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Documentation of Archaeological Excavation Sites with Terrestrial Laser Scanning and UAV Photogrammetry Methods

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Unmanned Aerial Vehicle,
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Abstract

This study discusses the modeling processes with Unmanned Aerial Vehicle (UAV) and Terrestrial Laser Scanner (TLS) and their performance in archaeological excavation sites. By analyzing and comparing the data obtained with both UAV and TLS, the study shows that both modeling methods are suitable for excavation site modeling and have different advantages. These results show that both methods have significant potential to facilitate and improve archaeological site planning and documentation.

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1. Introduction

Cultural and natural heritage structures and areas provide insights into various civilizations throughout history, including evidence of significant events (Kaya et al., 2021). It is our responsibility to preserve artifacts from past civilizations for future generations, and efforts to commemorate the places where humans have lived since the beginning of time persist (Babaoğlu & Akman, 2023). Cultural heritage sites are significant for cultural tourism and scientific studies (Ulvi et al., 2019). Archaeological materials provide insight into past conditions, while artistic structures like paintings and sculptures convey messages from past centuries (Kaya et al., 2021). Cultural heritage is at risk of destruction due to natural or human factors (Cömert et al., 2012; Tercan, 2017). To prevent the loss of historical artifacts, such as archaeological sites, documentation is necessary. This allows for detailed information to be archived and preserved for future generations (Telli, 2021). Documentation methods vary depending on the area being documented, the required level of sensitivity, and the scope of the area.

In recent years, terrestrial laser scanners (TLS) and unmanned aerial vehicles (UAV) have been increasingly used for documentation purposes in archaeological or historical areas (Akın & Erdoğan, 2022; Kaya et al., 2021). Studies show that TLS is widely used in archaeological areas (Kaya et al., 2021; Oruç & Baş, 2021). These scanners are utilized for creating three-dimensional (3D)

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models of objects discovered in archaeological sites. They are known for providing greater detail and accuracy compared to classical methods (Kaya et al., 2021). TLS and UAV technologies aid in the planning and documentation of archaeological sites, providing a digital foundation for the preservation, exhibition, and transfer of cultural heritage assets to future generations (Güngör, 2022). There are several important reasons for documenting excavation sites with TLS. TLS technology is a remote sensing method capable of high-precision 3D mapping (Jones & Bickler, 2019). The data obtained with TLS can accurately record the topography, details of structures, and environmental features of the excavation site (Nex & Rinaudo, 2010). This allows for the complete documentation and preservation of excavation sites. Documenting excavation sites with TLS technology provides important information to archaeologists and scientists (Peterson et al., 2019). This technology reveals hidden structures, traces, and details on excavation sites, providing more information about human life and cultural changes from prehistoric times to the present day. TLS technology has been used as an important tool for documenting and preserving excavation sites for these reasons (Klapa et al., 2017). However, TLS technology has some disadvantages. The main drawbacks are distance limitations, high acquisition costs, stabilization issues, and the inability to obtain object attribute data (Demir et al., 2004). The biggest disadvantage of this system is the need for multiple scanning sessions, especially in large areas. However, the integration of UAVs into photogrammetry for civilian use has enabled faster and more cost-effective data collection (Akkamış & Çalışkan, 2020).

Initially, UAVs were primarily used for remote aerial reconnaissance and surveillance operations in the military domain. These vehicles are typically equipped with cameras, sensors, and other data collection devices, and have a wide range of applications (Oruç & Ali, 2023; Cevher, 2023). UAVs are commonly utilized for civilian purposes, including geographical mapping, agricultural monitoring, disaster relief, environmental monitoring, and security surveillance. They have significantly contributed to the production of aerial photography and 3D data, particularly in the field of photogrammetry (Peterson et al., 2019; Ulutaş, 2022). Due to their significant contribution to the field of photogrammetry, the term 'UAV photogrammetry' has emerged and is now preferred for various purposes, particularly for 3D documentation in cultural heritage areas (Mirdan & Yakar, 2017). While UAV photogrammetry is a relatively new term, the underlying technology of photogrammetry is not new, and therefore its mathematical model is similar to that of other branches. UAV photogrammetry is generally capable of covering larger areas than the YLT method for documenting cultural heritage areas with photogrammetry (Yunus et al., 2021; Şenol et al., 2021). On the other hand, terrestrial laser scanning may take longer since it performs point-based scanning (Yaman, 2013).

The purpose of this study was to evaluate the accuracy of TLS and UAV photogrammetry in documenting excavation sites. Data were collected using both TLS and UAV photogrammetry. The final point cloud was created after removing noise from the data. Subsequently, C2C analysis was conducted using Cloud Compare software. The documentation of excavation sites was found to be more advantageous using UAV photogrammetry than LLT.

2. Materials and Methods

The study area selected was the Mersin Mezitli Soli Pompeiopolis excavation site, located in the Mezitli district of Mersin province, where remains from the ancient period have been found. Many artifacts and remains belonging to the Roman period were unearthed as a result of the excavations in this area. The Soli Pompeiopolis excavation site is a region of historical and archaeological importance that attracts the attention of visitors.

The excavation site was documented using the FARO Focus3D X 330 TLS (Figure 1) and the Anafi Parrot UAV (Figure 2). The TLS device works with 3D coordinates and intensity values that indicate the strength of the backscattered laser scanning signal of each point, recording it as an intensity value. This enables fast, non-contact, and precise measurement of objects. TLS is a powerful method for collecting spatial data. The TLS offers rapid, non-contact, and accurate measurements of both objects and entire areas. Technical details of the TLS can be found in Table 1.

Figure 1. FARO Focus3D X 330 local laser scanner.

Table 1. FARO Focus3D X 330 Technical Specifications.

Attribute	Value
Laser class	1
Measurement speed	Up to 976,000 points per second
Distance	0.6-330m
Distance error	± 2mm
Multi-Sensor	GPS, Compass Height Sensor
Dual Axis Compensator	Available
Integrated color camera	up to 70 mio. pixels
Size	240 x 200 x 100mm
Weight	5,2 kg
Scanner control	Touch screen

Laser scanners provide fast data acquisition, detailed 3D visualization, efficiency, accuracy, and safety in excavation. However, when using the TLS technique for documentation and 3D modeling work, there are deficiencies in scanning blind spots and pits in the excavation area. To address these issues, aerial photo collection with the help of UAVs, which are widely used in various fields due to technological advancements, can significantly cover these deficiencies. Aerial photography was conducted to obtain high-resolution images of the study area using cameras mounted on UAVs. The images were then processed using photogrammetry software. Technical information about the UAV used in the study is presented in Table 2.

Figure 2. Anafi Parrot UAV

3. Results

Initially, exploratory studies were conducted in the excavation area to determine the optimal positioning of the TLS device. The survey results indicated areas where the device would scan more effectively and avoid any gaps. The laser scanning process involved positioning the scanner in 29 different locations and conducting the scanning process. The resolution of the point cloud data is directly affected by the distance between the laser scanner and the scanned surface. Additionally, the quality of the point cloud data is affected by the beams from the laser scanner to the surface being scanned. It is crucial to obtain every detail in the excavation area due to their historical importance. To ensure complete coverage of the excavation area and capture any blind spots missed by the laser scanner, 29 six-minute sessions were conducted in a specific order. The resulting scan data was combined using the 'Scene' software, a 3D point cloud evaluation tool, to generate a 3D image of the archaeological excavation area (Figure 3).

After completing the data collection with TLS, data collection with UAV was initiated. Aerial overlapping photographs of the terrain were taken for documentation and 3D modeling using UAV photogrammetry techniques. A total of 223 photographs were obtained by UAV, and the necessary processes were applied in 'Agisoft Metashape' software. The first process applied was the automatic 'align' process, which aligned the photographs. A dense point cloud was automatically generated from the photographs, resulting in a 3D model of the excavation area. Figure 4 displays the 3D model created using 'Agisoft Metashape' software.

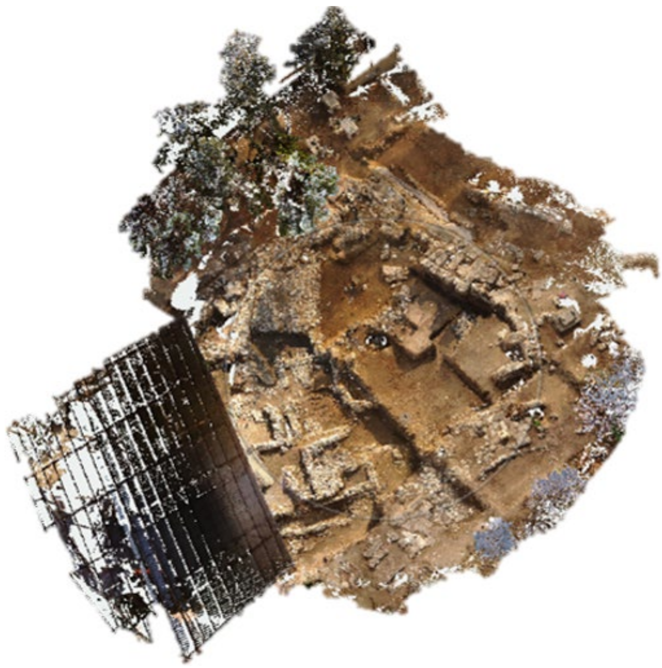

Figure 3. Point cloud obtained in Scene software using TLS data.

Figure 4. Point cloud obtained in Agisoft Metashape software using UAV images.

To improve accuracy in both methods, precise positioning and control points should be used. Additionally, special software and analysis techniques are utilized to compare and analyze the accuracy of the data obtained. The point clouds created by both methods were imported and brought to the same reference frame (same coordinate plane) using the 'Cloud Compare v2.13.beta' software. The point clouds were aligned and analyzed using point-to-point distance analysis (Cloud to Cloud/C2C). The resulting errors between the point clouds were displayed using a color scale. The ground-based laser scanner point cloud was used as the reference, and the differences between it and the UAV point cloud were analyzed (Figure 5).

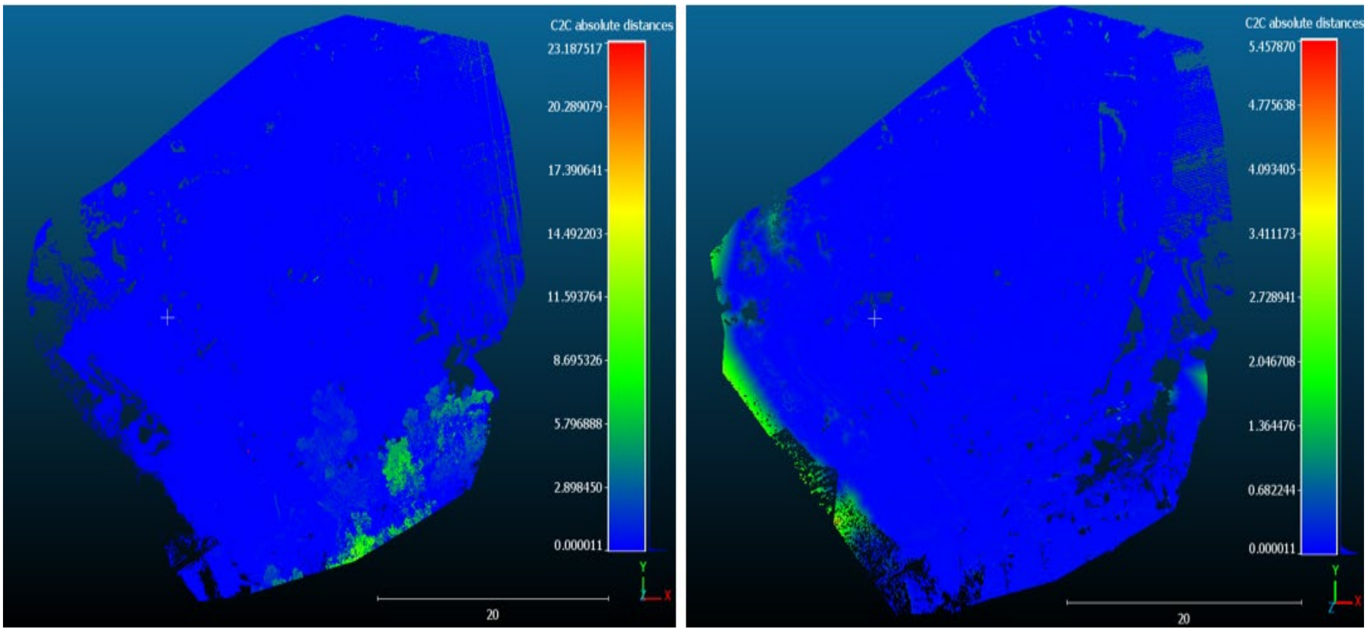

Figure 5. Left image with YLT data as reference, right image with UAV data as reference.

The scaler field for the C2C absolute distance between the point clouds is also displayed. C2C absolute distance is a fast technique used to calculate the shortest distance between two point clouds, without the need for meshing or gridding required in pixel-based methods to calculate the surface normal. The improved algorithm utilizes the Hausdorff distance technique and octree structures, as described by Girardeau-Montaut et al., to compare two registered point clouds. The Hausdorff distance is calculated as the distance from the closest point p in the first cloud to p in the second cloud. This ensures precise measurement of the distance between the two cloud data sets. This method uses least squares or 'octree' techniques based on the average distance between the two data sets to calculate the distance between the cloud data. The results of the C2C analysis for each test site are given by calculating the average distance values and standard deviations. This analysis was conducted to compare the performance of two different laser scanning devices.

4. Conclusion

The excavation site of Mersin Mezitli Soli Pompeiopolis was documented using TLS and UAV photogrammetry methods. The data obtained from both methods were compared, and it was determined that both modeling methods are suitable for excavation site modeling and have different advantages. The TLS technique accurately records the topography, structures, and environmental features of the excavation site, while UAV photogrammetry can cover larger areas. A C2C analysis between the point clouds generated by both methods revealed that UAV photogrammetry is more advantageous than TLS for excavation site documentation applications. This study demonstrates that UAV photogrammetry has significant potential to enhance archaeological site planning and documentation. These findings have the potential to establish a digital foundation for the preservation, display, and transfer of cultural heritage assets to future generations.

Author contributions

İsa Özdemir; Methodology, Fieldwork, and manuscript editing.
Azad Güngör; Fieldwork and original manuscript 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

Akin, E. S., & Erdoğan, A. (2022). İnsansız Hava Araçları (İHA) ile Arkeolojik Alanlarda Belgeleme: Sarıkaya Roma Hamamı (Therma Basilica) Örneği. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *26*(3), 335-343.

Akkamiş, M., & Çalişkan, S. (2020). İnsansız hava araçları ve tarımsal uygulamalarda kullanımı. *Türkiye İnsansız Hava Araçları Dergisi*, *2*(1), 8-16.

Babaoğlu, P., & Akman, Ç. (2023). İnsan hakları bağlamında kültürel mirasın korunması açısından dijital uygulamaların kullanımı. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *16*(4), 1143-1157.

Cevher, Ü. (2023). İnsansız Hava Araçlarında Dayanıklılık. *Avrupa Bilim ve Teknoloji Dergisi*, (51), 181-189.

Güngör, M. (2022). Yersel Lazer Tarayıcıların Arkeolojik Alanlardaki Kullanımının İncelenmesi. *Türkiye Lidar Dergisi*, *4*(2), 85-90.

Jones, B., & Bickler, S. H. (2019). Multi-scalar and semi-automatic approaches to detect archaeological features in NZ using Airborne LiDAR data. *Archaeology*, *10.*

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.

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.

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.

Klapa, P., Mitka, B., & Zygmunt, M. (2017, December). Application of integrated photogrammetric and terrestrial laser scanning data to cultural heritage surveying. In *IOP Conference Series: Earth and Environmental Science* (Vol. 95, No. 3, p. 032007). IOP Publishing.

Mirdan, O., & Yakar, M. (2017). Tarihi eserlerin İnsansız Hava Aracı ile modellenmesinde karşılaşılan sorunlar. *Geomatik*, *2*(3), 118-125.

Nex, F., & Rinaudo, F. (2010). Photogrammetric and LiDAR integration for the cultural heritage metric surveys. *International archives of photogrammetry, remote sensing and spatial information sciences*, *38*(Part 5), 490-495.

Oruç, M. E., & Ulvi, A. (2023). Maden Sahalarındaki Deformasyonların İHA'lar ile İzlenmesi. *Türkiye Fotogrametri Dergisi*, *5*(2), 43-57.

Oruç, M. E., & Baş, G. (2021). Kompleks Yapı ve Alanlarda Yersel Lazer Tarama Teknolojisinin Kullanımı. *Türkiye Lidar Dergisi*, *3*(2), 39-47.

Peterson, S., Lopez, J., & Munjy, R. (2019). Comparison of UAV imagery-derived point cloud to terrestrial laser scanner point cloud. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *4*, 149-155.

Scene. (2022). User manual for faro scene software. FAROSoftware; FARO© Technologies Inc. State of Florida, ABD. https://knowledge.faro.com/Software/FARO_SCENE/SCENE/User_Manual_for_SCENE

Şenol, H. İ., Yiğit, A. Y., Kaya, Y., & Ulvi, A. (2021). İHA ve yersel fotogrametrik veri füzyonu ile kültürel mirasın 3 boyutlu (3B) modelleme uygulaması: Kanlıdivane Örneği. *Türkiye Fotogrametri Dergisi*, 3(1), 29-36. https://doi.org/10.53030/tufod.935920

Telli, D. (2021). Yeniden işlevlendirilen endüstri yapılarında mekân ve mekân kurgusuna yapılan tasarım müdahalelerinin miras değerine etkilerinin değerlendirilmesi üzerine bir yöntem önerisi: Cibali tütün ve sigara fabrikası örneği, Doktora tezi, *Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü*, İstanbul, Türkiye.

Ulutaş, N. (2022). *Yersel lazer tarama verisinin mimari vektörel çizimlerdeki kullanılabilirliği ve mimari belgelemeye katkısı* (Master's thesis, Konya Teknik Üniversitesi).

Xu, Z., Wu, L., Shen, Y., Li, F., Wang, Q., & Wang, R. (2014). Tridimensional reconstruction applied to cultural heritage with the use of camera-equipped UAV and terrestrial laser scanner. *Remote sensing*, *6*(11), 10413-10434.

Yaman, A. (2013). *Yersel lazer tarayıcıların tarama açısı ve mesafesine bağlı olarak konum doğruluğunun araştırılması* (Master's thesis, Aksaray Üniversitesi Fen Bilimleri Enstitüsü).

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

Yunus, K., Polat, N., Şenol, H. İ., Memduhoğlu, A., & Ulukavak, M. (2021). Arkeolojik kalıntıların belgelenmesinde yersel ve İHA fotogrametrisinin birlikte kullanımı. *Türkiye Fotogrametri Dergisi*, *3*(1), 9-14.