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Analysis of 3D Laser Scanning Data of Farabi Mosque Using Various Softwaren

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Abstract

Three-dimensional laser scanners, which offer an alternative solution to traditional measurement methods, have enabled geomatics engineers to have much higher confidence in the accuracy of their measurements. When high-resolution data used in many different measurement applications, including 2D and 3D drawings, calculations such as area and volume calculations, and topographic measurements are evaluated, it is understood that the resolution and efficiency provided by traditional measurement methods are far inferior. Obtaining data about objects and gaining information about objects by evaluating this data in a computer environment, obtaining 3D images of objects one-to-one is an important issue today. As a result of the development of computer technology and laser scanning systems over time, Terresterial Laser Scanners (TLS) have rapidly begun to be used today. With the TLSs, the 3D geometric and visual information of objects can be obtained accurately, quickly, one-to-one and at low cost. In this study, the 3D model of the exterior of Farabi Mosque located on the Farabi campus of Bülent Ecevit University was obtained and evaluated in different softwares. After a successful merging of the data model, due to the limited functions of Faro Scene 2019 software, area calculation, mesh creation, and volume calculation operations were performed on the cloud data using Autodesk Recap 2020 V6.0, Gexcel Reconstructor 2020 V4.2.0, and Meshlab 2020.07 software, and operations were carried out on cloud data that looks close to reality.

1. Introduction

Terrestrial laser scanning is a new technology developed since the early 2000s (Mirdan, 2018) for precise and accurate distance and angle measurements in geomatics engineering applications. Terrestrial laser scanning (TLS) provides a representation by acquiring millions of three-dimensional data very quickly and integrating it with object images. TLS is achieved with mm accuracy by using laser shots at a distance of hundreds of meters to determine the distance to the object points and the three-dimensional (3D) position of the points (x, y, z). One of the key advantages of the TLS method is that it provides a more realistic representation of objects than other measurment imaging techniques.

Recent developments in terrestrial laser scanners have led to a wide range of applications, and these are increasing day by day (Akarsu an Nazari, 2020). Terrestrial laser scanners have been rapidly evolving as an effective measuring technology for 3D modeling, competing or alternative to existing systems (Yılmaz 2006). The generation of a three-dimensional (3D) model is generally achieved by non-contact systems based on light waves and can be completed on a computer (Yakar, 2010) The capability of the TLS has been extended to the spectral domain with the research-led development of omnidirectional and even hyperspectral lidar instruments (Danson et al. 2014). Increasingly used in a variety of applications by different disciplines, the terrestrial laser scanners are used in geomatics engineering, such as tunnels, mining, deformation

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measurements, urban modeling, restoration and surveying, archaeology, transportation and infrastructure, topography, mining, civil works surveying, architectural and industrial design, medical imaging and monitoring. Laser scanning is especially good for complex surfaces, surface analysis and visualization (Korumaz 2010; Alptekin & Yakar, 2021; Alptekin et al., 2022; Karabacak &Yakar, 2022; Kaya et all., 2021; Şenol et al., 2020) for this reason laser scanning technology is widely used in many professions (Kanun 2021) Obtained 3D data can be a resource for many professional disciplines in order to come up with solutions to problems that may occur in the future. (Şasi 2017; Şenol et al., 2017)

In TLS surveys, it is necessary to learn a lot of technical information in order to determine a strategy. Before scanning, if the object is a building, it is important to position the scanner device according to the technical specifications of the scanner and to place the target marks at the appropriate points in order to obtain best quality 3D data.

2. Method

Technological developments in recent years have brought the use of laser scanning measuring systems more prevalent. Although terrestrial laser scanning has some disadvantages, it has important advantages (Ulvi 2014) These developments have resulted in the development of the current series of Terrestrial Laser Scanners (TLS), which are now widely used, ranging from devices that are installed on an instrument stand and measure from fixed positions to devices that are mounted on vehicle platforms and that perform mobile mode topographic surveying applications (Vosselman and Maas, 2010).

Since the early 2000s, terrestrial laser scanning has evolved from a research and development (R&D) subject to a geo-data technology commercially available from geomatic engineering companies and other service providers around the world.

This technology predecessors were used to quickly obtain three-dimensional (3D) information of various topographic and industrial objects (Scaioni, 2002). Initially, the main use of scanners was to create models of architectural and engineering structures. Since laser scanners can reach all points of a projected object, they can be used in a wide variety of engineering projects. Using 3D information is one of the important techniques in today's digital age. For example, trying to provide an accurate and lifelike image of the surface of an object requires efficient acquisition of large amounts of 3D data. TLS is an important technique that uses laser light to obtain the coordinates of a distant object with only one scan of the object (Fröhlich and Mettenleiter 2004). In addition, emerging terrestrial laser scanner companies continue to develop new scanners, including accuracy, resolution and speed. For example, 2018 model Leica RTC360, one of the latest models, can measure 2 million points per second and is called the TLS with the fastest scanning ever reached, while the longest distance measurement device is the 2019 model VZ-6000 of RIEGL, which scans an object at a distance of 6000 meters (Table 1).

Table 1. Length and accuracy values of some terrestrial laser scanners

Brand	Faro	Riegl	ZOLLER + FRÖHLICH	Leica
Model	FocusS 350	VZ-6000	IMAGER 5016	RTC360
Measuring distance	0.6m-350m	5m-6000m	0.3m-365m	0.5m-130m
Measuring speed	976,000 nokta/saniye	222,000 nok/saniye	1,016,027 nokta/saniye	2,000,000 nokta/saniye
Scan angle	300ºx360º	60ºx360º	310ºx360º	300ºx360º
Distance Accuracy	± 1mm@25m	±15mm	± 1mm@50m	5.3mm@40m
Functional Feature	GPS, GLONASS	remote control , GNSS, Wifi	80Mp kamera	GNSS, 36mp 3kamerali

2.1. Data

After performing the scanning process, the most important step is the scanning data processing step (Chetverikov et al., 2005), and the following issues are important for ideal data analysis and evaluation.

- It should be chosen to provide a wide range of resolutions and accuracy, with varying price, different positional accuracies and scanning distances produced by many companies.

- For ideal scan data, the scan resolution should be chosen according to the application and the detail required, they can be defined based on the minimum feature size visible in the point cloud. Scanning smaller objects requires better accuracy and resolution.

• The selection and location of reference target types before scanning is necessary, which is important for georeferencing and merging point clouds obtained from different scanning centers.

When scanning is complete, the data is saved in the specified project file. Scan functions in TLS vary from one scanner type to another.

TLS can be considered as a combination of photogrammetric and reflectorless Total station compared to traditional 3D modeling methods (Abbas et al., 2014). The scanning process within the field of view is similar to capturing images and producing data with a total station in the 3D coordinate system. Most commercial software packages obtain the X, Y, and Z coordinate values of points in the 3D Cartesian coordinate system, as shown in Figure 1 with TLS, and calculate the r, φ, and θ measurement values (shown in Figure 1) in the 3D polar coordinate system using functional transformation equations (4), (5), and (6) through calculations (Akarsu,2005).

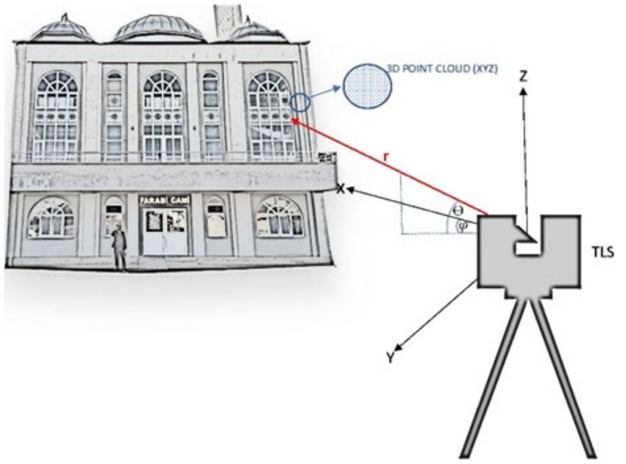

Figure 1. Data acquisition with terrestrial laser scanner

These transformations have an intensity value as an attribute. Therefore, raw dimension values in TLS are for further processing, and 3D data in global coordinates are more useful (Abbas et al., 2014). Thus, transformations from cartesian coordinates to spatial polar coordinates are performed with functions (1), (2) and (3) (Abbas et al., 2014).

$$\text{Range: } r = \sqrt{X^2 + Y^2 + z^2} \quad (1)$$

$$\text{Horizontal angle: } \varphi = \tan^{-1}\left(\frac{X}{Y}\right) \quad (2)$$

$$\text{Vertical angle: } \theta = \tan^{-1}\left(\frac{Z}{\sqrt{X^2 + Y^2}}\right) \quad (3)$$

The transformation from space spherical coordinates to cartesian coordinates is performed with (4), (5) and (6) functions (Abbas et al., 2014).

$$X = r\cos(\varphi)\cos(\Theta) \quad (4)$$

$$Y = r\sin(\varphi)\cos(\Theta) \quad (5)$$

$$Z = r\sin(\Theta) \quad (6)$$

2.2. Point cloud

A point cloud is a representation of an object or environment in three-dimensional space (Brenner, 2007). Often 3D laser scanners are used to create point clouds of real-life objects. A point cloud consists of many points. Each point contains space cartesian or space spherical coordinates, depending on the location coordinates of the point where the TLS is placed (Becerik-Gerber et al. 2011; Ulvi & Yiğit, 2022; Yakar et al., 2008; Yakar et al., 2009; Yılmaz & Yakar, 2016). To achieve a full three-dimensional scan of a room (Fig. 2) or object, several scans are required to avoid missing point clouds due to the restricted line of sight from the scanner. To obtain sufficient point clouds based on several scans, it is necessary to combine the scans (Registation). Merging is the process of combining two or more point clouds into a single cloud (Lindskog et al. 2013). The usage of point clouds can be very heavy for computer hardware, depending on the size of the dataset, often requiring a large amount of RAM, a powerful CPU, and sufficient GPU for smooth processing.

Figure 2. Comparison of high- and low-resolution point cloud (SCENE Workbook 2019)

3. Material and Method

In this study, real-looking, dense 3D data of Farabi Mosque is obtained with terrestrial laser scanning technology and its evaluation in different software is discussed.

The "Faro Laser Scanner Focus X 330" used in the study is a precision measuring instrument that creates 3D images and has the following features (Table 2).

Table 2. Faro Laser Scanner Focus 3D X 330 specifications (Faro Web 2019)

Distance Range	(0.60 – 330) m
Measuring Speed	976000 point/second
Speed distance error	± 2mm
Distance interference	@10m – raw data: 0.3mm @90% reflectance
Laser Class	Laser Class 1
Multi-Sensor	GPS, Compass, Altitude Sensor,
Scanner Control	Touchscreen and WLAN
Weight - Size	5,2 kg - 240 x 200 x 100 mm

Pre-scan measurement design is required and the main steps are as follows:

- **Predetermination of the area to be scanned**: When scanning large areas, the scanner should scan the object or area to be scanned at low resolution, which makes it possible to map the area to be used in other design processes. Large-scale maps can be useful in this regard.
- **Choosing the scanner to use**: A wide variety of scanners are available from many companies, at varying prices, with different positional accuracy and scanning distances. The important thing is to choose the most suitable one for the application to be made.
- **Selection of the most suitable location for scanning points:** It should be chosen to provide the required resolution and accuracy.
- **Selection of target types and pre-determination of targets**: In order to combine point clouds obtained from different scan centers, suitable targets should be selected based on geodetic reference points.
- **Define the expected resolution and accuracy of the point cloud obtained as a result of the scan:** These can be defined depending on the scale of the scan or whether the minimum feature size in the point cloud is visible. Scanning smaller objects requires better accuracy and resolution.
- Last Control**:** Finally, after each of the above-mentioned steps is done, a rough data is obtained by scanning the area or part of the object to be scanned. Considering the time elapsed in this scanning process, the time spent in the entire job can be estimated for the total data to be collected.

Scanning an object using TLS is not just pressing the button and waiting for the results, it is necessary to know all the steps with scanning knowledge (Figure 3).

Figure 3. Process flow chart with TLS

4. Application

In practice, due to the beautiful geometric shape and appearance of the mosque in the Farabi Campus of Bülent Ecevit University in Zonguldak, Türkiye, the Farabi Mosque was scanned and evaluated in Faro Scene 2019 software and various softwares (Figure 4).

The work consists of the following steps and is completed:

- Land Survey
- Positioning of reference spheres
- Scan process
- office work

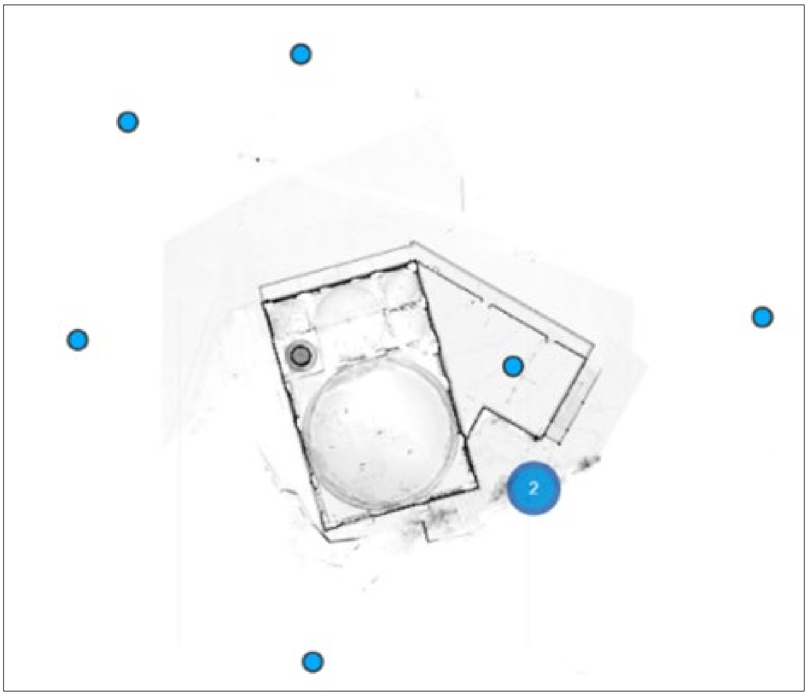

Figure 4. Locations of scanning session stations.

4.1. Registration and model creation

Common features shared by several scans are required for successful alignment of scans. Commonly, software uses special reference targets embedded in the scanned medium. Two common target types are spheres and checkerboards (Becerik-Gerber et al., 2011).

These features ensure accurate targeting and accurate localization of the sphere center point, which is then used as a reference point. The spherical shape allows the target to be scanned from any direction (Lindskog et al. 2013). The checkerboard target consists of two black squares printed on cardboard.

Setting goals requires careful planning to achieve good results (Kedzierski et al. 2009). Not all bonding software requires specific reference targets, instead software that uses a targetless bonding process relies on surfaces and vertices captured in various scans (Fig.5).

Any point cloud generated by a 3D laser scanner is likely to contain invalid data points and reflections. Errors may occur due to disturbances such as reflections or moving objects in the scanned area (Bi and Wang 2010).

Also, missing spatial data from adjacent areas will be included when windows or open doors are present in the scanned area. Faulty spots are eliminated by filtering on parameters such as density and distance. The filtration is then completed by manually deleting the erroneous data points.

In the application, at first, all the data of all sessions scanned with horizontal 360° were combined as they were (Fig.6). However, since they were common point clouds, automatic merging failed, so manual merging was performed.

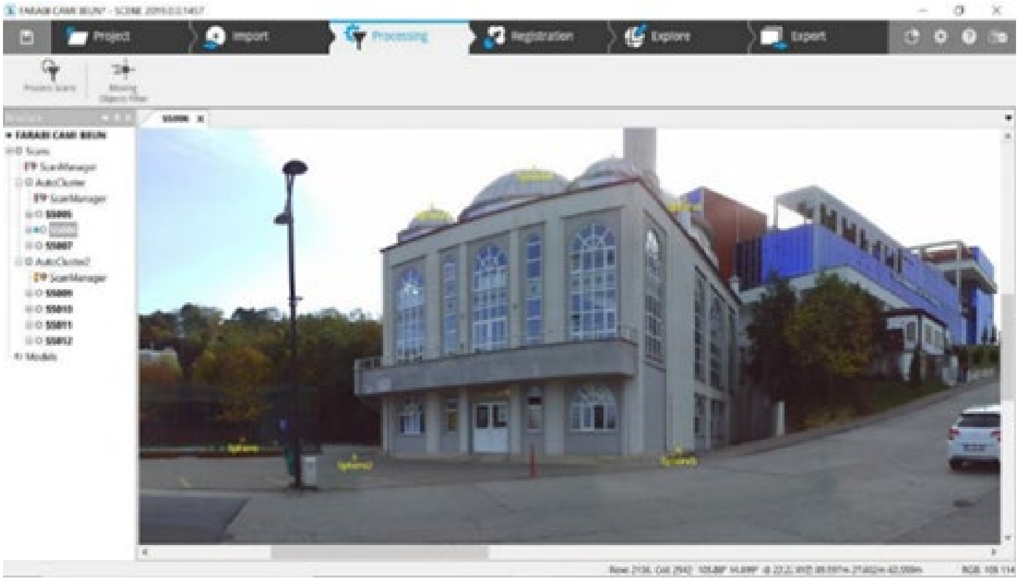

Figure 5. Automatic sphere selection phase of Scene 2019 software.

Figure 6. General view of point cloud obtained by 360° circular scan.

In order to create a 3D digital model of all objects, scans (point clouds) from all stations should be combined in a common (reference) coordinate system (Yildiz and Altuntaş, 2009). Scan points are recorded according to a relative coordinate system of the scanner. The starting point of the scanning coordinate system is the location where the laser meets the mirror. The job of determining the spatial relationship between the scans is called Registration, and the transition step of the scan from the local coordinate system to the general coordinate system is called transformation.

Registration is needed for two purposes (Gümüş, 2010): These are;

1-Merging point clouds from different observation points
2- Placing the object in a specific coordinate system (Geodetic positioning).

Planning and knowing how defragmentation works is essential for successful defragmentation. Some raster projects require only a single scan, while multiple scans are required to create a three-dimensional image. Each scan must be correctly positioned in relation to all other scans.

There are several important concepts associated with consolidation, including; coordinate systems, Common reference objects, sensor data and reference scans.

Connection or control points are required to perform positioning. These points can be a carefully chosen, recognizable point of the object (eg corners) or special targets (high reflective spheres or plates).

Any coordinate system or the coordinate system of one of the scans (usually the first scan) can be selected as a reference (Altuntaş, 2017).

A point cloud measured from a station is a data set in the local coordinate system, consisting of 3D point coordinates. The point cloud of the second dimension, which is superimposed with this dimension, is also in a different local coordinate system.

When the first point cloud (S1) is taken as a reference, the relationship between the first and second point cloud (S2) coordinates of the common points is expressed by the equation (7) (Altuntaş, 2017).

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{S_1} = R_{\omega\varphi\aleph} \cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix}_{S_2} + \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix} \quad (7)$$

The (x, y, z) coordinates in equation (7) are the three-dimensional Cartesian coordinates of the first (S1) and second (S2) point cloud of the same point. Here, Rωφℵ is the 3x3 dimensional rotation matrix formed by the rotation angles between the coordinate systems and [tx ty tz] T is the translation vector between the coordinate systems.

In the application, the scanning consisting of 8 sessions was completed with automatic merging at first, and since the desired 3D image was not obtained, the manual merging phase was started. In the manual assembly phase, the target spheres, the common point between the scans, and the common plane surface were realized with the Targed Based method. In each of the 8 scanning sessions, unnecessary point clouds that do not belong to the target building were cleaned, and then 35 700 815 points (point clouds) were captured and merged. It should be noted that since all sessions were scanned with horizontal 360°, manual merging was not achieved without deleting unnecessary point clouds at first, and the ideal 3D model was not obtained.

Table 3. Results of automatic and manual registration in Faro Scene software

Registration type	Mean point error (±mm)	Maksimum point error (±mm)	Minimum overlap (%)
Auto Merge (Before redundant data cleaning)	12.3	15.7	23.0
Manuel Registration	1.1	8.4	16.5

After removing redundant point clouds, it has been tested with 4 different registration methods to create the ideal 3D model. In Faro Scene 2019 software, these methods are; Cloud to Cloud, Target Based, Topview based and Topview and Cloud to Cloud are merging methods. These methods were carried out within the scope of automatic merging. The ideal 3D model was obtained by completing the manual assembly process with the Targed Based method in order to reduce the post-error average(Fig.7). The error and overlap comparison of the methods is shown in Table 4.

Figure 7. The view angles of 8 sessions after unnecessary points removal for manual registration.

Table 4. Comparison of merging methods made in Faro Scene 2019

Registration method	Maksimum point error (±mm)	Average point error	Registration method
Cloud to Cloud	13.8	5.2	3.5
Target Based	16.8	6.9	5.9
Top View	32.9	13.3	10.9
Topview and Cloud to Cloud	11.6	5.5	10.8
Manually Cloud to Cloud	8.4	4.1	16.5

Table 5. Cartesian coordinates of each session and ellipsoidal coordinates according to WGS-84.

Session no	Converted Local Orthogonal Coordinates			Standard Deviations (Mean Errors)			**Ellipsoidal Coordinates Latitude (φ) Longitude (λ) (°, … …)**	**Orientation Angle** (°,..)
	$x\ (m)$	$y\ (m)$	$z\ (m)$	$\sigma_x(m)$	$\sigma_y(m)$	$\sigma_z(m)$		
1-SS005	75.107258	54.269974	59.553361	-0.0105	0.008	0.9999	41.452391 31.761218	105.42
2-SS006	59.256501	47.95822	59.163336	0.0139	0.0043	0.9999	41.452336 31.761023	51.819
3-SS007	54.614466	27.993533	60.826367	-0.0218	0.009	0.9997	41.452145 31.760969	87.521
4-SS009	117.484677	30.166109	60.051512	-0.0141	-0.003	-1	41.452156 31.761653	149.04
5-SS010	100.338117	15.510721	59.558934	-0.0037	0.0095	-1	41.452152 31.76157	61.247
6-SS011	92.563827	13.16425	60.031081	-0.0334	0.0031	-0.999	41.45204 31.76148	27.834
7-SS012	94.667493	25.649157	63.651876	-0.0042	-0.01	-1	41.452149 31.761461	91.109
8-SS013	76.275529	-1.537738	80.141287	-0.0071	0.0094	-1	41.451946 31.761284	151.27

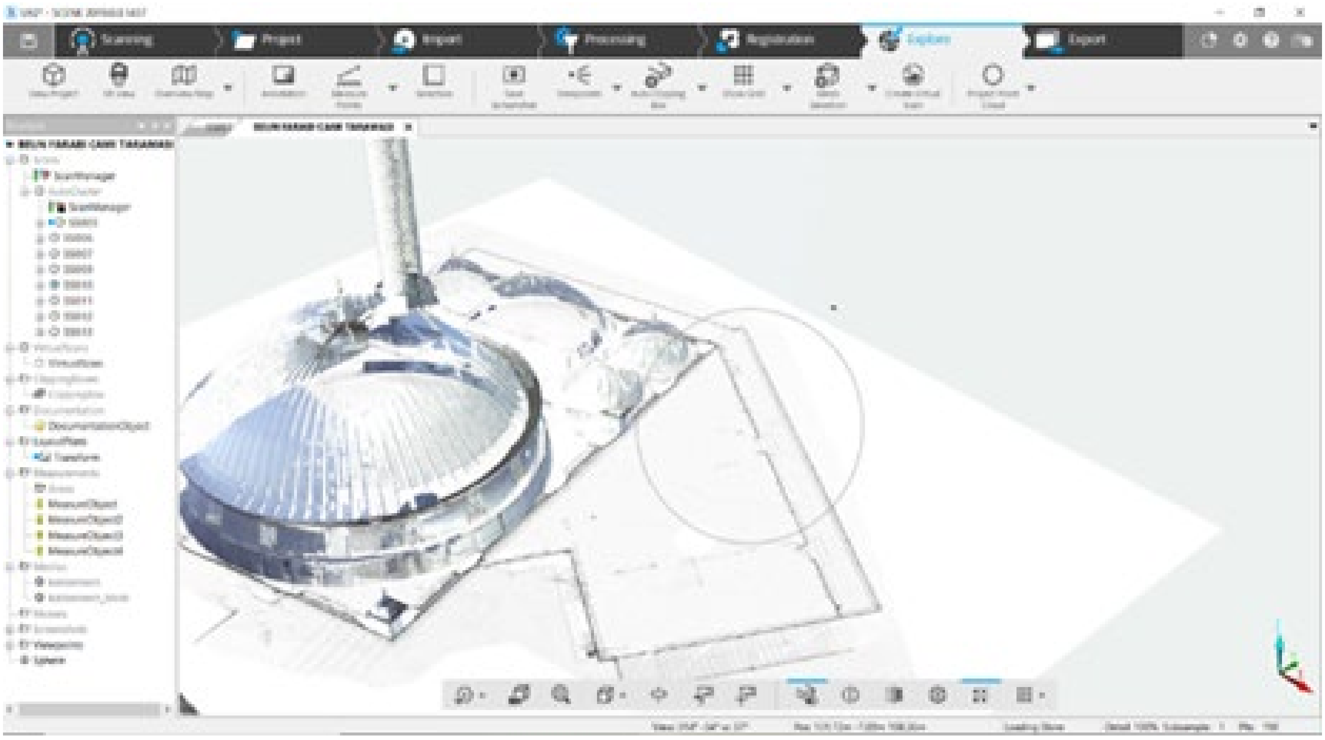

Figure 8. Placement view of the 3D model over the plan in Scene software.

After successful merging, due to the limited functions of the Faro Scene 2019 software, area calculation, mesh generation, and volume calculation operations were performed on the point cloud data using Autodesk Recap 2020 V6.0, Gexcel Reconstructor 2020 V4.2.0, and Meshlab 2020.07 softwares, and operations were carried out on the photorealistic point cloud data (Fig.8, Fig.9)

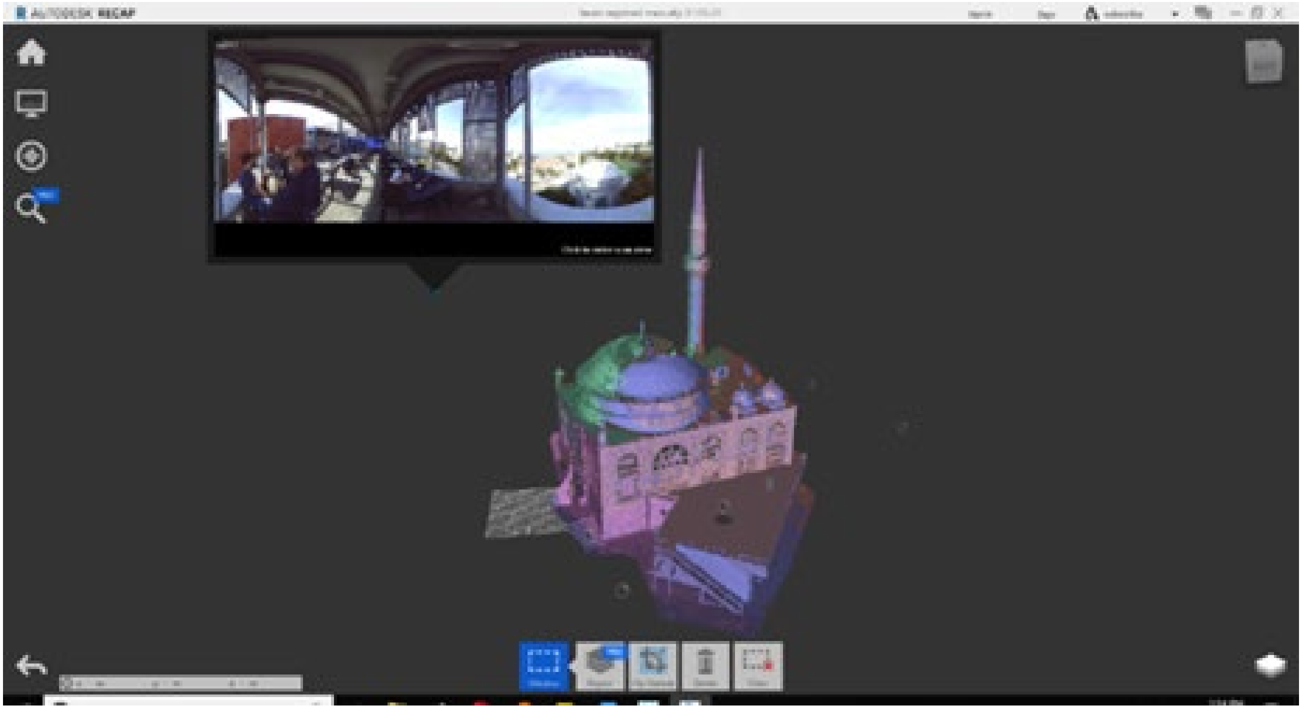

Figure 9. View of the model in Autodesk Recap software with scan locations.

The Focus3D X 330 is a terrestrial laser scanner with an integrated GPS receiver. During each of the 8 sessions, scanning was performed with the automatic GPS sensor feature enabled. The connection of all points in the point cloud was made using the transformation process of the coordinates obtained from the integrated GPS.

The ellipsoidal positional coordinates and Cartesian coordinates, as well as the orientation angles of each session, were converted to GPS WGS-84 ellipsoid and given in Table 5. Automatic and manual registration statistics in Faro Scene software are given in Table 6.

Table 6. Automatic and manual registration statistics in Faro Scene software

Scan No.	Tie	Max.point kta error(±mm)	Average point error (±mm)	Min. Overlap(%)
Manual merging of browsing sessions				
SS009	4	4.6	2.8	20.8
SS012	3	5.7	4.0	16.5
SS010	3	5.7	4.1	28.0
SS005	3	8.4	4.3	18.8
SS011	3	4.5	3.2	16.5
SS006	2	6.6	4.6	51.2
SS007	3	8.4	6.3	18.8
SS013	1	4.0	4.0	45.4
Automatic merging of scanning sessions İstatistikleri				
SS005	2	15.7	11.0	23.0
SS006	2	12.5	9.4	58.2
SS007	2	14.5	13.5	26.4
SS013	1	14.5	14.5	26.4

4.2 Plan, Section and Measurement

After a successful merge, the data is converted to a local or global coordinate system according to the study. Marking any desired point in the data cloud, coordinate information, measurement between points, area calculation and volumetric calculation processes are carried out (Fig.10, Fig.11, Fig.12, Fig.13, Fig14 and Fig,15).

In order for the model created with TLS data to be associated with other spatial data, it must be converted to a geodetic coordinate system. The geodetic coordinate system can be national or global (WGS84 datum parameters) scale. The conversion of measures to the geodetic coordinate system is called geodetic coordinating (georeferencing).

According to Wolf and Dewitt (Wolf et al. 2014), georeferencing (coordinating) can be defined as a technique in which the TLS coordinate system is processed so that the final result is converted to the earth coordinate system. This can be a national or local coordinate system. There are two approaches to implement the georeferencing procedure, either indirect or direct (Abbas et al. 2014).

In this study, direct georeferencing method was used by using GPS data integrated in Faro Focus X330 device in 8 session scans.

Measurement calculationsu made on Figure 12, Figure 13 and Figure 14 models are given in Table 7.

In order to evaluate the 3D data obtained in the Scene 2019 software, it was transferred in different formats. The created 3D models were converted to dxf and different formats. Autodesk Recap in dxf and pts formats, desired plan and measurement processes in Autodesk Autocad and distance measurement, area and volume calculations were made in Reconstructor and Meshlab software (Fig. 11, Fig.12).

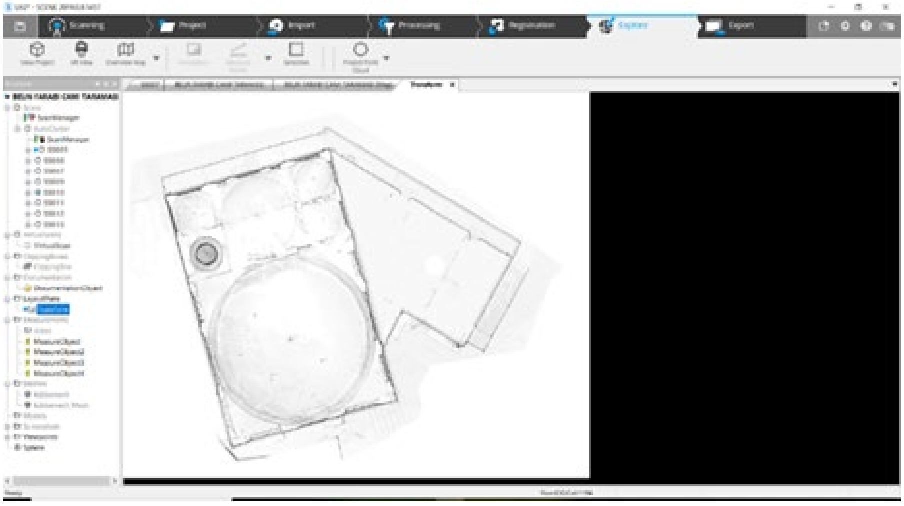

Figure 10. Plan view of the 3D model in Scene 2019 software.

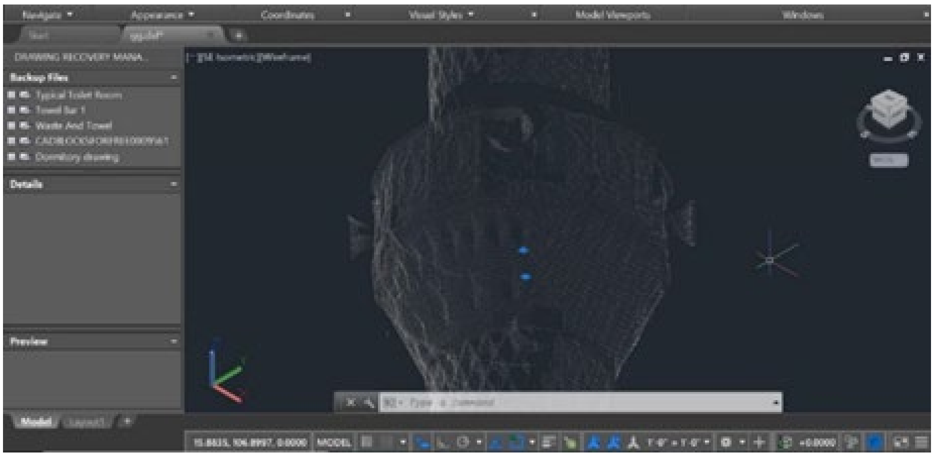

Figure 11. After transfer to Autocad software, 2-point selection image from minaret cloud

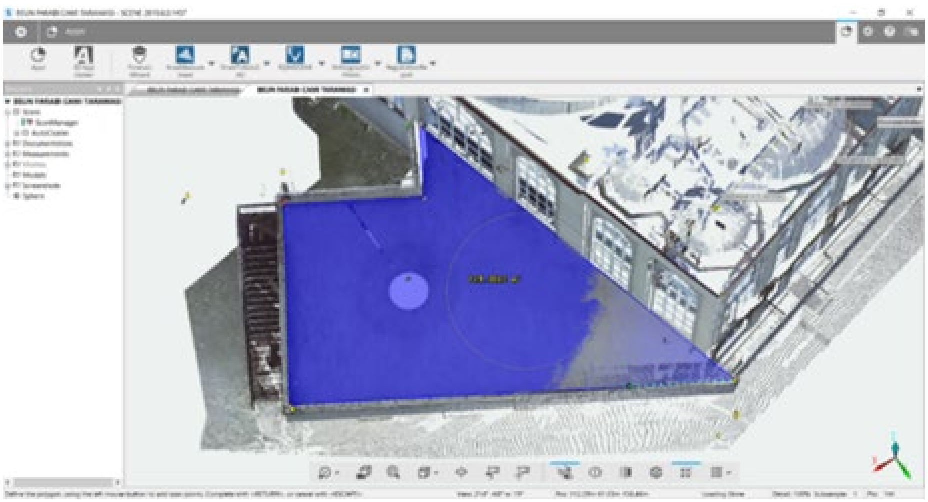

Figure 12. Calculation of terrace area in Scene 2019 software.

Table 7. Some geometric dimensions measured on the Farabi mosque 3D model.

Geometric features	**Length** (m) **/ Height** (m) **Area** (m^2) **/ Volume** (m^3)
front length	14.580
facade height	10.450
side length	21.554
minaret height	25.067
Large dome diameter	13.650
Length between two small domes	10.592
front area	148.820
terrace area	139.310
minaret volume: 53.6254	

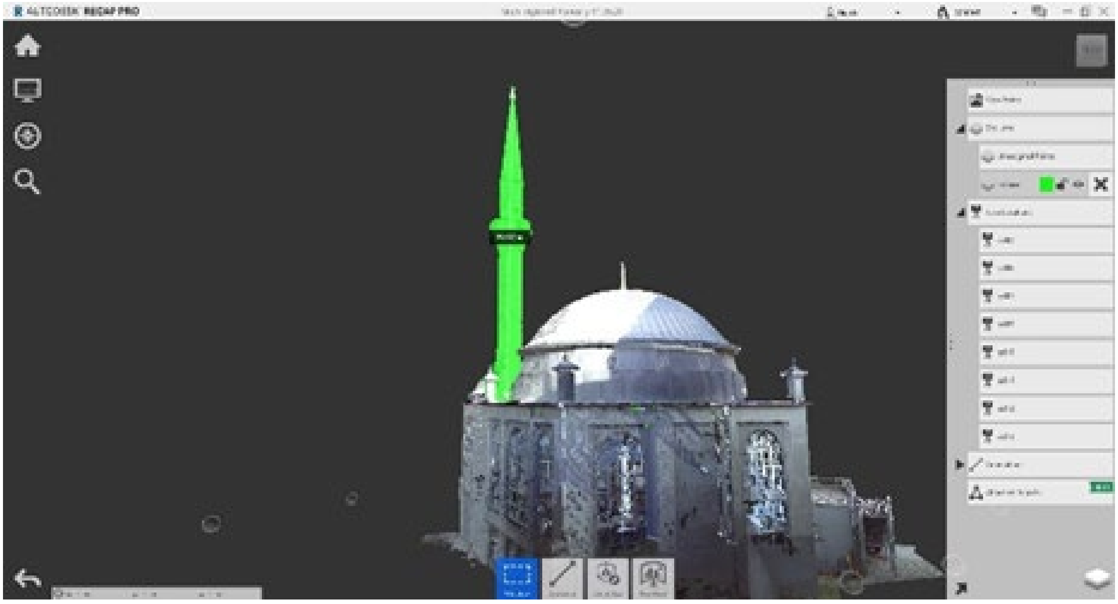

Figure 13. Minaret height measurement in Autodesk Recap 2020 software.

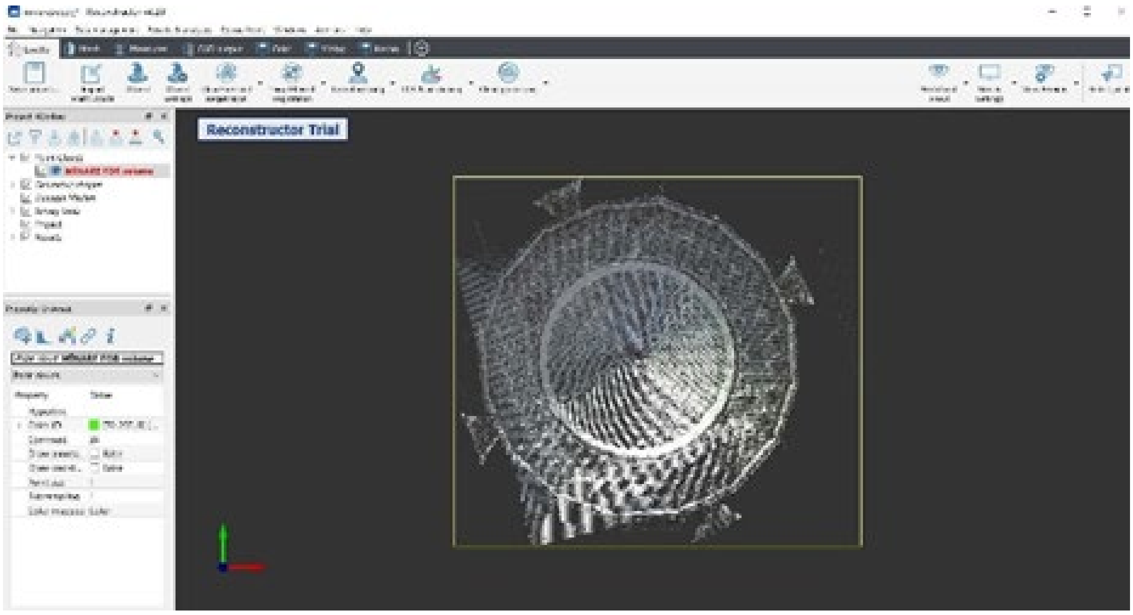

Figure 14. Mesh generation and volume calculation in Reconstructor 2020 software

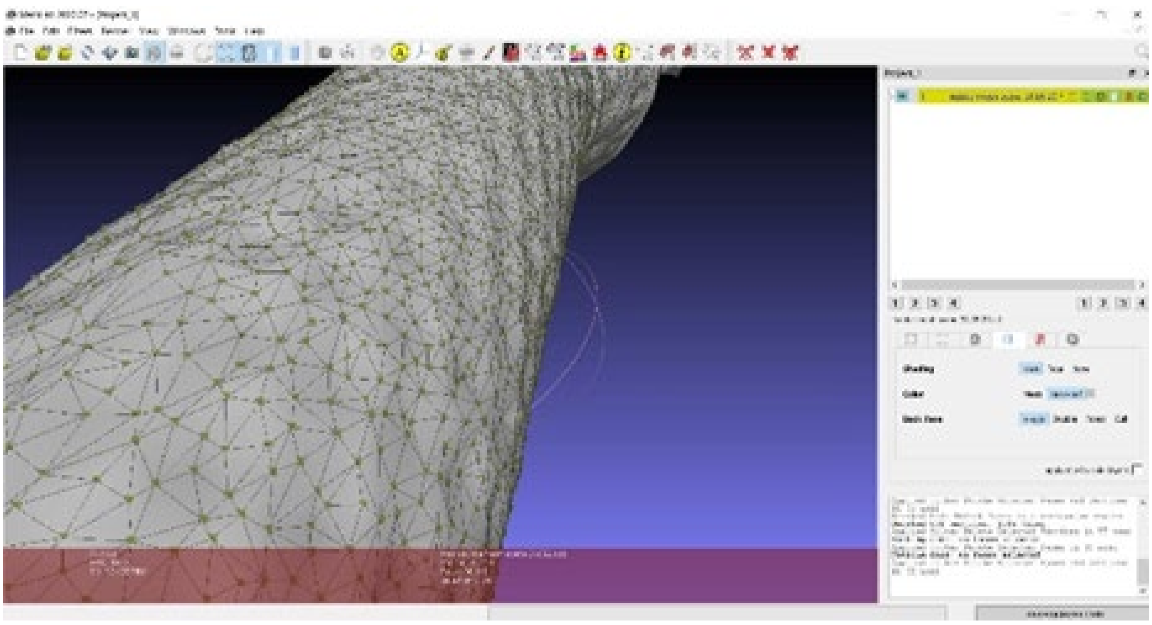

Figure 15. Volume calculation in Meshlab 2020 software

5. Conclusion

In terrestrial laser scanning, it is important to plan and evaluate the object to be scanned before scanning. That is to say, what type of scanning application to be made, which parameters will be given priority, which details of the object to be scanned will be important should be planned before the application. Thus, it will be possible to make evaluations with the accuracy and speed expected in office work. Even a newly released electronic device and evaluation software can always provide much more convenient opportunities in certain aspects than the old ones. In this sense; terrestrial laser scanning tools also follow the current technology, for example, while in old catalogs and old articles, tools with long-range scanning are categorized as having a range of 1000 m, as in the 2019 model Reigl VZ-6000 TLS, which currently has a range of 6000m, technical specifications in recent models, they show several variations.

After the pandemic of the Coronavirus (COVID-19) epidemic, today, which is the age of sensors, the use of thermometer thermal cameras, the use of virtual tourism recorded with TLS and the visits of virtual heritage structures, etc. significant increases in activities.

It is understood that the centers, which are applied by some workplaces that are scanned with TLS and uploaded to the virtual environment, and that offer the opportunity to browse and examine the workplace materials for marketing purposes, will increase after this period.

For example, it is known that the measuring instruments in the space belonging to an antique car dealer or a geomatics engineering tool dealer company can be scanned 3D through the Faro SCENE Webshare Cloud, allowing their customers to examine all the details of antique cars or measuring tools in 3D on the internet. It can be said that in the future, TLS technology will find a wider variety of applications.

In this study, TLS scans were made to obtain the 3D model of the outer surface of the Farabi Campus Mosque of Zonguldak Bülent Ecevit University. Scanning was performed with the Focus 3D X330 TLS instrument, which is Faro's 2013 model, from 8 points. In the office work, after the assembly process, models of other objects around the building and environmental errors are eliminated.

In the study, a real 3D model image was obtained with real color values, whether in color values determined by the scanner according to the structure of the scanned object.

In Scene 2019 software, distance measurement of point clouds can be made between any two points or objects. To calculate the area, Faro Scene required the installation of the free area calculation software Plugin (compatible additional software). Different software was required for volume calculation, so the model was evaluated in Reconstructor and Meshlab software.

The results obtained within the scope of the study reveal that terrestrial laser scanning technology is a very successful method for 3D modeling of objects. Terrestrial Laser Scanning saves time within the scope of the project compared to other measurement methods, and all desired detail measurements can be made on the 3D model obtained.

It should be emphasized that the object that is planned to be scanned with external shooting should be started by adjusting the horizontal and vertical viewing angles before scanning. When this stage is made reasonable, it is suggested that an economic gain will be achieved in the scanning period in the field and the office evaluation period after the scanning (Nazari, 2020). Another important issue at the stage of combining the scan data is that the target marks (target balls or target squares) should be placed in such a way that they can see each other and can be connected.

Author contributions

Shah Wali Nazari; Methodology, data collection, article writing,
Veli Akarsu; contributed to the writing of the article with the idea of the article, article writing,
Murat Yakar: Editing the manuscripthe, 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.

References

Abbasa, M. A.., Luha, L. C., Setana, H., Majida, Z., Chongc, A. K., Aspuria, A., Idrisa, K. M. & Ariffa, M. F. M. (2014). Terrestrial Laser Scanners Pre-Processing: Registration and Georeferencing, *Jurnal Teknologi (Sciences & Engineering)* 71(4).

Akarsu, V. (2005). Geometride Uzay, Düşey ve Yatay Açılar Arasındaki Fonksiyonelİlişki, *Selcuk-Teknik Online Dergi*, 4(3), 134-142.

Akarsu, V., Nazari, S. W. (2020). Yersel Lazer Tarama Teknolojisi İle Heyelanların İzlenmesi, Yerbilimleri Problemlerine Model Yaklaşımlar, Editör: Dr. Fatih Sünbül, 3-36, *İKSAD*, ISBN:978-625-9897-99-0, Ankara, Turkey.

Alptekin, A. & Yakar, M. (2021). Lazer Tarayıcının Jeolojik Olayların Modellenmesinde Kullanımı. *Türkiye Lidar Dergisi*, 3(2), 71-75. DOI: 10.51946/melid.1018197

Alptekin, A., Çelik, M. Ö., Doğan, Y. & Yakar, M. (2022, February). Illustrating of a landslide site with photogrammetric and LIDAR methods. In Research Developments in Geotechnics, Geo-Informatics and Remote Sensing: Proceedings of the 2nd Springer Conference of the Arabian Journal of Geosciences (CAJG-2), Tunisia 2019 (pp. 303-305). Cham: *Springer International Publishing.*

Altuntaş, A. (2017). Yersel Lazer Tarayıcı Nokta Bulutlarının Birleştirilmesi ve Jeodezik Koordinat Sistemine Dönüştürülmesi: Literatür Araştırması, Selçuk-Teknik Dergisi

Becerik-Gerber, B., Jazizadeh, F., Kavulya, G. & Calis, G. (2011). Assessment of target types and layouts in

3D laser scanning for registration accuracy. *Automation in Construction*

Bi, Z. & Wang, L. (2010). Advances in 3D data acquisition and processing for industrial applications. Robotics and Computer-Integrated Manufacturing

Brenner, C. (2007). Interpretation terrestrischer Scandaten. In: Proceedings of "Terrestrisches Laserscanning (TLS 2007), *Beiträge zum* 74. DVW Seminar".

Chetverikov, D., Stepanov, D., Krsek, P. (2005), Robust Euclidean alignment of 3D point sets:the trimmed iterative closest point algorithm, *Image and Vision Computing.*

Danson, F., Gaulton, R., Armitage, R. P., Disney, M. I., Gunawan, O., Lewis, P., Pearson, G. & Ramirez, A. F.. (2014). Developing a dual-wavelength full- laser scanner to characterize forest canopy structure. *Agric For Meteorol* 198.

Fröhlich, C. & Mettenleiter, M. (2004). Terrestrial laser scanning-new perspectives in 3D surveying, Germany.

Gümüş, M. (2010). YL Tez, Yersel Lazer Tarayıcıların Deformasyon Ölçmelerinde Kullanılabilirliği Üzerine bir Çalişma, *Selçuk Üniversitesi, Jedodezi ve Fotogrametri Mühendisliği.*

Kanun, E., Metin, A. & Yakar, M. (2021). Yersel Lazer Tarama Tekniği Kullanarak Ağzıkara Han'ın 3 Boyutlu Nokta Bulutunun Elde Edilmesi. *Türkiye Lidar Dergisi*, 3(2), 58-64.

Karabacak, A. & Yakar, M. (2022). Giyilebilir Mobil LİDAR Kullanım Alanları ve Cambazlı Kilisesinin 3B Modellemesi. *Türkiye Lidar Dergisi*, 4(2), 37-52. DOI: 10.51946/melid.1146383

Karataş, L., Alptekin, A. & Yakar, M. (2022). Analytical Documentation of Stone Material Deteriorations on Facades with Terrestrial Laser Scanning and Photogrammetric Methods: Case Study of Şanlıurfa Kışla Mosque. *Advanced LiDAR*, 2(2), 36-47.

Karataş, L., Alptekin, A. & Yakar, M. (2022). Creating Architectural Surveys of Traditional Buildings with the Help of Terrestrial Laser Scanning Method (TLS) and Orthophotos: Historical Diyarbakır Sur Mansion. *Advanced LiDAR*, 2(2), 54-63.

Kaya, Y., Yiğit, A. Y. Ulvi, A. & Yakar, M. (2021). Arkeolojik alanların dokümantasyonununda fotogrametrik tekniklerinin doğruluklarının karşılaştırmalı analizi: Konya Yunuslar Örneği. *Harita Dergisi,* 165, 57-72.

Kedzierski, M., Walczykowski, P. & Fryskowska, A. (2009), Application Of Terrestrıal Laser Scannıng In Assessment Of Hydrotechnıc Objects Conditıon, *Asprs 2009 Annual Conference Baltimore*, Maryland

Korumaz, A. G., Korumaz, M., Dulgerlera, O. N., Karasaka, L., Yıldız, F. & Yakar, M. (2010). Evaluation of laser scanner performance in documentation of historical and architectural ruins, a case study in Konya. *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 38(5), 361-366.

Lindskog, E., Berglund, J., Vallhagen, J. & Johansson, B. (2013). Visualization support for virtual redesign of manufacturing systems*. In Procedia CIRP* 7; 29-31 May, 2013

Mırdan, O. F. (2018). İç ve Dış Mekanların Nokta Bulutlarının Birleştirilmesi, Yüksek Lisans Tezi, *Selçuk Üniversitesi, Harita Mühendisliği Anabilim Dalı.*

Nazari, S. W. (2020). Yersel Lazer Tarayıcılar: Geomatik Mühendisliğinde Uygulama Örneği, ZBEÜ, *Fen Bilimleri Enstitüsü Geomatik Mühendisliği Anabilim Dalı*, Yüksek Lisans Tezi, s.111, Zonguldak, Turkey.

Şasi, A. & Yakar, M. (2017). Photogrammetric modelling of sakahane masjid using an unmanned aerial vehicle. *Turkish Journal of Engineering,* 1(2), 82-87.

Scaioni, M. (2002). Independent model triangulation of terrestrial laser scanner data, The ISPRS International Archives of Photogrammetry, *Remote Sensing and Spatial Information Sciences*

Scene, (2019). FARO Focus Laser Scanners, Training Workbook, Version 2019.

Şenol, H. I., Erdogan, S., Onal, M., Ulukavak, M., Memduhoglu, A., Mutlu, S. & Yilmaz, M. (2017). 3D Modeling of A Bazaar in Ancient Harran City Using Laser Scanning Technique*. International Archives of The Photogrammetry, Remote Sensing & Spatial Information Sciences*, 42.

Şenol, H. İ., Memduhoglu, A., & Ulukavak, M. (2020). Multi instrumental documentation and 3D modelling of an archaeological site: a case study in Kizilkoyun Necropolis Area. Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi, 11(3), 1241-1250.

Ulvi, A., & Yiğit, A. Y. (2022). Comparison of the Wearable Mobile Laser Scanner (WMLS) with Other Point Cloud Data Collection Methods in Cultural Heritage: A Case Study of Diokaisareia. *ACM Journal on Computing and Cultural Heritage,* 15(4), 1-19.

Ulvi, A., Yakar, M., Toprak, A. S. & Mutluoglu, O. (2014). Laser scanning and photogrammetric evaluation of Uzuncaburç Monumental Entrance. International *Journal of Applied Mathematics Electronics and Computers*, 3(1), 32-36.

Vosselman, G., Maas, H.-G. (Eds.). (2010). Airborne and Terrestrial Laser Scanning, first ed. CRC Press. *Boca Raton*, FL.

Wolf, P., DeWitt, B. & Wilkinson, B. (2014). Elements of Photogrammetry with Applications in GIS, 4th ed. *McGrawHill Education*.

Yakar, M., Yılmaz, H. M. & Mutluoğlu, Ö. (2008). Lazer Tarama Teknolojisi ve Fotogrametrik Yöntem ile Hacim Hesabı. *TÜBİTAK*, Proje No: 105M179, 90s.

Yakar, M., Yilmaz, H. M. & Mutluoglu, O. (2009). Comparative Evaluation of Excavation Volume by Terrestrial Laser Scanner and Total Topographic Station Based Methods*. Lasers in Engineering*, 19(5), 331.

Yakar, M., Yılmaz, H. M. & Mutluoğlu, Ö. (2010). Comparative evaluation of excavation volume by TLS and total topographic station-based methods. *Lasers in Eng*,19, 331-345

Yildiz, F. & Altuntaş, F. (2009). YL Tez, Yersel Lazer Tarayıcı Nokta Bulutlarının Jeodezik Koordinat Sistemine Dönüştürülmesi, *Selçuk Üniversitesi, Jedodezi ve Fotogrametri Mühendisliği Bölümü*, 42075 Selçuklu

Yılmaz, H. & Yakar, M. (2016). LiDAR (Light Detection and Ranging) Tarama Sistemi. *Yapı Teknolojileri Elektronik Dergisi*, 2(2), 23-33.

Yılmaz, H. M. & Yakar, M. (2006). Yersel lazer tarama Teknolojisi. *Yapı teknolojileri Elektronik dergisi*, 2(2), 43-48.