value exceeds 0.005, it means that scan registration is less accurate which caused from sphere or plane registration inaccuracy. On the main menu tab, select 3D view to view the registered point cloud as in **Figure 15**.

/Scans/ScanManager		
ScanManager Scan Results Ref. Tensions		
Managed Fits:		
Fit Object	Mean T...	Scan/Cluster
ScanFit	0.0009	Photolab002
ScanFit	0.0003	Photolab001
ScanFit	0.0011	Photolab004
ScanFit	0.0008	Photolab003
ScanFit	0.0006	Photolab005
ScanFit	0.0005	Photolab006
ScanFit	0.0004	Photolab007

Figure 14: RMS values for each scan station

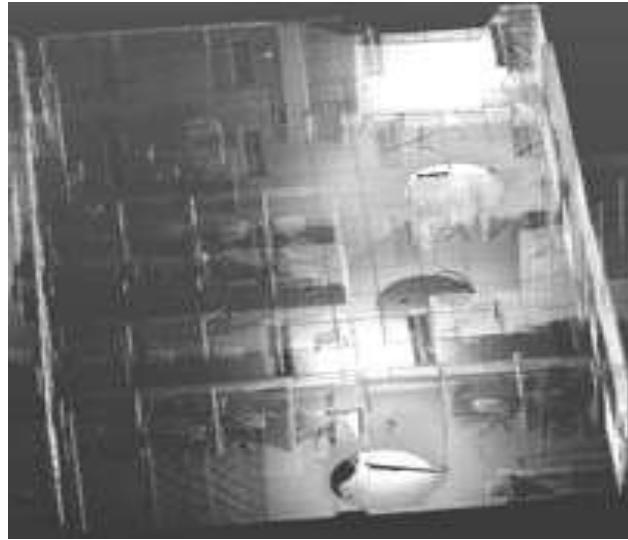


Figure 15: Registered point clouds data

3.4 3D Models and Attribute Registration

The creation of 3D model and attribute registration which is inserting object’s brand name and serial number procedure were shown in **Figure 16**. Import the point cloud from Faro Scene into AutoCAD 2011. Then, select Attach in order to view the point cloud in AutoCAD as shown in **Figure 17**. Next, change the visual styles into conceptual that can be changed at home tab. Next step is to create the model. Create a solid for a particular object from the point cloud. The completed models of objects in the room were shown in **Figure 18**. Meanwhile, the attributes for each objects is displayed on properties as shown in **Figure 19**.

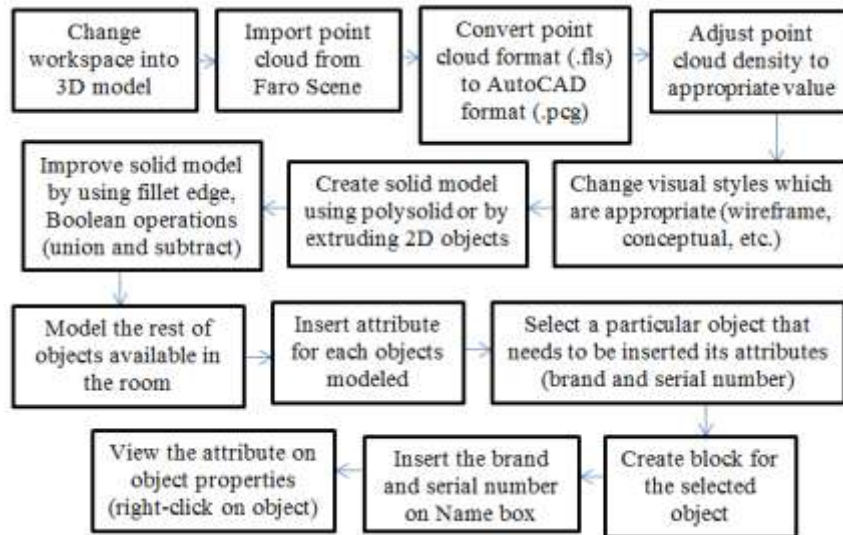


Figure 16: Point cloud displayed on AutoCAD 2011

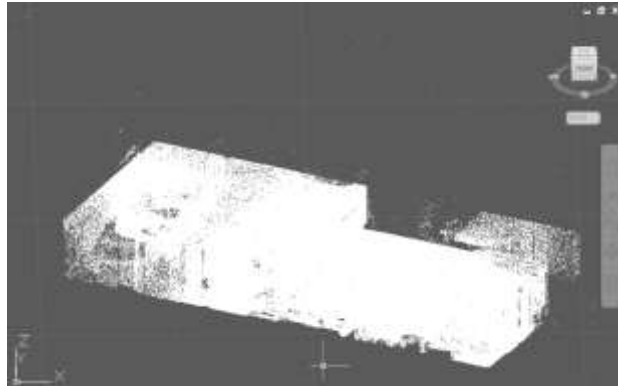


Figure 17: Point cloud displayed on AutoCAD 2011

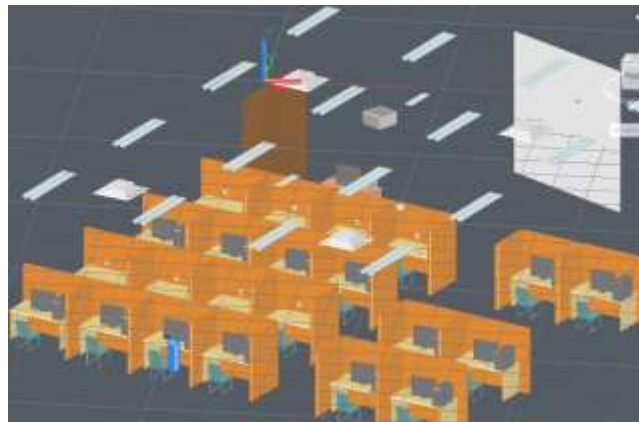


Figure 18: Completed 3D model

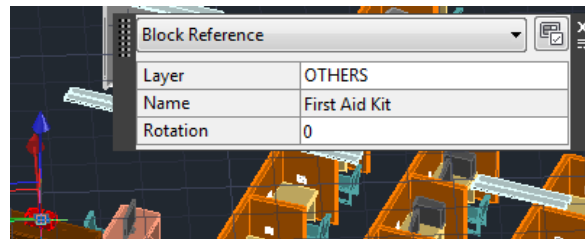


Figure 19: Attribute of the object is displayed at Name tab

4.0 RESULTS

The completed 3D models of objects available in the computer room are shown below in **Figure 20**. Together with the objects are the attributes shown next to the objects.

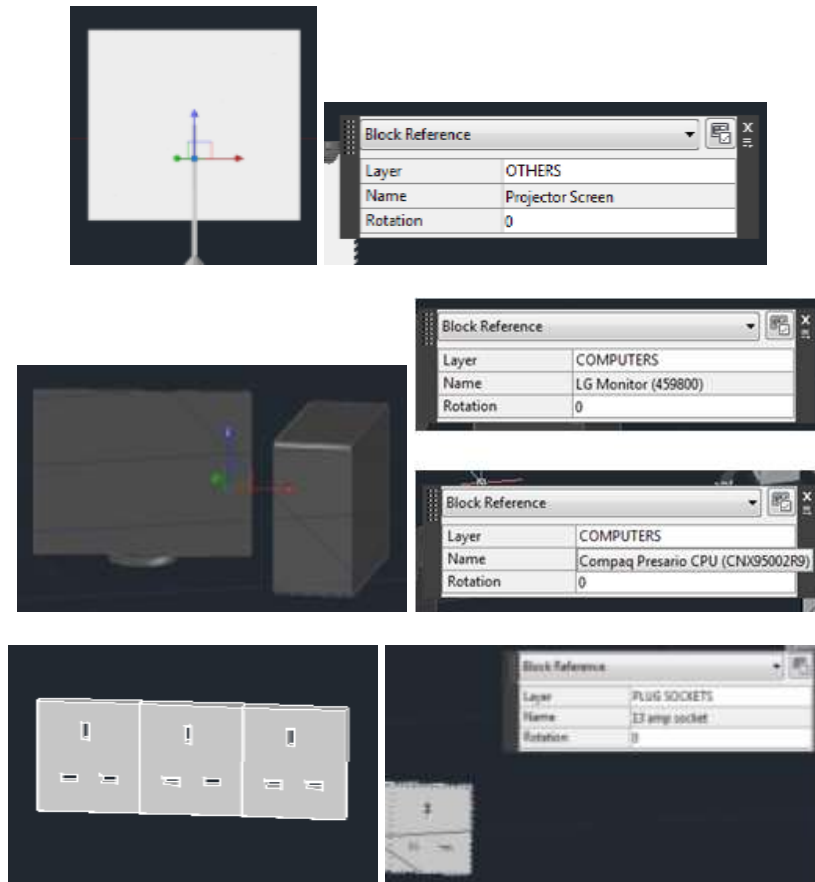


Figure 20: 3D model of objects and its attributes

Meanwhile, the analysis for this study includes measurement comparison between laser scanning measurements against measurements using Distomat, shown in **Table 2**. From that result, there were a few things can be concluded for measurement of the objects in the computer room which are:

- Both laser scanner and Distomat gave measurement until millimeter level.
- The highest measurement difference was on length of desk with -0.09m.
- The lowest measurement difference were the monitor size, central processing unit (CPU) height, wall socket width and entrance door height with ± 0.001 m. The latter height difference was +0.001m while the rest were -0.001m.

Table 2: Comparison between laser scanner measurement and Distomat measurement

Items	Dimension	Laser scanner (m)	Distomat (m)	Differences (m)
projector screen	width	1.602	1.604	-0.002
	length	1.776	1.768	0.008
monitor size (18.5")		0.473	0.474	-0.001
window panel	width	0.974	0.981	-0.007
	length	1.002	1.008	-0.006
entrance door	width	0.032	0.035	-0.003
	length	0.822	0.829	-0.007
	height	2.085	2.084	0.001
CPU	width	0.108	0.106	0.002
	length	0.378	0.38	-0.002
	height	0.304	0.305	-0.001
desk	width	0.602	0.6	0.002
	length	0.891	0.9	-0.009
wall socket	width	0.088	0.089	-0.001
	length	0.089	0.085	0.004

According to the comparison, it is proven that laser scanning method was accurate and sufficient to produced reliable virtual detailed 3D visualized model which target object consists of complex and small features. The accuracy of laser scanning was very close to the value from the Distomat. The difference was at millimeter level.

5.0 CONCLUSIONS

Based on measurements taken using terrestrial laser scanner, it provides better accuracy than using conventional equipment. Thus, it has achieved this study objective which is to develop a more accurate method for asset data capture. Accurate measurements are very important in asset data capture because it can affect decision-making process especially when rearrangement of items in a room needed to be done.

This study would be beneficial for asset managers because they will not have to go back to the site to recheck the assets. Besides, the implementation of laser scanner in asset data capture proved as a faster method of capturing data rather than conventional method that uses check form and photographic images.

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