

## **3D Strata Modelling Based on Indoor LiDAR**

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**Key words:** Terrestrial Laser Scanning (TLS), Mobile LS, Strata, LADM, 3D Cadastre

### **SUMMARY**

This paper discusses the current status of 3D cadastre situation in Malaysia and possible future developments. Land Administration Domain Model (LADM – ISO 19152) has being investigated by Malaysian National Mapping Agency (NMA) to serve the need for effective information handling as a basis for 3D Cadastral purposes. Currently, the authority utilises traditional technique and other existing floor plans for strata modelling. However, the existing technique (i.e. traditional building survey) is labourious and time consuming. Thus, it is the aim of this paper to investigate the most appropriate technique for 3D objects modelling purposes. The authority plans to utilise two most recent LiDAR based techniques such as static LiDAR and mobile LiDAR for 3D cadastre objects modelling. Various issues related to these approach will be investigated e.g. 3D modelling and accuracy. One of the issues – ‘party wall’ as part of Right, Restriction and Responsible (RRR). We also intend to incorporate the 3D cadastral objects with the Malaysian LADM model. In near future, we intend to incorporate Building Information Modelling (BIM) data with 3D cadastre.

# 3D Strata Modelling Based on Indoor LiDAR

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## 1. INTRODUCTION

Recently in Malaysia, the idea of having 3D database for the cadastral system has been discussed (Hassan, 2017). 3D approach in other domains such as 3D GIS (Geographical Information Systems) will make a 3D cadastral realizable as reported by Stoter and Oosterom, 2006. The current 2D cadastre system is regularly updated by the National Mapping Agency (NMA), i.e. the Department of Survey and Mapping Malaysia (JUPEM). However, this 2D information may not be able to serve complex situations. This means we need to extend into 3D cadastre. In the previous FIG Congress 2014 that was held in Kuala Lumpur, few papers were presented on the international standard of land administrative model concerning the LADM for 2D and 3D cadastre. The conceptual idea is to use international standard of Land Administration Domain Model (LADM – ISO 19152) on heading to have a complete 3D cadastre.

We have seen LiDAR data being collected by national and private data providers for various mapping tasks including for 3D city modelling, 3D cadastre and strata (Buyuksalih and Bayburt, 2017; Abdul-Rahman, 2016). This type of data has been captured and used in various places including in Malaysia. The data offers several advantages especially its high accuracy despite the high cost and huge data volume. 3D geospatial objects could be generated from the captured points cloud and there are many works have been initiated by the related agencies for 3D geoinformation. In Malaysia, the national mapping agency attempts to make use of LiDAR datasets (airborne and terrestrial) for 3D cadastre and recently the authority has deployed indoor laser scanning technique for strata purposes. We believe that indoor laser scanned data could be utilised for strata modelling, thus it forms major discussion of this paper. The paper also attempts to explore in the aspect of accuracy of the generated rooms geometry. Building information modelling (BIM) also will be briefly investigated especially the integration to geospatial component.

Section 2 discusses terrestrial laser scanning, the indoor LiDAR data as discuss in section 3. Section 4 and section 5 describes the 3D cadastre modelling and 3D cadastral initiative. Finally, conclusion in section 6.

## 2. TERRESTRIAL LASER SCANNING

Nowadays, terrestrial laser scanning (TLS) is being used for geomatics and engineering applications. The knowledge of the instrument is very important to analyse an object from a point cloud data. Laser technology is being used to scan the surface of objects in order to analyse shapes and their appearances. The collected data could be used to construct digital model either in two-dimensional (2D) or three-dimensional (3D) models. The usefulness of terrestrial laser scanning covers for variety of applications (Lerma Garcia and Jose Luis, 2008).

TLS method collects 3D points of the objects. The range of the object is about 5m – 350m. The advantage of this instrument is it can collect millions of point clouds data for an object or surface (Gordon *et al.*, 2001). The point cloud is quickly modelled into regular gridded or triangulated surfaces permitting local subsidence trends to be identified, which otherwise may have been missed by the traditional techniques. Additionally, signalized target for control points is not essential. Natural features are identified and used to register multiple scan clouds. The terrestrial laser scanning can achieve overall observation area that is closer to 360° around it. Figure 1 indicates that the horizontal scanning can reach the entire area of 360° while vertical scanning can reach up to 320°. This is very useful for extensive data acquisition. On the other hand, TLS also related to remote sensing measurement technology where the direct object accessibility is not required. This technique has no influent of the number of control point (Vežočník *et al.*, 2009).



Figure 1: Terrestrial laser scanning coverage angle (www.faro.com, 2016)

## 2.1 Concept of Terrestrial Laser Scanning Measurement

The measurement system in TLS is used to calculate the 3D position of the scanned object. These systems can measure over several thousands of data points per second that allow datasets to be collected far where it could not be obtained by traditional surveying (Riley & Crowe, 2006). The method used by the TLS is based on optical measurement method. Scanning unit is part of the 3D data obtained in the TLS system. They can be examined under three groups depending on the method of distance measurement described in Table 1 (Ergün, 2011; Schulz, 2007).

Table 1: Classification of TLS according to distance measurement

Measurement Model	Range (m)	Accuracy (mm)
Pulse-based / Time of Flight (TOF)	< 100	< 10
	< 10,000	< 2
Phase-based	< 100	< 20

It is advisable for users to determine the type of TLS needed to fulfil the requirement for their applications. The closer range has better precision. For surveying method, the direct TOF technique is mostly used.

## 2.2 Classification of Terrestrial Laser Scanning

The TLS uses advanced laser to obtain the point cloud data. The classification is based on measurement principle or technical specifications. The measurement principle is the time-based scanning principle, which is classified into two; the pulse-based (time of light) and phase-based measurement as shown in Figure 2.

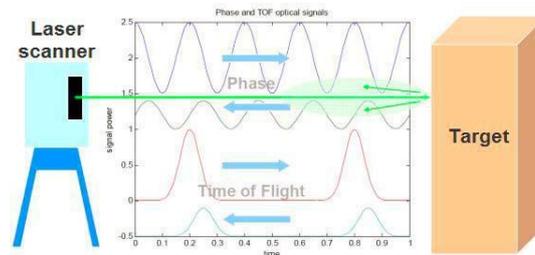


Figure 2: The operating principle of phase-based and time-of-flight terrestrial laser scanning (Hiremagalur et al., 2007)

The Time-of-Flight measurement technology is based upon the principle of sending out a laser pulse and observing the time taken for the pulse to reflect from an object and return to the instrument. The phase-based measurement technology measures the phase difference

between the reflected beam and the transmitted amplitude that modulates continuous wave of laser beam. The terrestrial laser scanning is capable of measuring up to 50 000 distances per second ( Hiremagalur et al., 2007).

### 2.2.1 Pulse-Based Principle

The pulse-based scanner uses laser light to detect the target. It is also known as time-of-flight (TOF) scanner. In the middle of this scanner is a time-of-flight laser rangefinder. This rangefinder finds the distance range of a surface by timing the round trip time of a pulse of light (Boehler & Marbs, 2002). TOF technique is based on time elapsed measured between the emission of a laser signal. Besides that, detection of its portion backscattered from the surface (Reshetyuk, 2009). Figure 3 shows pulse-based principle.

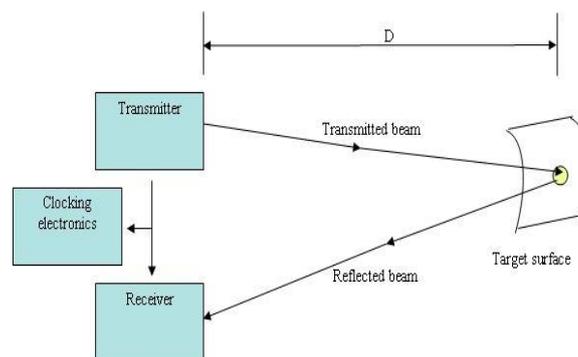


Figure 3: Pulse-based terrestrial laser scanning principle (Lerma Garcia and Jose Luis, 2008)

TOF TLS accuracy depends on the measurement of time ( $t$ ) travel. It only detects the one point of the distance in its direction of view. Thus, the scanner scans the entire field of view one point per time by changing the range finder's direction of view to scan different points. This direction of the laser rangefinder can be changed by using a system of rotating mirrors (Jacobs, 2005). The time-of-flight of terrestrial laser scanning could measure the distance of 1,000 to 150,000 points for every second. This equipment produces a high quality point cloud. Besides that, it has a long range of scanning field. However, the accuracy and scanning speed are lower than the phase-based scanner. It is seen that the length of the acquisition scan can be related to the weakness of this method (Romsek, 2008). The maximum range for TOF scanner is 6 km.

### 2.2.2 Phase-Based Principle

Phase-based terrestrial laser scanning has a high scanning speed and good accuracy rate. The suitable distance range is 10 meters. The transmitted beam is modulated with the harmonic wave. The distance is calculated using the phase difference between the transmitted and received waves. It has a higher precision and a higher measurement up to one million points in the second (Ergün, 2011; Romsek, 2008; Shan & Toth, 2008). Figure 4 shows Phased-Based terrestrial laser scanning principle.

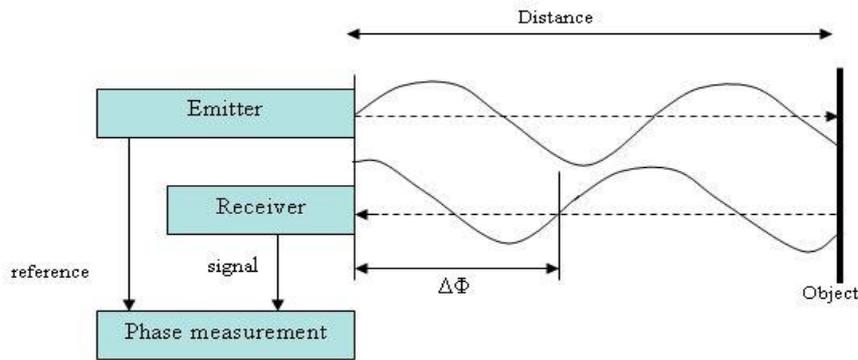


Figure 4: Phase-Based terrestrial laser scanning principle (L. Garcia and J. Luis, 2008)

Single modulated measurement would result less in the measurement precision. In order to solve this precision problem, more than one of the modulation wavelength are needed. Then, the longest wavelength would define the uniqueness range and the shortest wavelength would define the precision that is obtained. This is a medium range scanner. The phased-based principle has high scanning speed. Besides that, it has a wide field of scanning through 360°. It can also deliver more accurate data than direct TOF (Hajian & Becerik-Gerber, 2009).

### 2.2.3 Triangulation-Based System

An angle measurement can obtain a higher precision with terrestrial laser scanning (Pfeifer & Briese, 2007). Triangulation methods are used in applications such as ancient items, artifacts and antiques. Figure 5 shows the triangulation technique occurred in the terrestrial laser scanning instrument.

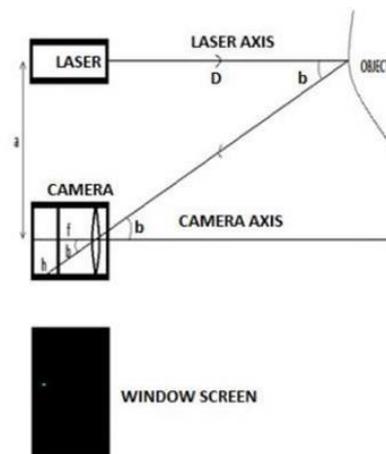


Figure 5: The triangulation technique for terrestrial laser scanning (Malhotra *et al.*, 2011)

It is known as the close-range terrestrial laser scanning. This method is based on the concept of the triangle that connects the laser device, charge couple device (CCD), camera scanner, and subjects (Majid *et al.*, 2008; Malhotra *et al.*, 2011). The method describes the measurement in a sequence of points along the "laser light" curve on the object. The number of points depends on the resolution camera. The results when using VGA resolution is 250,000 points per scan.

### 3. INDOOR LiDAR DATA

In providing this indoor data there are two important aspects, they are data collection and data processing. The good skill in data collection and processing will produce good results and minimize the error.

#### 3.1 Data Collection

In order to generate 3D model, there are two possible capturing methods namely Terrestrial Laser Scanning (TLS) and Indoor Mobile Laser Scanning (MLS). Both of these methods have advantages and disadvantages for the 3D modelling.

3.1.1 Indoor Mobile Laser Scanning Recently, indoor Mobile Laser Scanning (MLS) has been utilized for building modelling purposes. It speeds up the acquisition and post processing. It has been proven to be a popular survey tool as it provides accurate, semantically rich 3D data (Thomson *et al.*, 2013). Figure 6 shows the sample data of TLS and Indoor MLS.

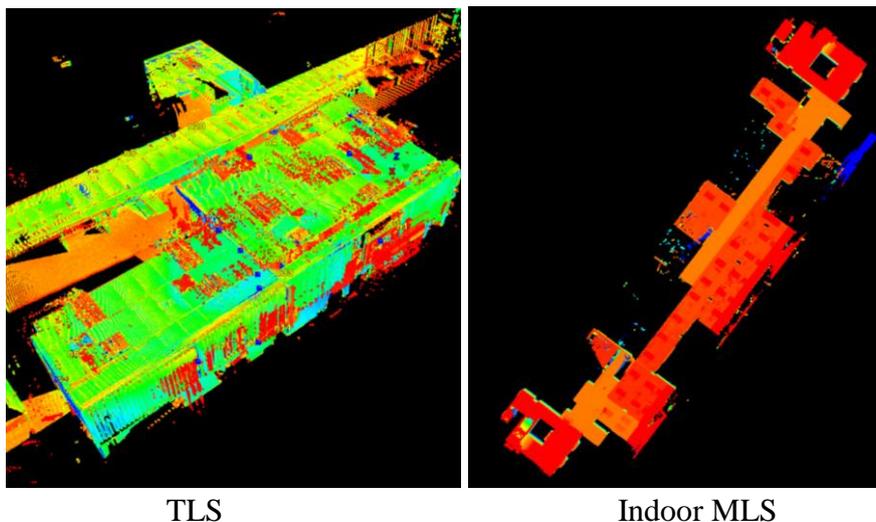


Figure 6: Sample data: static TLS (left image), indoor mobile laser scanned data (right image)

### 3.1.2 TLS vs Indoor Mobile TLS

TLS provides good quality of point cloud however the technique requires good planning. On the other hand, indoor MLS offers faster data acquisition (Lehtola et al., 2017). The MLS data acquisition requires proper planning in order to avoid data duplication and redundancy. In general TLS requires the use of Global Satellite System (GNSS) for the process of translating, rotating, and possibly transforming a point cloud into georeferenced data. The MLS utilizes inertial motion unit (IMU) for processing workflow.

The TLS technique requires several numbers of targets unlike MLS. In general, targets are needed to register point cloud. Then model space and filtering steps could be carried out as illustrated in Figure 7.

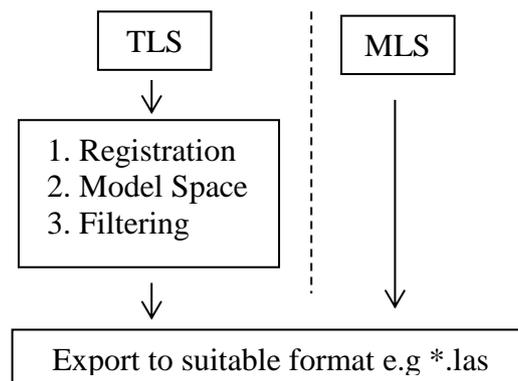


Figure 7: The different process TLS and MLS

## 3.2 Data Processing

LiDAR data processing requires high-end computing specifications due to huge number of data volume (point cloud). One of the tools for TLS data processing such as Cyclone (from Leica) on the other hand, RiSCAN PRO meant for MLS datasets. Then, the data in \*.las format could be transferred for 3D modelling task e.g. by using SketchUp tool. Tool within ArcGIS could be utilized for 3D primitive (multipatch feature and wireframe). The workflow as illustrated in Figure 8, Figure 9 and Figure 10.

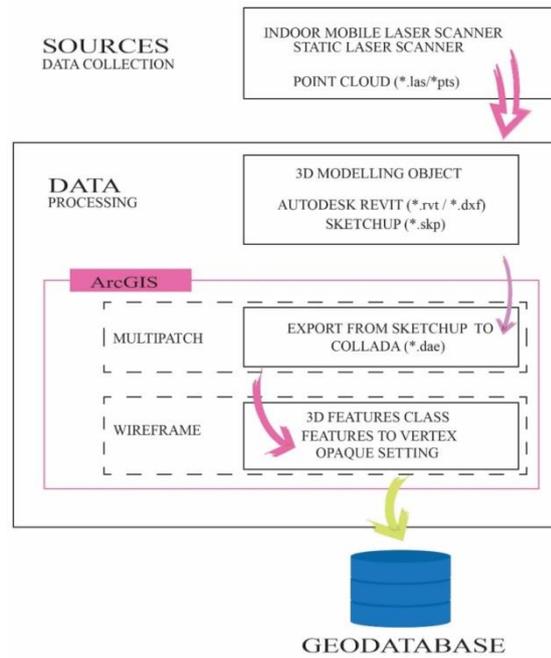


Figure 8: General process for generated 3D model from point cloud to wireframe

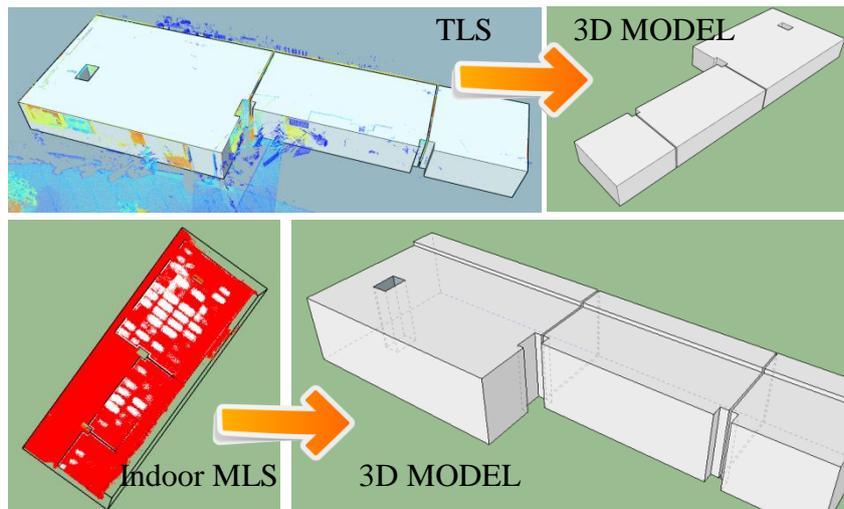


Figure 9: Points cloud to 3D model

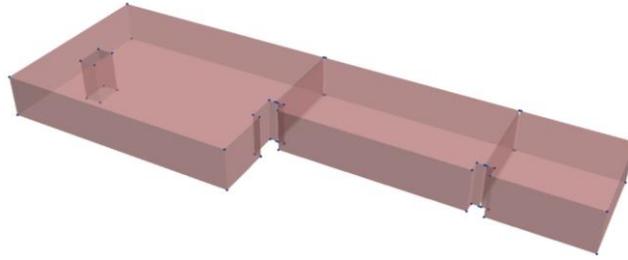


Figure 10: 3D model with nodes and edges for multipatch feature

#### 4. 3D CADASTRAL MODELLING

Apartment is one of the situations that need the 3D cadastre to register record and manage the information such as the spatial information such as the geometry of building and also the non-spatial information such as the ownerships. Apartment registration for strata title stores information about the particular unit on certain level or floor. The 3D model of the apartment has been captured using laser scanning technique and designed using SketchUp tool for the purpose of modelling in a 3D environment. However, the model did not have the functionality to store the coordinates in the database and the coordinates are arbitrary in nature (no geodetic reference).

The Unique Parcel Identifier (UPI) has been designed for 2D dataset. Meanwhile the identification for 3D objects needs more reliable method of identifier. Each none spatial record in the property registration database has a unique identifier that eventually can be linked to the appropriate record in the National Digital Cadastral Database (NDCDB). Then the same unique identifier can be used to identify the lot/parcel in the proposed 3D Cadastre spatial (object) database. Because of 3D component in the 3D cadastre also represent the lot/parcel geometrically in the 3D representation, so this 3D database should be managed by NMA.

Unique Feature Identifier (UFI) is needed to solve problems in 3D cadastre management in Malaysia. The UFI code structured from UPI together with additional 10 other characters as the additional codes for the 3D cadastral objects. The UPI code represents the State, District, Town/City, Section, and Lot Number been extended to Building (3 characters), Floor (3 characters), and Plot (4 characters). The UFI consists 26 characters code and it makes the particular 3D cadastre objects have a unique identification throughout the country. The example of the UFI can be seen clearly in Table 2 below. From the foregoing discussion it can be realized that the hybrid 3D cadastre approach certainly would be most suitable approach in order to have 3D Cadastre for Malaysia.

Table 2: Example of UFI Code

State	District	Town/City	Section	Lot No.	Building	Floor	Plot
06	08	40	000	0001234	<b>M01</b>	<b>001</b>	<b>0007</b>
UFI	0608400000001234 <b>M010010007</b>						

The approach of 3D modelling provides a new dimension of 3D cadastral that including the landed, strata and stratum environment. It is important that the 3D model represents 3D cadastral in Malaysia which means that all the data are linked with the NDCDB and the ownership records. The UFI will be created after the wireframe and 3D spatial objects been modelled as shown in Figure 11.

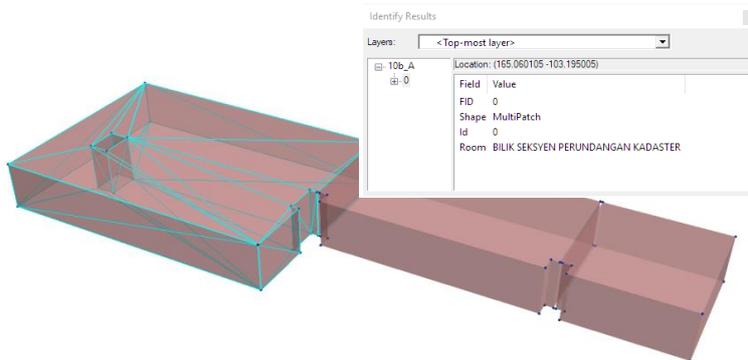


Figure 11: 3D model with Database

The legal, institutional and technical aspects of a 3D geospatial database for cadastre provides the framework for its successful development and implementation. However, data modelling is one of the elements of a successful 3D geospatial database. A standard data model is crucial in developing a 3D geospatial database. A standard data model is important to facilitate interaction among the database designer with the end-user. It also can improve the understanding of an organization for which the database is developed.

After the 3D geodatabase is created, it will be formed in Extensible Markup Language (XML) for accessing in Web services. Header from XML and all the geometric features can be read smoothly and the size is smallest.

## 5. 3D CADASTRAL INITIATIVE

In the future, 3D Strata Modelling will be integrated to Land Administration Domain Model (LADM), Strata Title and Building Information Modelling for efficient control and management.

## 5.1 BIM

Building Information Modelling (BIM) is an intelligent 3D model based process that gives architecture, engineering, and construction professional insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure. This BIM aspect for geomatics or geospatial will be investigated in the near-future. It is one of the research areas at Malaysian Survey and Mapping Agency (NMA), i.e. JUPEM. The outcome of this 3D modelling from indoor laser scanned (static and mobile) could be utilized for the potential BIM initiative.

## 5.2 Discussions

A measurement has been made to obtain the accuracy of the method. This work compares the length and the width of the room floor with the floor plan. Table 3, shows the measurements of two different techniques compared with the floor plan measurement.

Table 3: The difference measurements between TLS and MLS.

Technique / Source	Measurement		Difference	
	Length	Width	Length	Width
Floor Plan	7.512 m	5.591 m	-	-
TLS	7.497 m	5.590 m	0.015 m	0.001m
MLS	7.480 m	5.557 m	0.032 m	0.034 m

However on party-wall issues, the centre line of the wall can be derived from two edges of the point cloud surface (see Figure 12). The different point cloud density between TLS and MLS create vague edges, thus influence the accuracy on the edges detection.

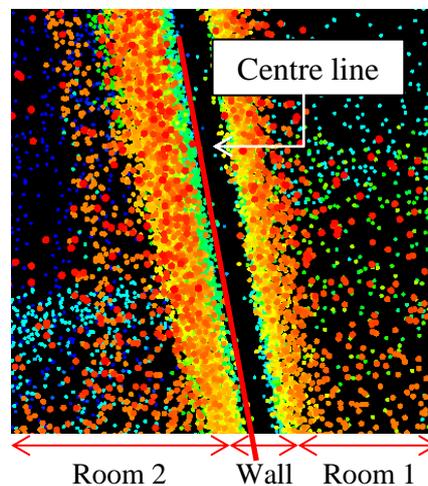


Figure 12: Determination of centre line for party-wall

## 6. CONCLUSION

There have been several works on this indoor LiDAR for cadastre purposes and 3D modelling in general, but very few on strata. In this paper, we have described some aspects of indoor TLS and MLS data collection for strata. The work presented in this paper is to provide indoor TLS/MLS implementation specifications for 3D primitives within the geodatabase. It shows that the indoor TLS/MLS has a potential in providing 3D data for building strata modelling purposes where aspect or issue of “party-wall” – middle line for adjacent properties could be addressed.

We anticipate extending this work as integration of strata 3D model with BIM.

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