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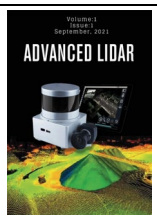

Application of Terrestrial Laser Scanning (TLS) Technology for Documentation of Cultural Heritage Buildings and Structures: A Case Study Sarı İsmail Sultan Tomb

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Abstract

One of the most fundamental duties in the management of cultural heritage artifacts in the field of conservation strategy is creating geometric documentation. For conservation or restoration work on historical objects and sites, 3D documentation is a requirement. At every stage of the conservation effort, the creation of particular documentation such as high-resolution 3D models is required. Türkiye is a very rich country in terms of historical artifacts. It is extremely important to document these artifacts in order to preserve them and transfer them to future generations. In documentation studies, the Terrestrial Laser Scanning (TLS) method has started to be preferred with the developing and advancing technology. In this study, the usability of the data obtained by the TLS technique in the documentation of cultural heritage was investigated. The study area, Sarı İsmail Sultan Tomb, was scanned with a terrestrial laser scanner using the TLS technique, the scan data were combined in commercial software and a 3D model of the cultural heritage was created.

1. Introduction

Cultural heritage is the reflection of important events, traditions, lifestyles, beliefs, works of art, architecture, and other cultural elements in human history. This heritage reconciles the past with the present and contains important information to be passed on to future generations (Guarnieri et al., 2006; Çelik et al., 2020; Yakar et al., 2005; Yakar et al., 2020). Documenting, protecting, and transferring cultural heritage to future generations is very important for preserving our cultural values. Documentation of cultural heritage includes the creation of digital copies of historical buildings, archaeological sites, works of art and other cultural objects (Yiğit and Yakar, 2023; Erdoğan et al., 2021). These copies allow cultural heritage to be preserved and passed on to future generations. In addition, these copies allow for better understanding and examination of cultural heritage (Fryskowska et al., 2015; Markiewicz et al., 2015; Ulvi and Yiğit, 2022; Pulat et al., 2022; Kabadayı, 2022).

Terrestrial Laser Scanning (TLS) technique has started to be preferred frequently in the studies of epigraphical examination of cultural heritage assets bearing the traces of past civilizations and their geography and containing writings and details that shed light on history, and in the creation of documentation in this context (Oruç and, Baş, 2021; Fidan et al., 2022; Uzun et al., 2022; Kabadayı & Erdoğan, 2022). This technique is included in the LIDAR (Light Detection and Ranging) system. In this method, a three-dimensional (3D) point cloud (point data set) of the scanned object can be obtained sensitively and quickly. A 3D model of the cultural heritage can be created from the obtained point cloud (Kaçarlar and Hamal, 2021; Yakar et al., 2021). This model serves as a base for determining the indoor and outdoor architectural features of the heritage, determining the lengths of the facades, making two-dimensional (2D) drawings, and restoration works in

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case the heritage is damaged (Capolupo, 2021; Oruç and Öztürk, 2021; Grenzdörffer et al., 2015; Alptekin & Yakar, 2021; Alptekin et al., 2022; Kanun et al., 2021; Karabacak Yakar, 2022; Karataş et al., 2022; Kaya et al., 2021). In this context, the frequency of the point cloud to be produced and the metric accuracy are extremely important. As a result of the features described above, the use of TLS method in the documentation of cultural heritage has started to increase (Varol et al., 2021; Yiğit and Uysal, 2021; Şenol et al., 2017; Şenol et al., 2020; Ulvi et al., 2015 ;Yakar et al., 2008).

The aim of the study is to investigate the usability of my TLS method and the data obtained as a result of this method in the documentation of cultural heritage. Within the scope of the documentation of the cultural heritage of Sarı İsmail Sultan Tomb in Kütahya as the study area, scanning was carried out at 10 station points with the Faro FocusS 350 terrestrial laser scanner, which uses TLS technique. As a result of the scans, a point cloud of the artifact was obtained, and a 3D model was created.

2. Materials and Methods

Terrestrial laser scanning systems are used effectively in many disciplines today and their use is increasing. Many results can be obtained with this technique, which is used in related studies. The terrestrial laser scanner used in the application phase is given in Figure 1 and its technical specifications are given in Table 1.

Laser scanners can produce 3D models directly, precisely and automatically, without any contact with the object. It stands out from other methods, as there is no need for any data other than spatial data and the data processing is done automatically in principle (Sarı et al., 2020; Alkadri et al., 2022; Yakar et al., 2010; Yakar et all., 2009; Yılmaz & Yakar, 2016). In addition, LIDAR technologies can provide digital data immediately after measurement. All these conveniences have increased the use of LIDAR technologies in different fields (Masaharu and Hasegawa 2000; Hamal et al., 2020).

Figure 1. Faro Focus S350 terrestrial laser scanner (Faro, 2023).

It performs its measurements according to the TLS phase difference method used in practice (Sánchez-Aparicio et al., 2018). In this operating principle, the scanner's sensor continuously emits a periodic signal of medium intensity. After this emitted signal is reflected from the surface of the object, it is detected by the sensor, then the phase values of the outgoing and incoming signal are compared (Chatzistamatis et al., 2018; Shao et al., 2019). Distances are calculated by analyzing this phase difference. Such scanners provide a wide field of view, high number of points, high range and high scanning speeds. These scanners generally use visible wavelengths (Faro, 2023).

Table 1. Technical specifications of terrestrial laser scanner (Faro, 2023).

Feature	Value
Weight	4,2 kg
Range	0,6- 50 m
Ranging error	±1 mm
Field of view (vertical, horizontal)	300° ,360°
Multi-Sensor	GPS, Compass, Height Sensor, Dual Axis Compensator
Measurement Speed	up to 976,000 points/second
Laser Class	Laser class 1
High Dynamic Range (HDR) Photo Recording	2x/3x/5x

3. Application

3.1. Study Area

The Sarı İsmail Sultan Tomb, which was determined as the study area, is in the Dedeler village of Tavşanlı district of Kütahya province (Figure 2). Inside the tomb, the tomb on the right belongs to Sarı İsmail Sultan, the tomb in the middle belongs to Dölek Ana, and the tomb on the far left belongs to Ataullah Efendi. Sarı İsmail is one of the pirs whose name is mentioned the most in Bektashi and Alevi literature. It is recorded in the records that he came to Anatolia in the 13th century and that he came to Hacı Bektaş together with Karaca Ahmet. He is known as one of the closest colleagues of Hacı Bektaşı Veli (URL-1).

Before the study, the field work was completed by scanning at 10 different stations (stop) determined around the work. The number and location of the stop points were determined to see one or more sides of the work to be scanned, and attention was paid to create less noise.

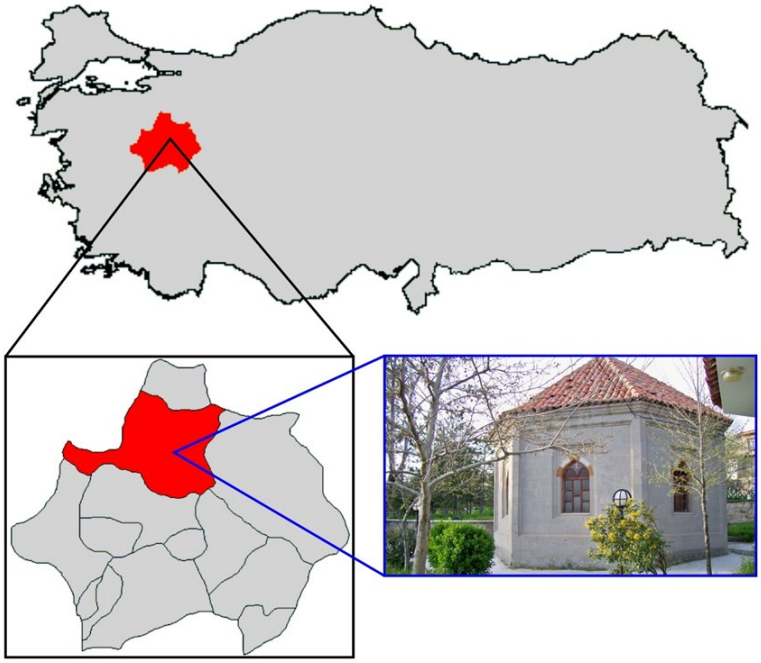

Figure 2. Study area.

3.2. Data Processing

Survey data of the study area were obtained by studywork. After this stage, the scans were combined in Faro Scene software, which is a commercial software, and a point cloud related to the work was produced. Then, a 3D model of the work was created from the point cloud. Thus, the usability of the data obtained by TLS method in the documentation of cultural heritage was investigated. Faro Scene software has been developed for all Faro Focus and other laser scanners capable of 3D scanning (Faro, 2023). With the technical features of this software such as real-time scanning, automatic object recognition, scanning record creation and positioning, scanning data can be processed and managed effectively and simply (Guarnieri et al., 2017). The data obtained because of the scans were transferred to the software and then the data processing stage was started. Scans were combined with the Cloud-to-cloud technique with an error of 0.4 mm. Point cloud data contains a lot of messy and redundant data other than the job being scanned. This irrelevant data has been cleared. This process, which is done to create a healthier and higher quality 3D model of the work, is expressed as noise removal (Tucci, 2019; Saponaro et al., 2020). After this step, a point cloud was generated (Figure 3), followed by a mesh model (Figure 4).

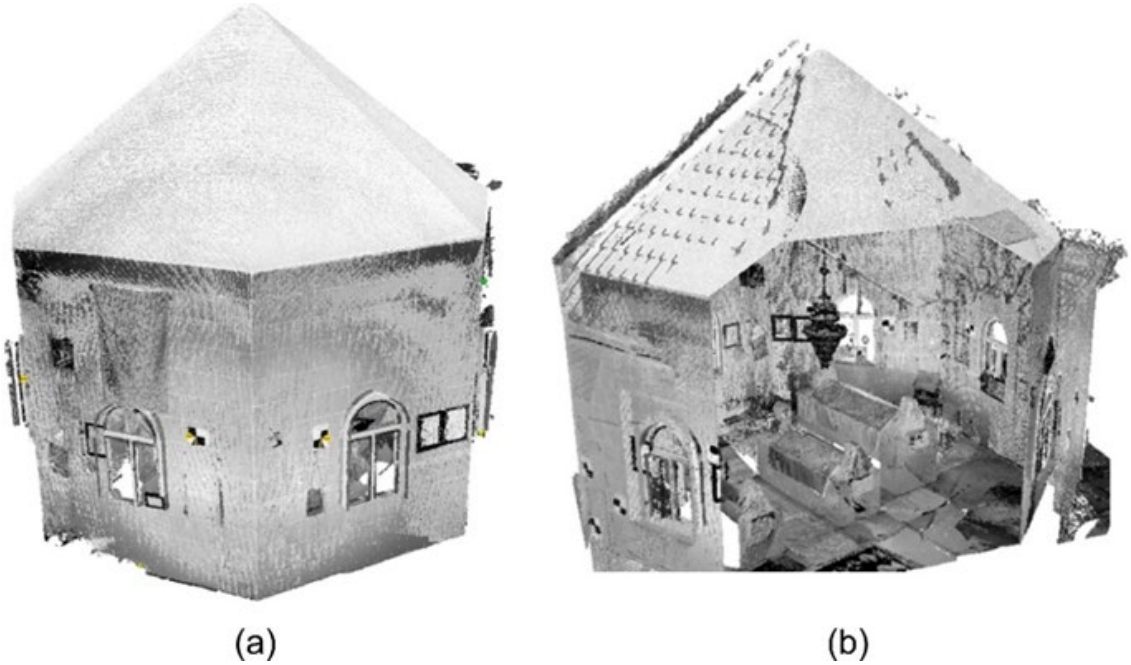

Figure 3. 3D point cloud of the tomb (outdoor) (a), indoor (b)

Figure 4. 3D mesh model of the tomb

4. Discussion and Conclusions

Documentation studies are carried out with different methods and tools in order to shed light on the architectural features of cultural heritages, to shed light on the past, to carry the traces of history to the future and to protect them in this context. In these studies, it takes time to carry out measurement processes with classical terrestrial measurement techniques. With the development of technology, TLS has become a standard method that is frequently preferred for these studies. In this method, a point cloud can be obtained by reflecting back the laser beam sent to the object. As a result, a realistic 3D model of the desired structure can be produced. Through the created model, the position, shape, and architectural features of the object can be observed. In TLS technique, data with high accuracy and sensitivity can be obtained in a much shorter time compared to classical terrestrial measurement techniques. In addition, architectural drawings to be made in the documentation of cultural heritage can be made by taking sections from the data obtained from the TLS method. This more multidisciplinary work has not only saved engineers time, but also saved time for experts in other fields.

TLS has some advantages as well as some disadvantages. The location of the station points is important in the scanning process to be performed with the terrestrial laser scanner, which is a part of this system. If the height of the device is less than the object and/or the device is positioned to not see the entire object, then reliable data about the object will not be obtained. In particular, the point cloud of the apex of the scanned structure will not be created, and as a result, the 3D model will not be as desired. In order to avoid such problems in applications, the device should be positioned in line with the object or at a high point. However, this condition cannot always be met due to factors such as different terrain conditions and the large size of the object to be scanned. The use of the Unmanned Aerial Vehicle (UAV) system is among the strong alternative options in order to prevent this negative situation and to create the model to be produced in a complete and healthy way. However, high resolution scans result in dense datasets (point clouds). Depending on the size of the study area, it is highly likely that the processing of these data will be a problem. In addition, the point cloud produced can be colored if a photograph is taken when the documentation is done using the TLS method. In this way, the real color information of the work is obtained. Data obtained from scanning in this study; The workstation with a powerful processor and high-performance graphics card has been processed on a computer. Thus, the data processing process was completed in approximately 3 hours. It is recommended that researchers who will do various studies in different fields with TLS method should pay attention to this point.

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Author contributions

Sena Köse; Methodology, data collection, article writing, Editing the manuscripthe.
Hazal Us; contributed to the writing of the article with the idea of the article, article writing, article writing.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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