Intercontinental Geoinformation Days

http://igd.mersin.edu.tr/2020/

Using terrestrial liDAR data in 3D CAD modeling applications

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Keywords
LIDAR
Terrestrial Laser Scanning
Point Cloud
ArchitecturalDocumentation
3D-Modeling

ABSTRACT

Preserving historical and cultural artifacts through generations is essential for maintaining the roots and ensuring the development of any civilization.Conservation and restoration works are crucial in order to save numerous historical and cultural heritages in our country and the world and also pass on them from generation to generation. Nowadays, the increasing development in measurement technologies and the integration of photogrammetry into architectural applications have provided different perspective in architectural documentation applications. In this context, Terrestrial laser scanning method is a current method used in documentation studies today. The most important advantages of terrestrial laser scanning in this study are as follows: -the point cloud data obtained by terrestrial laser scanners provides the opportunity to reach the correct data at the desired frequency in a short time, -obtaining appropriate and practical results for the targeted study,- the possibility of using scanners in different working areas. In this context, laser scanners have become one of the popular methods in which effective and successful results are obtained in architectural documentation projects such as survey, restitution and restoration. Within the scope of this study, ''Ali Efendi Muallimhanesi'', which is one of the historical and cultural heritage of Konya province, was scanned with a terrestrial laser scanner and a architectural survey was carried out with the help of the obtained scanning data.

1. INTRODUCTION

Our country has an extremely rich and important cultural potential that contains numerous historical and cultural artifacts (Ministry of Culture and Tourism, 2021). Although today's modern buildings are designed to withstand various events, historical structures have suffered many natural or human-induced damages until today. Architectural documentation studies for the transfer of these precious historical artifacts from the past to the present have proven to be an effective and useful method for the reconstruction and preservation of the building (Kuswaha et al.2020). Nowadays, different perspectives have been obtained in architectural documentation applications thanks to the increasing developments in measurement technologies and the integration of photogrammetry into architectural applications. Terrestrial laser scanning method has become a more effective and current method compared to traditional measurement methods for architectural documentation studies. Terrestrial laser scanning technique is basically evaluated within the LIDAR (Light Detection and Ranging) system(Yakar et al. 2020). LIDAR technology is the name given to a remote sensing technology, commonly known as laser scanning technology, referred to as beam capture and distance determination (Sevgen 2018). TLS is a method based on obtaining the XYZ coordinates of many points as a result of sending laser pulses to the target object and measuring the distance between the device and the target (Costabile et al. 2021; Gumilar et al. 2020; Uzun and Spor 2019). Using 3D point cloud data obtained by laser scanning method, the following studies can be performed through CAD applications: basic measurement data, orthophoto image extraction, 2D or 3D drawings, solid surface models, 3D animations, texture covered 3D model extraction.It is seen that high resolution 3D point cloud data is used in architectural survey studies, in the production of orthopho to ready for CAD drawing (Hassan 2019; Lin et al. 2019; Bonfanti et al. 2013).

In this study, 3D CAD drawings of Ali Efendi Muallimhane, one of the historical and cultural works of Konya province, were created from high resolution 3D point cloud data and their orthophotos.

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Cite this study

Karasaka L & Ulutaş N (2021). Using terrestrial liDAR data in 3D CAD modeling applications . 2nd Intercontinental Geoinformation Days (IGD), 218-221, Mersin, Turkey

2. METHOD

2.1. Terrestrial Laser Scanner Method

Terrestrial laser scanning technology is a method that samples or scans objects directly, precisely and automatically obtaining 3D coordinates (x, y, z) with the help of LiDAR technology. (Costabile et al. 2021;Beg 2018;Bonfanti et al. 2013). It is based on a system that scans the target object in series of points within limited angles in horizontal and vertical directions and enables it to be displayed as point clouds (Lichti and Gordon 2004). The location of a point is determined by the time it takes for the LiDAR signal to hit the target and the beam reflected from the target back to the scanner (Equation1). Scanner centered polar coordinates are obtained as a result of these operations. These polar coordinates are converted into cartesian coordinates (Figure1).

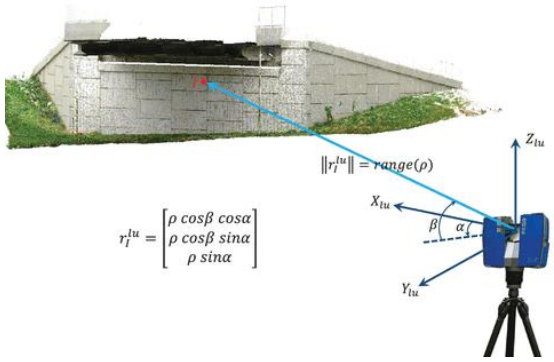

Figure 1. A typical pulsed laser telemeter, the operating principle.(Lin et al. 2019).

$$\Delta R = c\frac{\Delta t}{2} \quad (1)$$

R: the distance between point A and point B
c: the velocity of electromagnetic radiation
r: measured time interval

As a result, the point cloud formed by millions of points is obtained .These point clouds contain different resolutions, sampling densities and attributes as well as different scenes and objects(Kuswaha et al. 2020; Beg 2018).

2.2. Usability of Terrestrial Laser Scanners in Architectural Documentation Studies

High resolution 3D point cloud data is frequently used in documentation studies of historical and cultural heritage such as survey, restitution and restoration (Wojtkowska et al. 2021). In the documentation process of a building, terrestrial laser scanners are frequently preferred in architectural facade scans because they provide an accuracy of mm level. Thanks to this point cloud data representing the structure, 3D coordinate data of objects or structures that are difficult to survey can be obtained (Okuyucu and Çoban 2019; Kersten et al. 2009; Hassan 2019). Architectural documentation studies are carried out within certain standards. The survey work to be carried out with 3D point cloud data of any object or area to be recorded shows the feature of base data for restitution and restoration works to be carried out in the future. Using this data, the 3D model of the object or structure to be scanned can be recorded and stored. When compared with traditional measurement methods, it is seen that models created with point cloud data make accurate measurements at a rate of 99.9%. Thanks to this method, in which the most complex geometries of the structures are revealed exactly, the process-result relationship in architectural documentation processes works extremely quickly. (Uzun and Spor 2019).

With the transfer of the obtained point cloud data of the object or structures to the CAD program, the preparation of floor plans and section drawings and technical drawing operations can be performed. Thanks to the high quality orthophotos obtained from the point cloud data, 2D technical drawings can be made in architectural survey studies. In this way, the details of the object or the building can be shown on the 3D point cloud data, and the current state of the building can be completed in the form of architectural survey work. Restitution studies can be prepared for problematic sections by integrating with previously obtained photographs and data obtained during the survey on the works that have been destroyed or structurally damaged(Uzun and Spor 2019).

Today, there are many software (AutoCAD, Sketchup, etc.) that offer the opportunity to work on point cloud. For example, AutoCAD software provides certain improvements and enhancements when working over the point cloud.With the point cloud plugin, using clipping tools, an existing area on the cloud can be focused and drawings can be made on the cropped area with the help of points. The cropped area includes any objects left within this area, along with the crop border. In addition, since these clipped areas now show a cross-section feature, they allow object creation with using point clouds depending on the density of the cloud.Another drawing method is to correctly identify the dynamic user-defined coordinate system on the target surface to be drawn(Prota Altar 2021).

2.3. Study Area

The determined working site called ‘‘Ali Efendi Muallimhanesi’’ is located opposite to the northern entrance of Şerafettin Mosque in Karatay District of Konya Province. The ‘Muallimhane’, which was built by Hacı Ali in the early 15th century, was initially named ‘Daru'l Kurra’, and depending on the need, the school and ‘Daru'l Huffaz’sections were opened and turned into an educational institution that includes levels that complement each other. It was allocated to Konya Provincial Mufti in February 2015 by Konya Governorship for use in Quran and Islamic Related Services(Konya Metropolitan Municipality 2021).

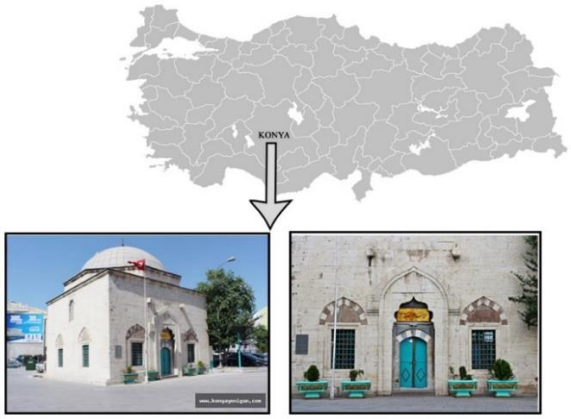

Figure 2. Study area , "Ali Efendi Muallimhanesi", Konya

3. APPLICATION

In this study, Faro Laser Scanner X-330 Hdr was used. The scanner is a suitable device for 3D documentation and land surveys (Faro 2021).

Scanning operations of the target object were carried out from the station points determined in such a way that one or more facade of the target can be seen and from the appropriate distance. The process of combining the scan data and creating the point cloud cluster for the target object has been completed in the faro scene software. From this stage on, the survey drawings of the façades of the building were made by taking 2D orthophotos obtained from the point cloud data (Figure 5). In addition,a drawing has been made illustrating the details of the building that has been made through points with the help of point cloud.

4.RESULTS

Preserving cultural heritage is a requisite duty for all civilizations around the World (Moussa et al. 2013). In order to keep the traces of civilizations alive, it is extremely necessary to pass on historical and cultural artifacts from generation to generation.

The terrestrial laser scanning method has become the reason of preference for many disciplines with its potential to obtain cost effective, high-accuracy data in a short time (Okuyucu and Çoban 2019). Laser scanners, which ensure that the architectural documentation studies are carried out in a healthy way and in the specified standards, have become preferred by users in our country and in the world.

In the last few years, 2D representation of historical and cultural heritage and 3D modeling studies have accelerated the design processes thanks to the developing CAD software. Technical drawings, analyzes and simulations can be obtained with CAD software, which includes many modules that allow 2D and 3D work. Thanks to the point cloud function that comes with the AutoCAD software used within the scope of the study, points in the point cloud can be captured and 3D visualization can be done. It is extremely important that the software enables 3D drawing through the point cloud.

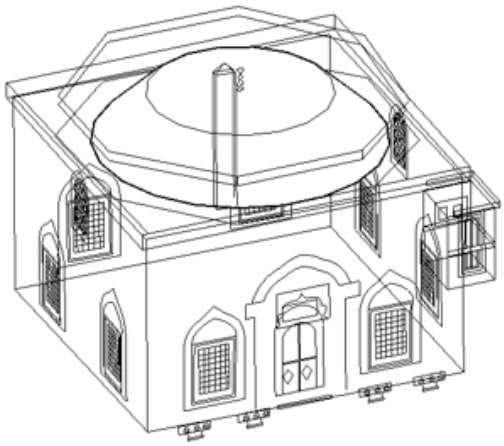

Figure 3. Drawing made by using Point Cloud

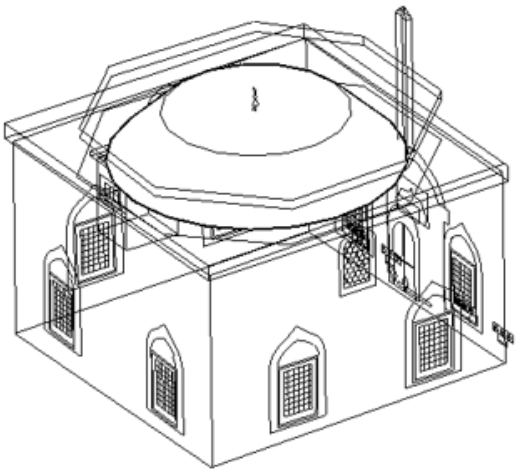

Figure 4. Drawing made by using Point Cloud

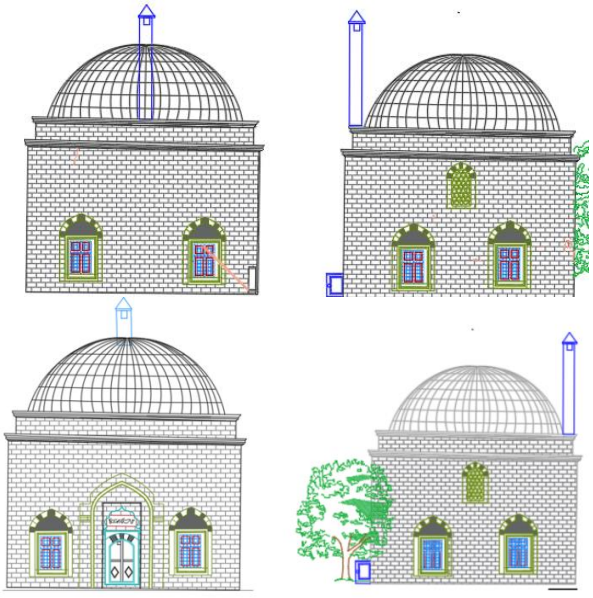

Figure 5. Architectural drawings of building facades made by using orthophoto

However, in accordance with the standards accepted in the survey studies, it is not possible to show the details of the building exactly in the drawings to be obtained by this method. This is due to the fact that points in a

frequent and complex arrangement do not allow the drawing of the details of the building. In order to make 2D drawings for use in survey studies, orthophotos are produced over the desired sections from the point cloud data. In this way, 3D data is reduced to 2D data in the most accurate way. By means of orthophotos obtained, 2D or 3D technical drawings, 3D models in the form of solid surfaces and animations can be obtained (Guidi et al.2019).

In addition, floor plans and section drawings of the whole building can be obtained easily. In this study, meaningful drawings have been created in which the details of the object can be reflected more easily as a result of the drawing made using orthophotos.

In our country, 3D modelling studies are preferred in documenting our historical and cultural heritage values. With the constantly developing CAD software facilities, the opportunity to work on 3D point cloud data will become easier and the details of complex objects will be drawn more easily. In this way, studies conducted over point clouds can provide different dimensions and new gains to heritage documentation studies.

ACKNOWLEDGEMENT

We would like to thank to Azim Metin, Geomatics Engineer for providing the scanned data of the study area.

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