6th Intercontinental Geoinformation Days

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The 3D virtual restitution of historical buildings using photogrammetry: A case study of the Dungeon-Cistern structure in the Ancient City of Dara (Anastasiopolis), Mardin

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Keywords
3D Documentation
Photogrammetry
Restitution
Virtual Restitution
Mardin

Abstract

To accurately document cultural heritage buildings, a preliminary study phase that assesses the building's characteristics is crucial. Historical data is necessary to have a basic understanding of the building's past, so both geometric surface surveys and in-depth historical and archival research should be conducted. In recent years, 3D digitization and geomatics technologies have been applied in the field of cultural heritage, particularly for documentation and preservation purposes. The goal is to document and preserve the significant historical features (form, appearance) of a cultural heritage structure along with relevant data, in case of natural or other damages. In this context, the purpose of the presented paper is to propose the restitution of the Zindan-Sarnıç structure in Dara (Anastasiopolis) ancient city, which is a unique cultural heritage site, through a three-dimensional model created using photogrammetry. The documentation/survey, dating/reconstruction, conservation/restoration, and consolidation interventions, including the three-dimensional model, encompass the identification of problems related to the structure and its immediate surroundings, determining the life process/history and values/potentials from its construction periods to the present, and establishing the fundamental principles and approaches for the conservation and consolidation interventions of the structure.

1. Introduction

Cultural heritage, especially immovable assets such as monuments, archaeological sites, etc., is the primary application area for new approaches. A digital 3D model, produced as part of the documentation process for architectural structures, is now an urgent necessity. The digital 3D model should be transformed into a vital reference framework for conservation experts. This will enable the creation of a suitable data source (graphic and semantic) to assist restoration and reconstruction systems (Penttilä et al., 2007).

In recent years, 3D digitization and geomatic technologies have been applied in the field of cultural heritage, particularly for documentation and preservation purposes. The aim is to document and preserve the significant historical features (such as form and appearance) of a cultural heritage structure using relevant data, in case of natural or other damages (Gomes et al., 2014).

To document cultural heritage buildings accurately, it is crucial to conduct a preliminary study phase where building features are evaluated (Karataş & Dal, 2023). Since having basic information about the building's history is necessary, both geometric surface investigation and in-depth historical and archival research should be conducted (Karataş, 2022a, b, c, d).

The aim of this study is to present a restitution proposal for the Zindan-Cistern structure in the unique cultural heritage site of Dara (Anastasiopolis) ancient city, using a 3D model created through photogrammetry.

1.1. Study area and significance of the structure

Dara (Anastasiopolis), located approximately 30 km southeast of Mardin, is an important ancient border city

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Cite this study

Karataş, L., Dal, M., Alptekin, A., & Yakar, M. (2023). The 3D virtual restitution of historical buildings using photogrammetry: A case study of the Dungeon-Cistern structure in the Ancient City of Dara (Anastasiopolis), Mardin. Intercontinental Geoinformation Days (IGD), 6, 5-8, Baku, Azerbaijan

dating back to the late antique period. It is known as Dara in the local language and has historical significance as a city established during the 6th century, similar to other newly founded cities of that era such as Rusafa and Zenobia in Syria, and Justiniana Prima in Serbia. This city, established in the 6th century, provides valuable tangible evidence of urban planning, different types of structures, and their functions, serving as important documents that convey knowledge about the urban development of that period (Al-Mashhadani, 2017; Celik, 2018; Mardin Governorship, 2013).

Figure 1. The location of Dara Ancient City

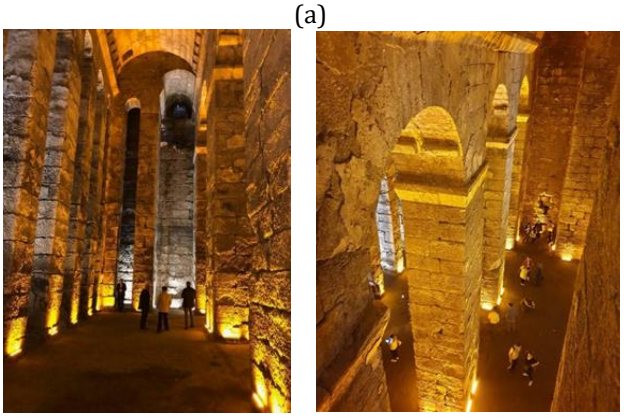
Figure 2. 3D model of the Dara Necropolis Area.

The archaeological remains of Dara, including the city walls, public structures, private residential areas, necropolis, and stone quarries, are among the important features that make Dara city significant (Karataş, 2016). The Zindan-Cistern structure, belonging to the ancient city of Dara/Anastasiopolis, is one of the notable structures in the area (Figure 3).

2. Method

The initial stage of the restitution study involved archival research on the structure. The 3D model generated using various software and programs forms the basis for analysis and examination. The archival research started with the evaluation and interpretation (periodization-contextualization) of the structure's historical, architectural, and lived aspects from its construction period to the present day. It concluded with the interpretation of the area's historical, cultural, and natural values in order to ensure their preservation and continuity, following the principles of scientific conservation. The study provided details on physical/spatial interventions for conservation/restoration and consolidation, in line with the scientific conservation principles.

(a)



(b)

Figure 3. Dara (Anastasiopolis) ancient city Zindan-Cistern structure: (a) Exterior appearance (b) Interior space

In the second stage of the study, the documentation of the original state of the structure revealed through archival research was carried out using a 3D model. For this purpose, the Zindan-Sarnıç structure of Dara/Anastasiopolis ancient city was examined on-site and photographed. During these fieldwork activities, two cameras were used: a Fuji FinePix HS10 model with 30X optical zoom, panoramic shooting feature, and 10.3-megapixel resolution, and an Olympus SP-550UZ model with 18X optical zoom and 7.1-megapixel resolution, both operated with tripod stands. Numerous photographs were taken from different perspectives to thoroughly and comprehensively document all parts of the structure, capturing both general views and detailed components (Figure 4).

Photoscan software was used to merge the photos. A total of 120 photos taken from different angles of the structure were utilized. Initially, the photo data of the structure was introduced to the software. The processing of the images captured with a smartphone was carried

out using PhotoScan Professional software developed by Agisoft LLC, which utilizes the Shape from Motion (SFM) algorithm (Agisoft, 2018). PhotoScan applies the SFM algorithm to generate a 3D model from the images. During the image processing phase with PhotoScan, the uploaded photos were adjusted using the software. A total of 120 high-resolution photo frames were obtained and the previously determined 9 coordinate points, latitude, longitude, and elevation information were entered to align the photos in a coordinated manner. In this phase of photo correction, PhotoScan calculated the camera positions and orientations for each image, resulting in the production of orthophotos. As a result of all these processes, a 3D model and orthophoto of the Dara church-underground structure were generated. The restitution descriptions were defined based on these 3D documents.

The Table 1 summarizes the methodology followed step by step.

3. Results

Within the scope of the study and the proposed restitution for the structure, a detailed archival research and photogrammetric-based 3D modeling approach were followed. The findings regarding the restitution of the obtained structure in the study are explained below:

The Dungeon-Cistern structure of the ancient city of Dara (Anastasiopolis) is located approximately 100 meters northwest of Agora Street. It is a large cistern with well-cut stone walls, and its original entrance is on the eastern facade. Despite the fact that the connected structures and adjacent spaces are still underground and a house has been built on top of the structure at a later date, the structure still retains its grandeur. Above the two-story structure, the city's cathedral (great church) is located, of which only one wall remains standing today in the western part. According to the historian Procopius, there are two significant churches in Dara. One of them is the 'Great Church,' and the other is the Bartholomew Church. According to the historian Theodorus Lector, Saint Bartholomew appeared in the dream of Anastasius and asked for the protection of the city. In response to this, Anastasius had Bartholomew's bones brought from Cyprus to Dara. Until the 14th century, there was a Syriac metropolitanate in Dara (Gabriel, 1940; Abdulgani Efendi, 1999).

According to Honatio Southgate, there are ten cisterns located next to the hill where the Muslim settlement is situated. Each cistern is approximately 150 steps long, 75 steps deep, and 15 or 20 steps wide. Currently, three out of these ten cisterns have disappeared, while the remaining seven, although not actively used by the villagers, still defy time. These cisterns were constructed by excavating the bedrock and then completing the upper parts with small stones. The bedrock was hollowed out from top to bottom, allowing water collected from the mountains to reach and be stored in these cisterns without waste. According to some historians, Dara was the city where the first dam and irrigation channels were established in Mesopotamia. The water cisterns comprised a system that could control the flow, proportion, and retention of water. In the ancient city of Dara, outside the city walls, another cistern, dating back to the 6th century and known as the "zindan" among the locals, was identified. The interior of the cistern, which had its upper covering collapsed, was filled with 18 meters of soil. Through excavation, the soil filling inside the cistern, which was used as a stable, was emptied, and its vaulted upper covering was restored using its original stones without the use of any new stones (Gabriel, 1940; Abdulgani Efendi, 1999; Akyüz, 1988). The interior of the structure is a symmetrical rectangle approximately 23x16 meters in size, extending in the east-west direction. Its height is approximately 15 meters (Figure 4).

Table 1. Workflow

	Step	Description
1	**Archival Research**	Historical documents, old photographs, drawings, and written sources related to the structure were examined. These archival materials provided information about the original design and details of the structure, forming the basis for the restitution study.
2	**Photo Analysis**	The 120 photographs used in the restitution process were thoroughly analyzed using a detailed photo analysis method. The details, angles, perspectives, and different sections of the structure depicted in the photographs were carefully evaluated.
3	**Photo Processing and 3D Modeling**	The processing of the photographs and the generation of a 3D model were carried out using the Photoscan software. The photographs were analyzed using the SFM algorithm to create a 3D model. In this stage, the coordination of the photographs, calculation of camera positions and orientations, and production of orthophotos were ensured.
4	**Restitution Study**	A restitution study was conducted using the obtained 3D model and other archival information. Missing or damaged parts of the structure were reconstructed or restored according to the original design and details. The restitution process was based on the information obtained from archival research and examinations conducted on the structure.
5	**Restitution Proposal**	As a result of the restitution study, a detailed 3D model of the structure has been obtained. The work carried out during the restitution process has been documented, and the methodology of restitution has been explained. These findings can be utilized in restoration projects with the aim of preserving the original details, design, and historical features of the structure.

(a) (b)

Figure 4. a) A professional digital camera, Fuji FinePix HS10 model, with 30X optical zoom, panoramic shooting feature, and a resolution of 10.3 megapixels.
b) A semi-professional digital camera, Olympus SP-550UZ model, with 18X optical zoom and a resolution of 7.1 megapixels.

4. Discussion and Conclusion

The restitution study conducted within the scope of this project aims to recreate the original appearance of the structure and provide a foundation for restoration efforts, using a detailed approach that includes archival research and photogrammetric-based 3D modeling processes. In this article, the Dungeon-Cistern structure in the ancient city of Dara (Anastasiopolis) is examined as a case study. Due to the continuous need for restoration and maintenance works, as well as its complexity, size, and unique features, the Dara Dungeon-Cistern structure presents a significant example of challenges and issues, making it a suitable case study to apply the proposed methodology. However, the methodology applied can also be applied to other similar historical buildings.

According to the findings of the study, the Dara Dungeon-Cistern structure is dated back to the 6th century and has survived to the present day. Currently, the main issues are related to structural integrity and material deterioration. Regarding the former, these mainly arise from the high loads on the columns within the immense volume of the structure and the weight of the stones, which result in significant protrusions on the side walls and compression of the elements below. As for material deterioration on the exterior facades, it is caused by the presence of limestone, which is highly sensitive to atmospheric agents and tends to undergo layer separation and fragmentation. In future studies, integrated visualized damage assessment techniques are seen as key elements to identify material damages, aiming to preserve the structure and transmit it to future generations.

Acknowledgement

We extend our gratitude to the local community for their assistance during the data collection phase of this study at Dara Ancient City.

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