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Investigating the utilization of iPhone lidar sensor in documenting cultural heritage

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Abstract

Historical artifacts and archaeological remains are critical documents that contribute to our understanding of a society's history, culture, and lifestyle. Historical artifacts can be damaged for various reasons. Damages hinder the sustainable preservation of the artwork by complicating the understanding of culture and art. Therefore, documenting the current state of historical artifacts and recording their features helps minimize damage. There are various methods for documenting historical heritage, one of which is photogrammetry, an image-based technique that obtains three-dimensional data by combining two-dimensional images taken from different angles., Another technique that can be employed in the documentation process is Light Detection and Ranging (LIDAR). A Lidar device sends out brief pulses of laser beams to its surroundings. These beams collide with and bounce off objects nearby. Lidar measures distance by detecting these reflected beams. In this study, a 3D point cloud of a relief sculpture in the Kizilkoyun Necropolis was created using photogrammetry and the LIDAR sensor added to smartphones.

1. Introduction

Historical artifacts and archaeological remains are important works that provide information about a society's history, culture, and lifestyles. These works can be damaged by human intervention such as artwork urbanization, warfare, smuggling, or natural disasters like earthquakes and floods. The resulting damages make it difficult for people to connect with the past, understand culture and art, and hinder the sustainable preservation of the artwork. Therefore, documenting the current state of historical artifacts, recording their features, and preserving can assist in passing them on to future generations and minimizing damage.

The efforts made to obtain accurate and reliable data in documenting historical artifacts have led to the emergence of new techniques in the field of documentation (Korumaz et al., 2011). With advancing technology, traditional methods such as hand drawing and photographing with analog cameras have been replaced by modern documentation techniques such as high-resolution digital photography, laser scanning, and photogrammetry for 3D modeling (Yiğit and Uysal, 2021). Photogrammetry is an image-based technique that gathers three-dimensional data from two-dimensional images taken from different angles and positions (Remondino and El-Hakim, 2006). Its ability to determine the characteristics of an object in three dimensions without direct contact and to cover the resulting model with attributes and real textures has contributed to its popularity (Obradović et al., 2020). Due to its speed, low cost, and high-quality data in terms of accuracy, it is frequently preferred for documenting and 3D modeling cultural heritage (Uslu et al., 2016; Zeybek and Kaya, 2020).

Another method that can be employed in the documentation process is LIDAR. A Lidar device sends out brief pulses of laser beams to its surroundings. These beams collide with and bounce off objects nearby. Lidar measures distance by detecting these reflected beams (Polat and Uysal, 2016; Jiang et al., 2005). It has many advantages, such as high accuracy, high point density, and the ability to rapidly collect a large number of point data. Despite the previously perceived high equipment cost, recent technological developments have allowed for the miniaturization of equipment and improvements in sensors, enabling the integration of LIDAR into smartphones. In line with these developments, Apple Inc. released the iPhone 12 and iPhone 12 Pro Max models in

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2020, the first series of phones equipped with a LIDAR sensor (Aslan and Polat, N 2022). The LIDAR sensor was added to the camera system in these models to provide precise positioning in augmented reality (AR) applications and enhance depth perception (Luetzenburg et al., 2021). In this study, the 3D point cloud of the soldier relief found in the M16 rock tomb of the Kizilkoyun Necropolis, a cultural heritage site, was created using an iPhone 14 Pro Max. The point cloud obtained using the LIDAR sensor was compared with the cloud obtained through terrestrial photogrammetry.

2. Method

2.1. Study area

The chosen study area is the Kizilkoyun Necropolis Archaeological Site. Located at the foothills of the Sanliurfa Tilfindir Hill, the Kizilkoyun Necropolis is bordered to the east by the Yenimahalle archaeological area, to the west by the Haleplibahçe archaeopark area, and to the south by the Sanliurfa Castle and the Balikligöl. Its location within the city center and surrounded by archaeological sites enhances the value of the study area (Tel and Yüksel, 2017). The relief sculpture to be captured in point cloud within the study area is shown in Figure 1.

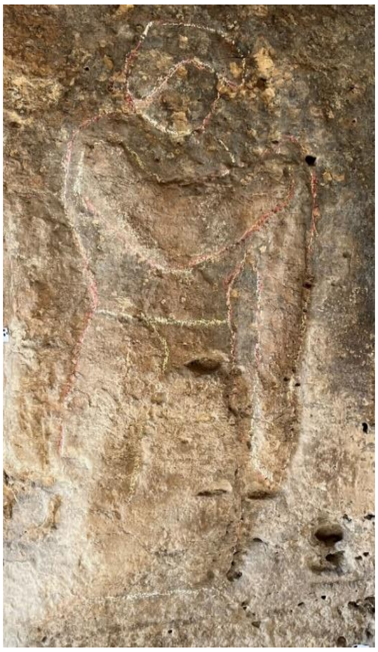


Figure 1. Historical soldier relief

2.2. Equipment

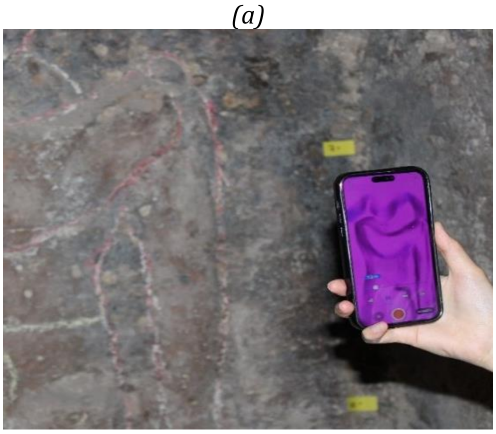
The model production is divided into two stages: fieldwork and office work. The fieldwork stage aims to collect data. For this purpose, photographs of the relief sculpture located north of the rock tomb M16 were taken with a Canon EOS 2000D, as specified in Table 1. Care was taken to ensure that the images were overlapping during the photo shoot. A total of 67 photos were taken with the relevant camera. High-resolution photos from different angles were obtained to capture all the details of the relief. The photos obtained in this stage will constitute the visual data set to be used in the subsequent photogrammetric modeling process. The distance between the markers attached around the relief was measured in meters and recorded.

Table 1. Camera specifications

Camera manufacturer	Canon
Camera model	Canon EOS 200D
F-stop	f/7.1
Exposure time	1/25 sn.
Focal length	18mm

Subsequently, scanning was performed using the iPhone 14 Pro Max mobile device for the point cloud to be created using LIDAR data. The 3D Scanner App application was preferred for scanning. The interface of the LIDAR sensor belonging to the device and the scanning application used is shown in Figure 2.

(a)



(b)

Figure 2. The LIDAR sensor of the used device *(a)*, Interface of the scanning application *(b)*

2.3. Lidar scanning and S*f*M processing

The scanning parameters were set as follows: resolution 5 mm, distance 1.2 m, processing HD. The Lidar scanning process with the iPhone took an average of 15 minutes. During the scan, the phone was held upright to ensure the sensor's front side could see. Care was taken to avoid creating shadow situations. Lidar sensors have a specific working range, so during the scan, it was ensured that the sensor was at a compatible distance with the target relief sculpture. Attention was paid to avoid areas that were not scanned or had too much overlapping scanning. The fieldwork was completed, and the office work phase began. Special software was used to process the photos at this stage.

The software analyzes the photos, identifies common points, and based on this data, reconstructs the three-dimensional structure. The images obtained from the camera were processed using Agisoft Metashape, an independent software that offers significant capabilities for performing photogrammetric processes on digital images. The software utilizes the Structure from Motion (S*f*M) technique to process the photos. Structure from Motion (S*f*M) refers to the process of creating three-dimensional objects from a series of two-dimensional images. S*f*M is used in various applications such as 3D scanning, augmented reality, visual simultaneous localization and mapping (*SLAM*), and mapping (Korumaz et al., 2011; Yilmaz et al., 2008). S*f*M can achieve faster results compared to other methods, model various objects regardless of size, and is suitable for tasks requiring precise measurements due to its use of high-resolution images (Berra and Peppa, 2020). The evaluation and processing of the images resulted in the creation of a point cloud.

3. Results and Discussion

Using 62 photos, a 3D point cloud was generated with S*f*M. The produced dense point cloud and the locations of the photo captures can be seen in Figure 3.

(a)

(b)

Figure 3. Photo capture locations *(a)*, Generated built dense cloud *(b).*

The generated point cloud contains over 2 million colored points.

The generated point cloud contains colored points marked with '80.000' The same relief sculpture was scanned with the iPhone's Lidar Advanced mode. The resulting point cloud is provided in Figure 4.

Figure 4. The point cloud obtained through Lidar scanning

The LiDAR point cloud is sparse than SfM point cloud. It contains over 80-thousand-point cloud.

Both data sets have been scaled using markers. The visual representation of the markers used is shown in Figure 5, and the distances between the markers are provided in Table 2.

Figure 5. The markers on the relief sculpture.

Table 2. Distance between markers

Marker Number	Distance
12-14	95 cm
14-4	190 cm
4-2	106 cm
2-12	189 cm

Both scaled point clouds were registered using markers in the *CloudCompare* software. In CloudCompare, Cloud-to-Cloud Distance module (C2C) was utilized to detect differences between overlapping point clouds after the registration process. In this process, the photogrammetric point cloud was accepted as the reference since it is denser and more comprehensive. The C2C results are provided in Figure 6.

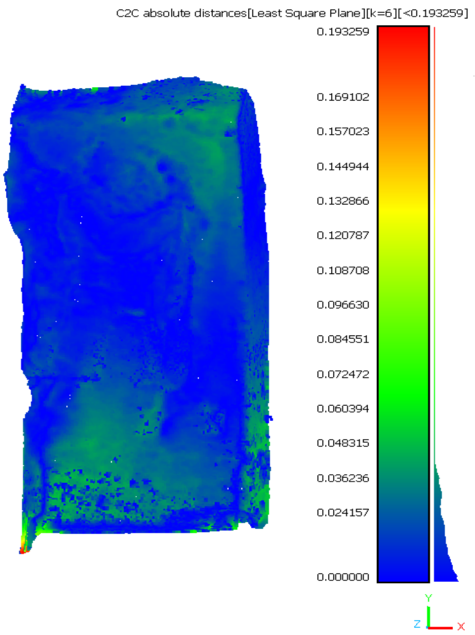


Figure 6. The result of C2C

Upon examination of Figure 6, it is observed that both point clouds overlap significantly. The average difference between the two-point clouds is calculated as 1.5 cm, with the highest difference being 19 cm. The obtained 19 cm difference is not from the relief sculpture but originates from the surrounding wall and floor. In this regard, it can be considered that the overlapping process carried out using markers is successful. Additionally, the point clouds are also usable in terms of the integrity of the object.

4. Conclusion

This study examined the critical endeavor of documenting historical artifacts and cultural heritage, with a specific focus on the utilization of innovative techniques for accurate and reliable data acquisition. The study centered on a cultural heritage site, the Kizilkoyun Necropolis, and employed both photogrammetry and LIDAR techniques for data acquisition. In the photogrammetric process, overlapping high-resolution photos were captured. Simultaneously, LIDAR scanning was performed using the iPhone 14 Pro Max equipped with a LIDAR sensor, making use of a scanning application.

The results revealed successful data acquisition through both methods, with minimal differences in point cloud data. The photogrammetric technique produced a dense point cloud using 62 photos, and the LIDAR scanning generated a point cloud with precise details. The integration of markers in both datasets proved effective in achieving a high level of accuracy and completeness. The comparative analysis showed that the average difference between the two point clouds was only 1.5 cm, with the highest difference being 19 cm, attributed to the surrounding wall and floor rather than the relief sculpture itself. These findings underscore the potential of modern technologies, such as photogrammetry and smartphone-integrated LIDAR, in the documentation and preservation of cultural heritage. They ensure the transfer of knowledge across generations while minimizing the risk of damage to historical artifacts, making it a valuable contribution to the field of cultural heritage documentation.

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