

# Application of Terrestrial Laser Scanning Technology for the Purpose of Creating 3D Models of Objects

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**Key words:** terrestrial laser scanning, 3D model, object, point cloud

## SUMMARY

Modern development, increased capabilities and performance of software and hardware products have caused higher standards in many spheres of work and business, including construction, design and reconstruction of facilities. Efficient collection of three-dimensional data in less time and with less resources has become imperative in maintaining business competitiveness. The methodology of terrestrial laser scanning enables the creation of detailed 3D models of objects and areas of interest over which it is possible to conduct various analyzes, calculations and create additional necessary products. The case study in this paper presents a scanning of the facade and interior of a seven-storey building (basement, ground floor and 5 floors) with a TLS (*Terrestrial Laser Scanner*) and data processing of the realized scanning. Scanning using TLS was performed in order to obtain a 3D model of the object for the needs of reconstruction, i.e. designing a new state of both the interior and exterior of the building, and as a basis for the development of BIM (*Building Information Model*). The final product of the case study analysis will be elaborated complete project implementation methodology that covers all phases of the project flow, from the initial one which includes planning of scanning using TLS to the final one in which the final results of the applied technology are reached.

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## **1. INTRODUCTION**

Laser scanning is one of the modern technologies that are used today in the field of geodesy and many other areas for the purpose of obtaining three-dimensional spatial data. TLS can be used to obtain three-dimensional (3D) location information for a structural member or an entire building without being restricted to a particular location on the structure or affected significantly by the environmental conditions [1]. Today, the implementation of construction projects with a high level of detail requires up-to-date and high quality spatial data, which meet the needs of modern design and monitoring of buildings. The development of hardware and software solutions with the use of modern data collection technologies opens the possibility for creating quality 3D models of objects that can serve as a basis for creating BIM and monitoring the condition of the object, its potential deformations, reconstruction of the object and its supervision. Through this concept, data about the object and its parts in the form of a database become available at any time.

BIM is widely seen as a catalyst for innovation and productivity in the construction industry [2]. It is an intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. Three main BIM benefits are the elimination, visualization, and collaboration. First of all, visualization mainly indicates the advantages for the improvement and an individual in her/his personal realization as a consequence of utilizing the BIM. Second of all, collaboration can be the cooperative behavior of some members in the team as the BIM is encouraging and facilitating it. Finally, elimination refers generally project-related advantages, for example decreasing the waste, risk, and conflicts [3].

## **2. LITERATURE REVIEW**

Many papers deal with usage of laser scanning technology and its implementation for creating 3D models.

Comparative analysis of using two laser technology instruments for creating 3D model of Cangkuang Temple is given in paper [4]. Instruments used are: Topcon GLS-1000 (Geodetic Laser Scanner), which is a robotic long-range scanning instrument, and a Topcon Image Station (IS), which is a robotic imaging total station. The 3D distances were calculated for each model. Differences in distance were considered as errors in the x, y, and z direction. The 3D surface model visualization that was created from the GLS-1000 data was more precise than the one

created from the IS data. It is concluded that such 3D surface model visualization could be used for documentation, preservation and reconstruction of heritage buildings.

The case study presented in the paper [5] gives the workflow and methodology for collecting and processing data for the purpose of creating a BIM model for data management purposes. Complete procedure presented in the paper went through the following stages: establishing the external and internal geodetic survey networks, planning and conducting laser scanning of the external part of the building, planning and conducting a total station survey of the internal part of the building. At the end of each stage, data processing was performed, and finally a BIM model was generated. One of the main benefit resulting from creation of a BIM model using a point cloud that was concluded in the paper is the ability to detect and define the extent of facade damage.

Aim of study given in paper [6] is to study the limitation uses of TLS and its suitability for building survey and mapping. The efficiency of TLS Leica C10 for building survey was determined in term of its accuracy and comparing with Zeb-Revo Handheld MLS (*Mobile Laser Scanning*) and the distometer. 3D model of the building for both data, TLS and MLS were produced to analyze the visualization for different type of scanners. The RMSE (*Root Mean Square Error*) for TLS technique is 0.001m meanwhile, RMSE for MLS technique is 0.007m. The 3D model of building for both models did not have too much difference but the scanned data from TLS is much easier to process and generate the 3D model compared to scanned data from MLS. It is because the scanned data from TLS comes with an image, while none from MLS scanned data. There are limitations of TLS for building survey such as water and glass window but this study proved that acquiring data by TLS is better than using MLS.

Paper [7] gives discussion of the advantages of using TLS in managing existing buildings, from various cases of national heritage preservation to clash detection for renovation work. Based from the case studies shown, it can be concluded that TLS has helped to shorten the overall process of collecting the data representing the scene, due to its ability in generating a high point density, rapid acquisition of 3D data and its good accuracy. With the help of suitable software available in the market, the process of developing such model to manage existing buildings has become easier. However, a number of challenges ahead as the adaptation of the elements of BIM, i.e. the 3D models are still deliberated compared to its usage towards pre-constructed buildings which has become mature.

Novel methodology for the accurate and computationally efficient parsing of urban building facades from TLS point clouds is presented in paper [8]. The main novelty of the proposed methodology is that it is a systematic and hierarchical approach that considers, in an adaptive way, the semantic and underlying structures of the urban facades for segmentation and subsequent accurate modeling. Performance of the proposed method was evaluated using several TLS facade datasets. Qualitative and quantitative performance comparisons with several other state-of-the-art methods dealing with the same facade parsing problem have demonstrated its superiority in performance and its effectiveness in improving segmentation accuracy.

### 3. TERRESTRIAL LASER SCANNING

Terrestrial laser scanning enables fast and easy collection of spatial geometric data on buildings, machines, objects, etc. With the help of a laser scanner, the area of interest is digitized. The oblique length  $S'$  and the two orthogonal angles  $w_1$  and  $w_2$  are measured up to each point from which the laser beam is reflected (Figure 1). Based on these data and the intensity of the reflected signal, the position of each point in the 3D local coordinate system is determined. The intensity of the reflected wave is important for visualization, especially in complex and dense point clouds [9].

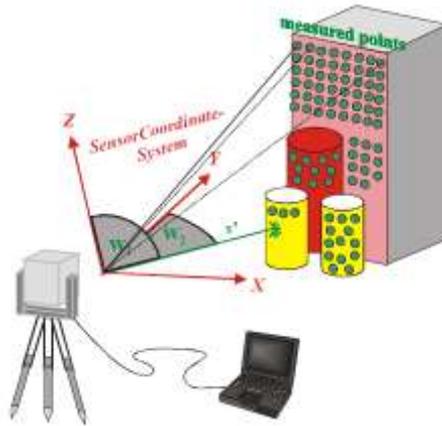
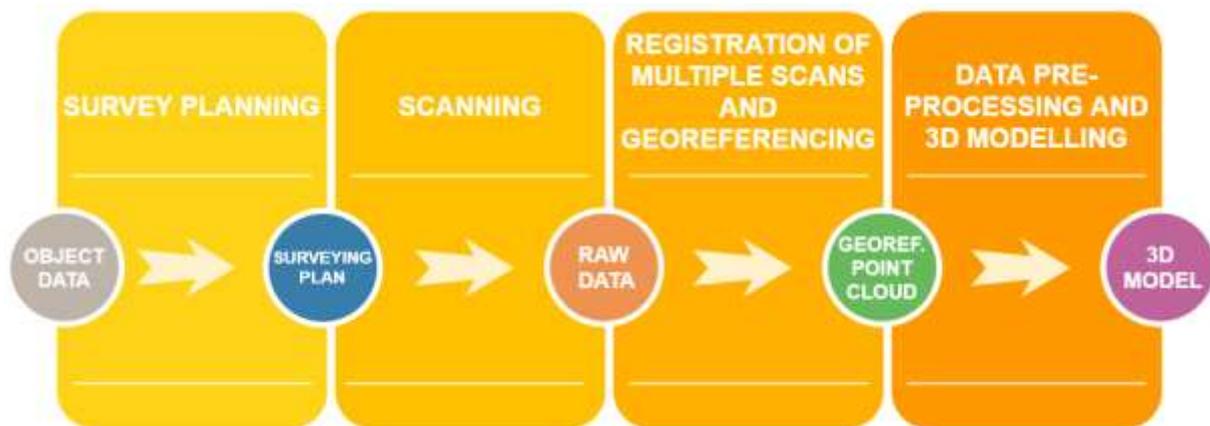


Figure 1. Terrestrial Laser Scanning [9]

With this technology it is possible to remotely survey very complex, inaccessible and hazardous objects and areas, where the traditional methods would fail. Also since the data is largely independent of ambient illumination it is even possible to scan at night or in dark conditions. The major advantage of this measuring system is the complete and detailed 3D data acquisition of objects for many different applications. Specifically, the use of terrestrial laser scanning for 3D modeling, deformation measurements, monitoring and analysis gives full automation in the process, non-contact, higher resolution, efficiency, higher accuracy and precision [10], [11].

The disadvantage of using TLS is that the scanning process should be done from the location as close as possible to the object in order to achieve the highest accuracy and density of points, which means that the ground around the object should be stable over time. An ISO standard has not yet been defined to further define the procedures for testing TLS, despite the fact that the first TLS appeared on the market more than a decade ago [12]. Problems in the implementation of this method are the instrument calibration, the need for experts both for the measurement process and for the processing and filtering large amounts of data, then the lack of fully automated data processing methods. TLS offers wide applications in construction industry and maintenance strategies. TLS has also great potential to be utilized for inspection processes due to its ability to capture objects in high speed with accuracy up to sub-millimeter and is low cost in comparison to other traditional inspection methods [13].

General overview of TLS surveying procedure is given in Figure 2.



*Figure 2. TLS surveying procedure*

Survey planning is still an open question in TLS and no standard rules have been established so far. However, it includes [14]:

- Definition of the area to be surveyed and its preliminary investigation,
- Definition of the expected resolution and accuracy of the point cloud depending on the type of the final deliverables,
- Selecting the scanner to be used,
- Optimal locations for the scanning stations should be chosen to guarantee the required coverage and accuracy,
- Choosing types of the targets for the registration and georeferencing, places for their location and their geometric configuration.

Before the scanning starts, the operator sets up the instrument at the defined location, defines the 3D section of the scene to be captured and selects the necessary options in the scanning software, e.g. sampling resolution, accuracy mode, number of scans, first or last pulse measurements etc. After the scanning has started, the operator can follow the process on the screen of the laptop computer. When the scanning is complete, the data are saved in a specified project file [14].

Objects being surveyed with a laser scanner are often quite large and complex in shape and therefore several scans should be made from different setups of the instrument. Point clouds obtained from each setup are referenced to the instrument-fixed, i.e. internal coordinate system of the scanner. To obtain a complete representation of the scanned object, the point clouds (scans) should be first transformed to a common coordinate system, i.e. the coordinate system of a chosen scan. This procedure is called registration, following which the registered scans are combined in one dataset. Georeferencing is process of transforming data to desired coordinate system, e.g. national coordinate system [14].

After the point clouds have been registered and georeferenced, they can be used for modelling. The “raw” point clouds cannot be used directly for a specific purpose because they contain noise (cars, people passing across the scanning path) that should be eliminated and redundancy in the scan overlaps should be reduced. 3D modelling is performed to obtain a 3D model of the object surface. Generally, two modelling approaches can be distinguished - Fitting geometric primitives and Meshing [14].

#### 4. SURVEYING OBJECT, METHODOLOGY OF COLLECTING AND PROCESSING DATA AND RESULTS

The building that is presented in the paper and is the subject of the survey is located in the vicinity of Frankfurt. The building consists of a basement, ground floor and five floors. The Trimble X7 terrestrial laser scanner (Figure 3) was used for scanning each floor separately. The specification of this instrument is given in Table 1.



Figure 3. Trimble X7 [15]

Table 1. Specification of Trimble X7 [15]

<i>Range</i>	0,6 - 80 m
<i>3D Point Accuracy @ 20m</i>	3,5 mm
<i>Range Accuracy</i>	2 mm
<i>Angular Accuracy</i>	21''
<i>Typical Scan Duration</i>	4 mns
<i>Imaging</i>	3 x 10 MP.1 mn
<i>Weight (incl. battery)</i>	5,8 kg
<i>Calibration</i>	Automatic Calibration
<i>Typical Workflow</i>	Full in-field registration
<i>Field Software</i>	Trimble Perspective

Number of scans collected per each floor is given in Table 2.

Table 2. Number of scans per each floor

<i>Facade</i>	<i>Basement</i>	<i>Ground floor</i>	<i>1st floor</i>	<i>2nd floor</i>	<i>3rd floor</i>	<i>4th floor</i>	<i>5th floor</i>
16	21	7	15	17	13	10	12

After collecting data on the field, scans were uploaded in *Trimble Business Center* software and fitted. Figure 4 represents point cloud of whole object.



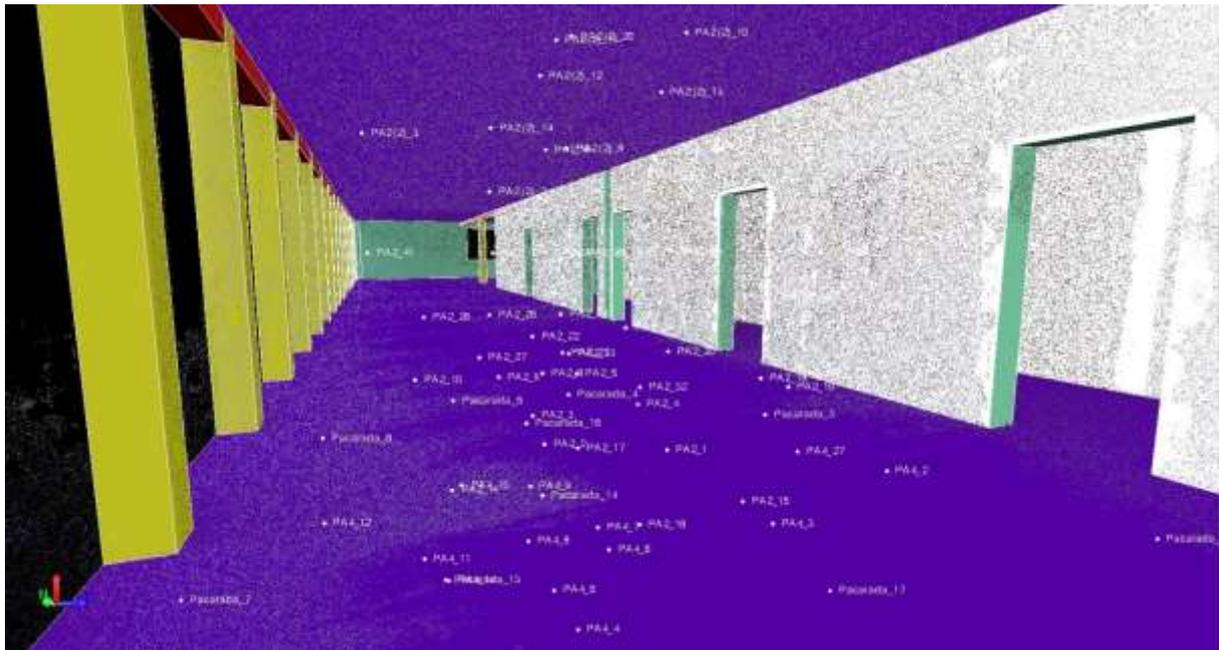
a)



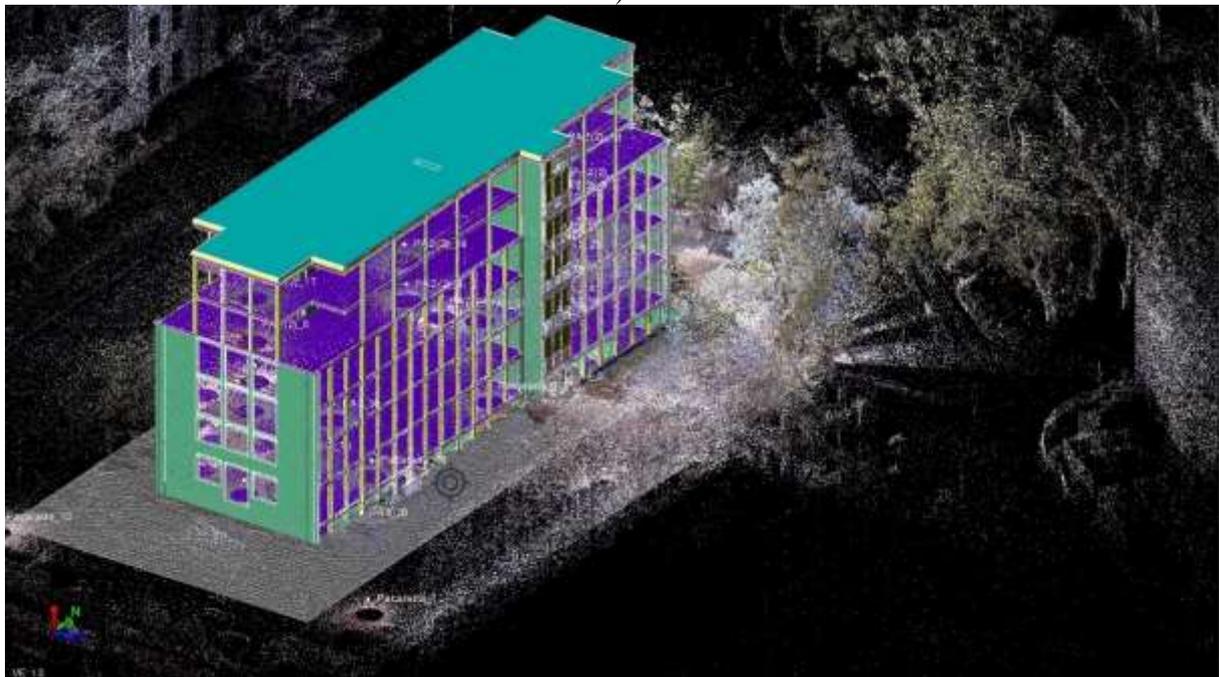
b)

Figure 4. Point cloud of scanned object – a) part of the object b) whole object

Based on obtained point cloud, the digitalization of the façade and all the surveyed floors of the building was performed using *Revit* software (Figure 5).



a)



b)

*Figure 5. Digitalized façade and interior of the building – a) part of the object b) whole object*

## 5. CONCLUSION

The popularity of Terrestrial Laser Scanners to capture three dimensional objects surrounding us is growing and it can be used for various applications. Development in 3D models has also led people to visualize the environment in 3D. Visualization of objects in a city environment in 3D can be useful for many applications such as building restoration, renovation, designing, monitoring and planning environment. Precisely for this reason, the importance and applicability of 3D modeling of objects in this paper is chosen topic concerning 3D modeling of objects based on surveying with a terrestrial laser scanner. The paper presents a way in which a 3D model of wide applications can be obtained by scanning an object of interest and processing the collected data.

## REFERENCES

- [1] M. Markovic, M. Laban, T. Kuzmic, M. Vujinovic, and S. Draganic, "Application of Modern Technologies in Assessing Facade Condition of Building Structures," in *FIG Working Week 2020 Smart surveyors for land and water management*, no. May 2020.
- [2] N. Bui, C. Merschbrock, and B. E. Munkvold, "A Review of Building Information Modelling for Construction in Developing Countries," *Procedia Eng.*, vol. 164, no. 1877, pp. 487–494, 2016.
- [3] Saeed Reza Mohandes and H. Omrany, "Building Information Modeling in Construction Industry - Review Paper," *Int. Res. J. Eng. Technol.*, no. 2015, pp. 1324–1329, 2016.
- [4] S. Hendriatiningsih, D. Suwardhi, and Januragadi, "3D model based on terrestrial laser scanning (TLS) case study: The cangkuang temple, Garut district, West Java, Indonesia," *J. Eng. Technol. Sci.*, vol. 47, no. 1, pp. 1–19, 2015.
- [5] T. Mill, A. Alt, and R. Liias, "Combined 3D building surveying techniques-Terrestrial laser scanning (TLS) and total station surveying for BIM data management purposes," *J. Civ. Eng. Manag.*, vol. 19, no. SUPPL.1, pp. 23–32, 2013.
- [6] N. A. S. Russhakim *et al.*, "THE SUITABILITY of TERRESTRIAL LASER SCANNING for BUILDING SURVEY and MAPPING APPLICATIONS," *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.*, vol. 42, no. 2/W9, pp. 663–670, 2019.
- [7] S. A. A. Shukora, R. Wongb, E. Rushforthc, S. N. Basaha, and A. Zakariaa, "3D TERRESTRIAL LASER SCANNER FOR MANAGING EXISTING BUILDING," *J. Teknol.*, vol. 2, pp. 19–25, 2013.
- [8] Z. Li *et al.*, "A hierarchical methodology for urban facade parsing from TLS point clouds," *ISPRS J. Photogramm. Remote Sens.*, vol. 123, pp. 75–93, 2017.
- [9] R. Staiger, "Terrestrial Laser Scanning Technology, Systems and Applications," *Proc. 2nd FIG Reg. Conf.*, pp. 1–10, 2003.
- [10] M. Tkáč, P. Mesároš, and T. Mandičák, "Terrestrial laser scanning - Effective technology for creating building information models," *Pollack Period. - An Int. J. Eng. Inf. Sci.*, vol. 13, no. 3, pp. 61–72, 2018.
- [11] D. Belton and K. Bae, "Automating Post - Processing of Terrestrial Laser Scanning Point Clouds for Road Feature Surveys," *Int. Arch. Photogramm. Remote Sens. Spat.*

- Inf. Sci.*, vol. XXXVIII, no. 2004, pp. 74–79, 2010.
- [12] C. I. Vintilă, A. C. Rădulescu, and P. I. Dragomir, “Modern Techniques of Lands and Constructions Deformation Monitoring,” *RevCAD J. Geod. Cadastre*, vol. 17, pp. 177–184, 2014.
- [13] M. Rashidi, M. Mohammadi, S. S. Kivi, M. M. Abdolvand, L. Truong-Hong, and B. Samali, “A decade of modern bridge monitoring using terrestrial laser scanning: Review and future directions,” *Remote Sens.*, vol. 12, no. 22, pp. 1–34, 2020.
- [14] Y. Reshetyuk, “Investigation and Calibration of Pulsed Time-of-Flight Terrestrial Laser Scanners,” Royal Institute of Technology (KTH), 2006.
- [15] “Trimble Geospatial; DataSheet - Trimble XT 3D Laser Scanning System.” pp. 1–4.

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