

# 3D Laser Scanning to Detect Property Encroachment

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**Key words:** Cadastre, Cadastral Survey, Laser Scanning, Terrestrial Laser Scanner, LiDAR, Property Encroachment, GIS.

## SUMMARY

Three-dimension (3D) laser scanning technique employs the LiDAR (Light Detection and Ranging) scanner to capture millions of data points of a real-world environment in 3D, allowing users to view that environment virtually. The data points are known as point clouds which can be used to produce accurate and realistic 3D maps/models for use in a variety of applications including surveying, mapping, engineering, monitoring and investigations of crime/accident scenes etc. The major advantage of this surveying technique is that it facilitates high accuracy, high resolution, complete and detailed 3D data acquisition of objects and environment rapidly.

Property encroachment is the situation which occurs when a structure is built in whole or in part on a neighbour's property. It may be the result of incorrect surveys, or mistakes or miscalculations by builders or owners when erecting a structure. Traditionally, the survey work processes to detect encroachment is tedious and the plan created is not easy to visualise.

This paper describes the usage of 3D laser scanner to capture accurate 3D point clouds data and to detect encroachment. Point clouds data collected will be overlaid with existing cadastre boundary Geographic Information System (GIS) data for better understanding of the encroachment and better decision making.

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## 1. INTRODUCTION

Three-dimension (3D) laser scanning technique has recently become popular in many industries, such as surveying, mapping, engineering, monitoring and investigations of crime/accident scenes etc. These industries can benefit from laser scanner due to its ability to capture 3D points in  $x, y, z$  accurately, rapidly, completely and in high resolution compared to conventional measuring instruments.

Property encroachment occurs when a structure is built in whole or in part on a neighbour's property/land. The existence of an encroachment is usually confirmed with a boundary line survey or technically known as a Cadastral Survey. Results of such a survey are usually recorded in a survey plan. A property owner whose land is being encroached upon may insist that the encroaching structure be altered or removed. If the encroaching structure is not removed, the encroaching party may also be required to pay a rent to the property owner.

Singapore Land Authority (SLA) manages approximately 14,000 ha of State land and 5000 State buildings. It's Building Management and Land Management teams ensure that all vacant State land and buildings are taken care of with basic, reasonable maintenance until and while they are leased for interim uses. The team also enforces any encroachment onto State land and buildings. The Land Survey Division of SLA works closely with the Building and Land Management teams in the detection of encroachment onto State lands and properties.

The Land Survey Division has acquired a terrestrial laser scanner (TLS) which allow us to harvest the benefits of the technology into our daily operations especially in encroachment survey. Besides that, we also adopt this technology in topographic survey, state properties management and indoor mapping. This paper aims to describe the usage of 3D laser scanner to capture accurate 3D point clouds data and to detect encroachment.

## 2. EVOLUTION IN SURVEYING TECHNIQUES

Surveying techniques have being existed for several thousand years. Sir Henry Lyons (1927) claimed that during the ancient Egypt time, by using simple geometry, Egyptians re-established their washed out farm boundaries due to the over flown of Nile River. Also, the Great Pyramids of Giza, built 2700 B.C. were accurately set out and constructed with its nearly perfect squareness and north-south orientation.



**Figure 1:** Land-Measurers at work, from wall-painting in tomb of Menna at Sheikh Abd el Qurna, Thebes.(Sir Henry Lyons, 1927)

Another scene showing chainmen measuring on a field which appeared in the tomb situated in the Theban burial ground (**Figure 1**). What is indicated in the recorded history there were some surveying techniques established to support the construction and administration of the Old Kingdom.

For the past hundreds of years, land surveyors had been using chain and compass to measure distances and angles. Until the recent decades, another advancement where the theodolite and electronic distance measurement (EDM) came in handy which allow surveyors to measure angles and distances more accurately and precisely. Shortly, it evolved into electronic total station, which measures angles and distances with the push of a button.

Laser scanner, TLS in particular has been taking up a greater stake in modern land surveying industry. 3D TLS emits laser pulse at the rate around 1MHz for range measurement, while the scanner mechanism rotates in vertical and horizontal planes through the centre of instrument in identical angular step sizes. The simultaneous measurement of angle and distance generate a 3D coordinate from each pulse returned to create a 3D image of  $x, y, z$  points, which is called point cloud.

### 3. ENCROACHMENT DETECTION

The Land Survey Division assists and provides advice to the Building and Land Management teams in the detection of encroachment onto State lands and properties. During the day-to-day operation of the Building and Land Management team, they will come across encroachment

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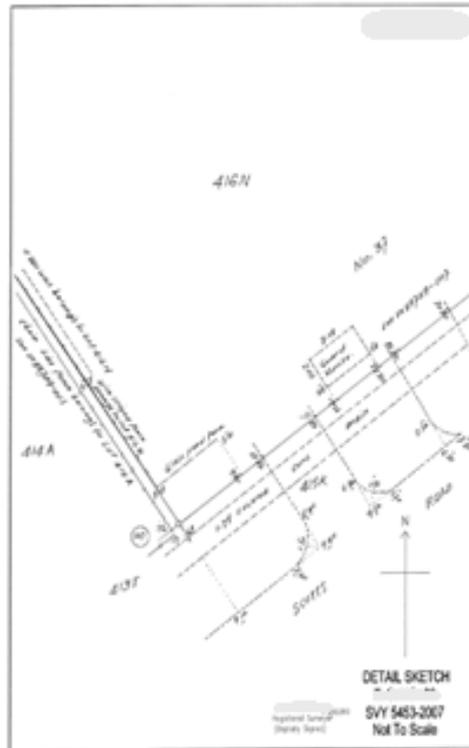
onto state lands or properties. In the case that boundary marks are found on site or the boundary lines are easily established, encroachment structure and size can be detected and determined easily. These cases generally will not be referred to Land Survey Division. However, Land Survey team will be activated when the boundary marks are not found on site and the encroachments are not apparent.

Conventionally, Total Stations are being used in the detection and determination of encroachment. Traverses have to be established based on the control markers available on ground or via Real Time Kinematic (RTK) method. From the traverses established, surveyors will determine the property boundaries on ground. With the boundary lines determined, it will help the surveyor to determine the encroached structures or objects. **Figure 2** shows a surveyor picking up the location of encroached structures. This field process is a slow and potentially unsafe.

After the survey, a 2D sketch is drawn to depict the dimension of the encroachment and to determine the encroachment area. **Figure 3** shows the surveyed encroachment details drawn in 2D plan. By looking on the 2D plan itself, some imaginations are required to relate the drawing to the encroached features on the ground. Users with less experience might have difficulties to visualise the 2D plan.



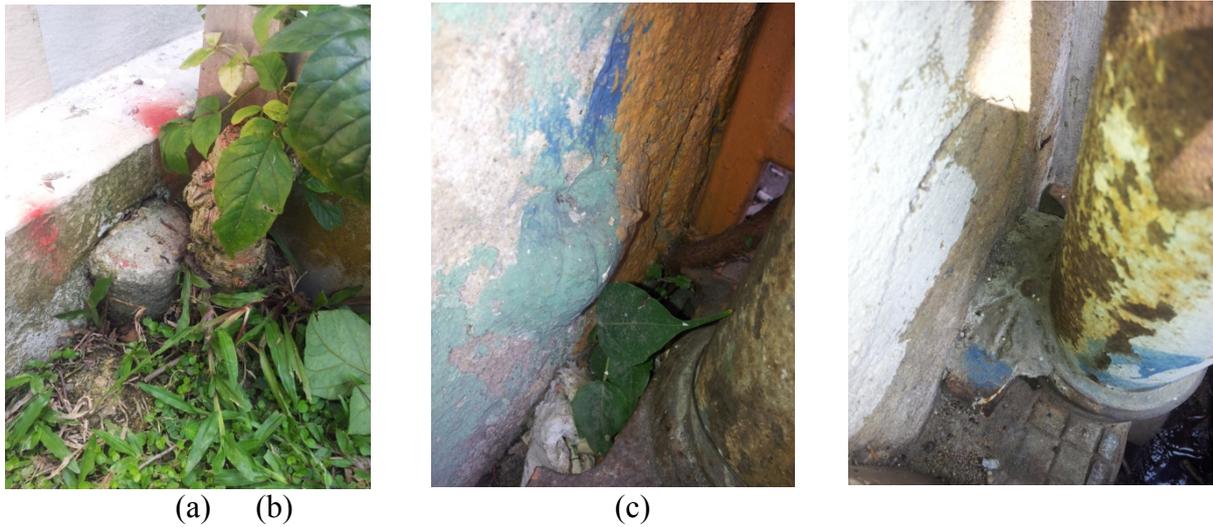
**Figure 2:** Surveyors using Total Station to pick up location of encroached structure by placing a mini prism on the encroached object.



**Figure 3:**A 2D encroachment sketch showing the dimension and area of the encroachment.

### 3.1 Laser Scanning Approach

With the laser scanning approach, a 3D laser scanner is used to record and identify possible encroachments of properties into state lands. This approach is effective for the scenario of “zero set-back” in which the walls of the building are located very near or on the property boundary. **Figure 4(a), (b) & (c)** show a few examples of such situation. With laser scanning, it is possible to capture and derive building corners, without the need to consider prism offsets to the exact corner. Another common situation which scanning has advantages is where there are multifaceted structure encroachment such as air conditioning units, awnings, exhaust trunkings, signboards, balcony extensions, wall extensions, which are protruded from the side of a building. **Figure 5** demonstrates some of the possible encroached features.



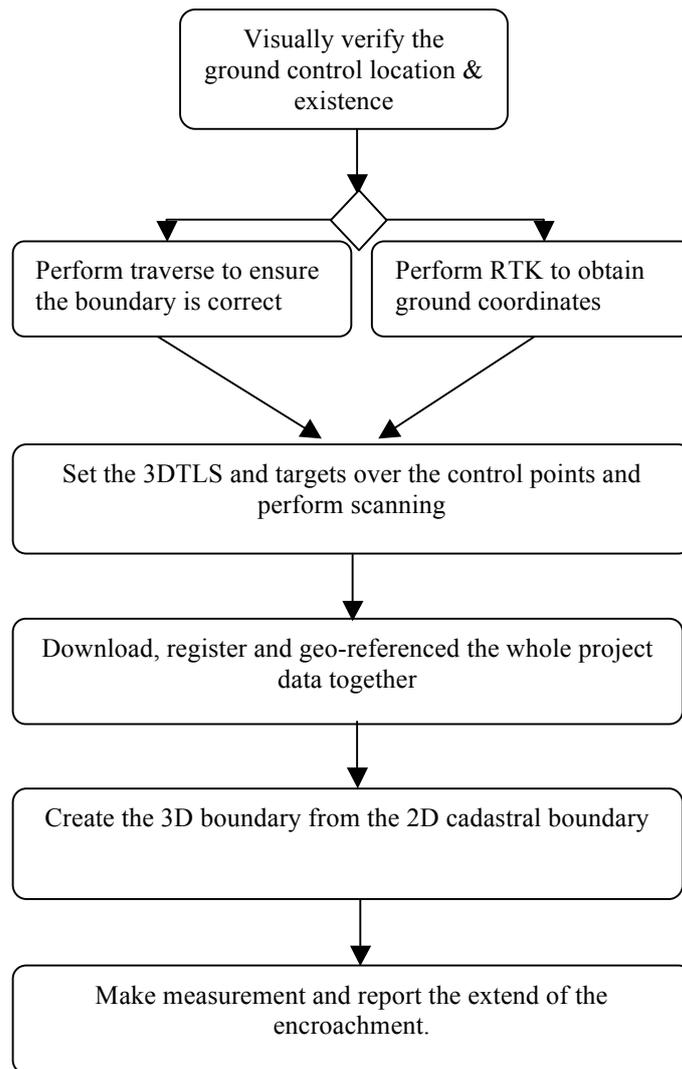
**Figure 4:** (a) Boundary stones, (b)&(c) cut marks which are close proximity to the walls.



**Figure 5:** Features extended from building walls.

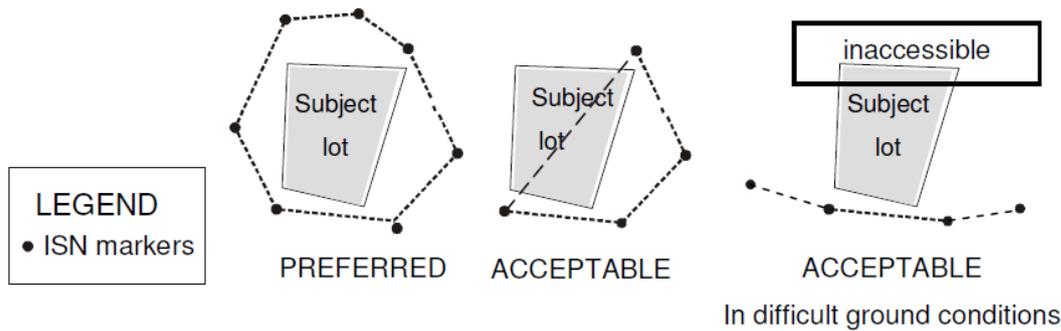
### 3.2 Data Acquisition and Processing

The concept of 3D TLS on encroachment work is not much different from conventional survey. The basic rules of verifying and checking the building boundaries still apply. **Figure 6** summarises the workflow using TLS for encroachment detection.



**Figure 6:**The general workflow of TLS in encroachment detection.

Based on the survey plan which shows the final approved boundaries and areas of the lots, a recce was carried out on the affected lots to identify and confirm the existence of boundary markers or cut mark as depicted on the plan. Upon verification, a cadastral survey (closed loop traverse) based on SVY 21 datum and connected to at least four survey control markers on the geound, known asIntegrated Survey Network (ISN) markers will be conducted using a total station. Refer to **Figure 7**for conducting of the traverse.



**Figure 7:**Connection to ISN markers. (SLA, 2011)

Well spread of RTK points also can be use as controls for commencement of scanning work. Generally there are several methods of registering two or more scenes together, in choosing which method to be adopted it depends on site conditions and project requirements. Often, one or combination of the methods can be adopted. The common one will be:

- Target to target, where minimum 3 common targets are required to be seen on the desired two or more scenes to be registered. Special identification number is assign on each target to allow ease of matching the targets during registration process.
- Cloud to cloud,requires sufficient overlapping of point cloud on the desired two or more scenes to be registered. This method is useful when the site condition does not allow the setup of targets. Minimum 3 distinct edges are recommended to be seen in every scan so they can easily identified and can be used as initial estimation for the registration software to match and adjust the common cloud planes.
- Traverse workflow, similar to total station it can be close loop or open loop traverse. This method only requires two targets to set the back and forward bearing of the instrument, height of target and instrument are needed for registration.

For encroachment work, common targets and traverse workflow method are adopted for registering the scenes together with theusing of coordinates obtained from the cadastral survey or RTK system. To ensure quality and completeness of data coverage, it is imperative to setup the 3DTLS in the optimum position where the scan angle to the subject is small and with good overlaps to pickup details of encroachment.

The scanned data are in seperate pieces acoording to the multiple scanner setups. Theyhave to go through pre-processing so the data are stitched into one piece and usable for further analyses.Office processing will include the following steps before measurements are taken:

- Imports of scanned project, the separate scenes are download into a common working folder.
- Import of survey coordinates file, the coordinates obtained from total station or RTK are required in this process to be used as controls to geo-reference the point cloud data. Every point in point cloud will then be referenced according to the adopted survey datum.

- Import of cadastral boundary, the boundary lines are to be converted to a format that can be imported into the software database for overlaying purpose.

Once the project data is registered and geo-referenced via the relevant software, the next crucial work will be to remove noise and obstruction that will impaired the view of the subject cloud. The point cloud data is then ready to be used to evaluate the encroachment issues.

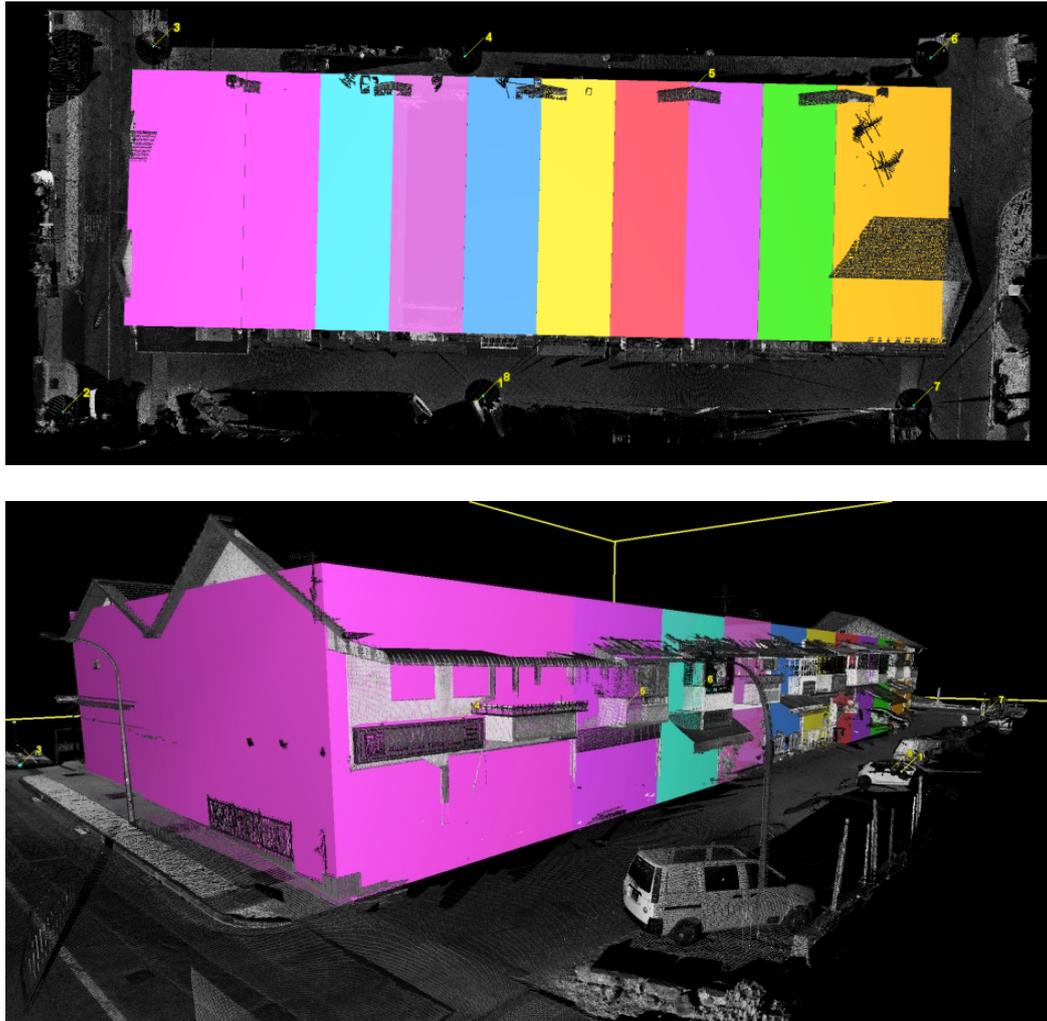
#### 4. VIRTUAL SURVEY USING 3D POINT CLOUD

The corresponding cadastral survey lot boundaries were extracted from SLA cadastre database known as Consolidated GIS System (CGS), to be overlaid on the pre-processed point cloud data, as shown in **Figure 8**. The CGS contains the coordinated land parcel geometries in SVY21 system which SLA implemented in year 2004. (Khoo and Soh, 2005)



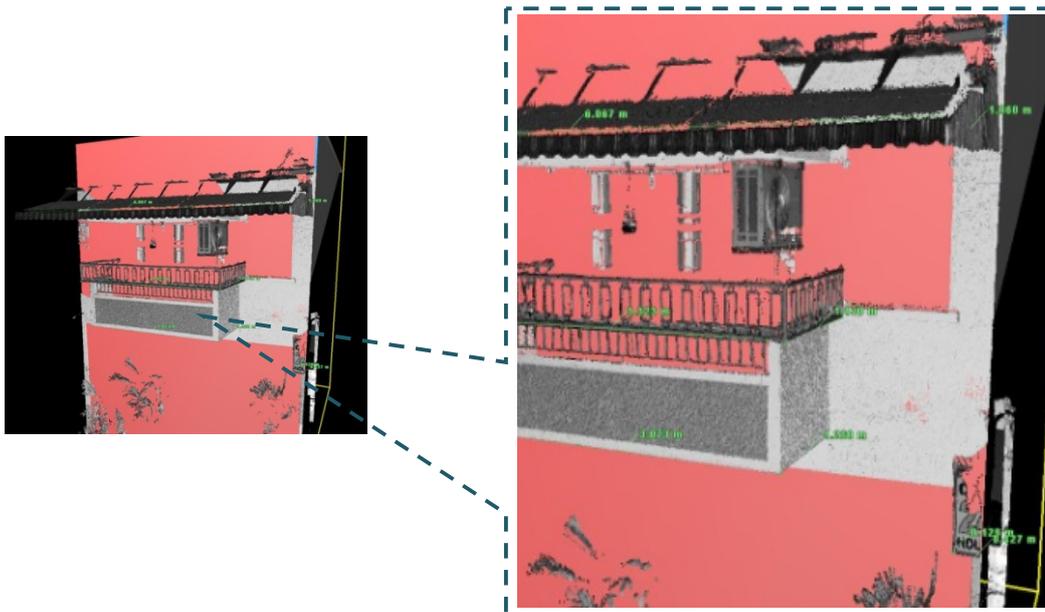
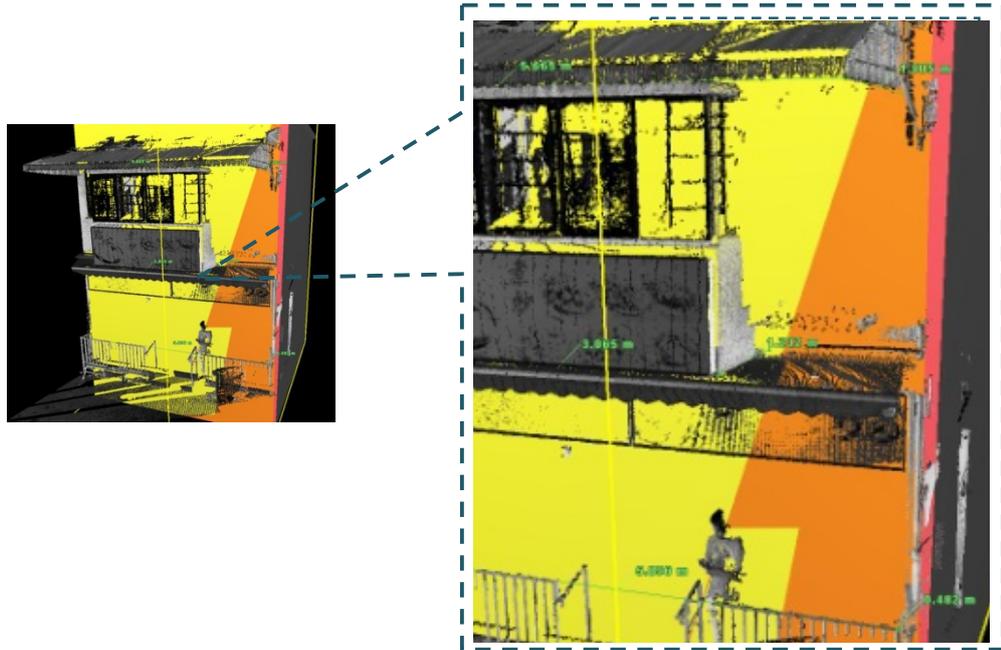
**Figure 8:** Overlaying of coordinated cadastre boundaries on point cloud.

The cadastral lot boundary lines are maintained in 2D without the vertical dimension, so the boundaries appeared in zero z-coordinates in the overlaying. Boundary lines of single individual lot were then made into extruded patches (refer **Figure 9**) to illustrate boxes of land parcels which include the column of airspace above the surface and subterranean space under the surface.



**Figure 9:** Boundary lines are extruded into 3D boxes and shaded in different colors to represent every different lot. (Above) Top view & (below) perspective view.

With the boundary lines extruded, the encroached features can be easily identified. As the vertical planes cut through the point cloud, everything that can be seen outside the plane is considered as encroachment. While the whole scene of interest is captured and every point in point cloud has the  $x$ ,  $y$ ,  $z$  coordinates, this allows us to zoom in to measure the encroached features one-by-one to obtain the required dimensions for reporting purpose. **Figure 10** illustrates the measurements done on the point cloud data with reference to the extruded boundary patches.



**Figure 10:** Measurements on every single encroached feature.

## 5. BENEFITS OF TLS IN ENCROACHMENT DETECTION

The main advantages of TLS scanning are fast, accurate and comprehensive. The capability of TLS to capture millions of points in a typical survey session, enable the surveying of complex features to be completed many times faster than using total station. It would take several days to complete the survey for the project mentioned in Paragraph 4 by using the conventional point and shoot method, but with TLS the whole area was scanned in just 3 hours. And because everything was captured, it shifts the making of decision from the site to the office. Which minimize the misjudgments and overlook of surveyors on the site, while the comprehensive scanned data allows user to go in to measure and extract information in “virtual survey” mode comfortably in office. So this eliminates the effort to return to site for re-survey.

Another advantage of laser scanning, it is safer. Scanners can capture the surfaces and points that are otherwise hard to reach or not safe to go near to. It keeps away the survey personnel from dangerous areas such as freeways, unstable structures, and material piles. The remote data capture capability of scanner, especially on high objects; it eliminates the need to use man-lifts or other means to physically reach to the objects.

## 6. CONCLUDING REMARKS

This paper describes the usage and workflow of TSL in the encroachment detection. The benefits are obvious especially for “zero set-back” condition and for massive and complex encroachment condition. In addition, the point cloud data captured overlaid with cadastral survey boundaries GIS data allows user to visualise, identify and extract the needed information efficiently. For these 2 conditions, the usage of laser scanning can improve productivity, reduce risk of field surveyors and avoid missing out any encroached structure.

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## BIOGRAPHICAL NOTES

**Dr. Victor Khoo** is the Deputy Director of the Land Survey Division of Singapore Land Authority (SLA). He received his Ph.D. and Master of Engineering degree from Nanyang Technological University (NTU), Singapore and his Bachelor degree in Land Surveying from the University Technology of Malaysia (UTM). Prior to his appointment in SLA, he was involved in various GPS, geospatial related and satellite remote sensing research projects for a period of 8 years. He holds appointments as Associate Scientist in the Centre for Remote Imaging, Sensing and Processing (CRISP) in NUS and Research Associate in the Spatial Information Laboratory, School of Civil and Environmental Engineering, NTU. Victor is a Registered Surveyor; a professional surveyor, registered under the purview of Land Surveyors Act. Currently, His specific areas of interest include 3D Mapping, Differential GNSS, Cadastral Survey and Spatial Data Infrastructure.

**Mr. Eric Low** is a Senior Executive at the Land Survey Division of Singapore Land Authority. He obtained his BSc. in Computing from University of Portsmouth and Basic Land Surveying certificate from Singapore Institute of Surveyors and Valuers (SISV). His current work involvement is in LiDAR Mapping and 3D coastline. He has previously been involved in GPS reference station work and underground research project utilizing 3D TLS for surveying and geological work.

**Mr. Ng Zhen Hao** is a Surveyor at the Land Survey Division of Singapore Land Authority. He obtained his BSc. in Geomatics from Universiti Teknologi Malaysia. His current work focuses on utilizing LiDAR Mapping and Remote Sensing techniques for SLA's 3D mapping and other surveying operations. He has been involved in laser scanning for offshore piping and structure dimension control and modeling during his previous employment.

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