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Assessment of structural degradation at Germus Church: A UAV-based study

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Abstract

Turkiye, with its rich history, has witnessed the rise and fall of many civilizations over the centuries. The preservation and documentation of historical artifacts and archaeological sites left behind by these civilizations are vital for the transmission of cultural heritage to future generations. In this regard, the application of photogrammetry has emerged as a promising method for modeling cultural heritage, and it has gained significant popularity in recent years, especially with the advancements in unmanned aerial vehicles (UAVs). In a recent study, researchers conducted the UAV-based photogrammetric reconstruction of the Germus Church, a historical structure believed to have been constructed in the 19th century. This innovative approach combines the use of UAVs and photogrammetry techniques to create accurate and detailed 3D models of the church. By capturing high-resolution aerial photographs from different angles, the researchers were able to reconstruct the entire structure digitally, capturing its intricate architectural details. The utilization of UAVs in photogrammetry not only allows for efficient data collection but also offers a non-intrusive method for surveying cultural heritage sites. This technology enables researchers and conservationists to document and study historical structures with precision, aiding in their preservation and restoration efforts. The study on the Germus Church serves as an example of how modern techniques can contribute to the safeguarding and understanding of Turkey's diverse cultural heritage. By employing UAV-based photogrammetry, researchers are able to create virtual representations of historical sites, ensuring that the knowledge and beauty of these structures are preserved for generations to come.

1. Introduction

It is possible, and indeed necessary, to transmit historical artifacts that encompass all stages of history and provide us with every clue related to history to future generations through a robust documentation process. Documentation of historical or cultural structures encompasses determining the current state of the structure (shape and position) in three-dimensional space, creating its map, conducting studies, processes, storage, and presentation steps necessary for all possible analyses (Kaya et al., 2019).

Until recent times, terrestrial observation systems have been widely used in the documentation of cultural heritage. However, in last decades, satellite technologies with higher spatial resolution have provided new opportunities for modeling efforts worldwide. With advancements in aviation and remote sensing technologies, photogrammetry and Unmanned Aerial Vehicle (UAV) systems have also started to be utilized more effectively in the field of modeling. (Toprak et al., 2019)

The photogrammetric applications conducted using photographs captured by a camera integrated into an unmanned aerial vehicle (UAV) are referred to as UAV photogrammetry (Ulvi, 2018). UAV photogrammetry, which we frequently encounter in the literature, has emerged in the field of 3D modeling of cultural heritage, thanks to its advantages in terms of time, cost, and data collection (Ulvi, 2021; Polat et al., 2020)

With the production of unmanned aerial vehicles in various shapes, sizes, and features, it is observed that 3D modeling has also advanced, making it easier to detect the current state and deformations of structures. (Uysal et al., 2015). In this study, the advantages of UAV photogrammetry were utilized to create a 3D model of the Germus Church, which is a cultural heritage site.

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2. Method

The production of the model consists of two stages: fieldwork and office work.

During the fieldwork stage, data acquisition takes place. This involves capturing aerial photographs or images of the Germus Church using the unmanned aerial vehicle (UAV) equipped with a camera. The UAV is flown over the site, and high-resolution images are taken from different angles and positions. The purpose of this stage is to collect visual data that will be used for the subsequent modeling process (Uslu et al. 2016).

In this study, the DJI Mavic 2 Pro, a UAV system from the DJI brand, was used to generate a 3D model of the historical church. The DJI Mavic 2 Pro is a successful system with features such as an effective range of 8 km, a maximum flight time of 31 minutes, 4K recording with a Hasselblad camera, a 1" CMOS sensor, GPS sensor, 4-way obstacle sensing, automatic return to home, and a weight of approximately 1 kg (Akca and Polat, 2022). The UAV used in the study is depicted in Figure 1.

Figure 1. DJI Mavic 2 Pro UAV system used in the study

For the photo capture in the flight plan, a 80% overlap in the flight direction and a 60% overlap in the cross direction were set. The flight progressed for 20 minutes, and a total of 239 photos were taken. After the flight, aerial photographs of the area were obtained. Blurry photos taken during takeoff and landing were excluded from the dataset due to weather conditions. Once the fieldwork is completed, the collected images are transferred to the office for processing. This is where the office work stage begins. In this stage, specialized software is used to process the images and create a 3D model. The software analyzes the images, identifies common points and features, and reconstructs the three-dimensional structure of the Germuş Church based on these data points. The acquired images from the unmanned aerial vehicle were processed using Agisoft Photoscan, an independent software that offers significant capabilities for performing photogrammetric operations on digital images. A point cloud and a 3D model were created based on the evaluation of the images.

3. Study area

The selected study area, Germuş Church, is located in the Dagetegi near at the foothills of Germus Mountain, which is situated 10 kilometers northeast of the city center of Sanliurfa. The historical church is positioned at coordinates 37°12'06.0" latitude and 38°51'04.2" longitude and is located 5 kilometers away from Göbekli Tepe, which is known as the "zero point" of history. The location information for the study area is depicted in Figure 2.

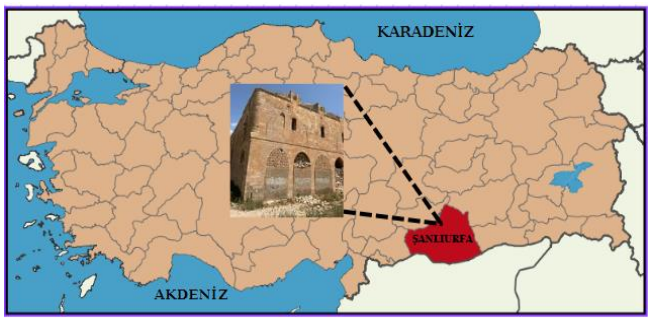

Figure 2. The study area

4. Discussion

In this study, UAV-based 3D modeling of the historical heritage site known as Germuş Church, located in the Haliliye district of Sanliurfa province, has been successfully accomplished. The use of UAVs was employed to contribute to the surface investigation prior to the planned restoration of the historical church and to produce topographic products that could serve as a basis for the restoration works. The findings and processes involved in the production of the 3D model reveal that the UAV-based capture, which is overlapping, precise, and highly accurate, plays a significant role in generating the point cloud. The generated dense point cloud contains 7,800,413 points. The obtained point cloud is presented in Figure 3.

Figure 3. The generated point cloud

When evaluating the Agisoft software used for image processing, it can be observed that photos with regular overlap rates are processed accurately, resulting in a 3D model that closely resembles reality (Yakar et al. 2016). However, it is noted that as the number of added photos increases for the purpose of achieving greater accuracy, the processing time of the model also increases. Therefore, it is important to aim for an optimal balance between image input parameters and processing time (Atik and Duran, 2022).

When evaluating the generated 3D model and the fieldwork, it is clearly visible that the domes of the historical church have collapsed and the side facades have suffered damage. The deformed parts of the historical church are indicated on the 3D model in Figure 4 and Figure 5.

During the fieldwork, it was observed that both the interior and exterior of the church had been explored and excavated by individuals searching for artifacts. This

situation demonstrates the suitability of using unmanned aerial vehicles in the documentation of historical sites that are dangerous to enter and explore. Furthermore, the obtained 3D model can serve as a reference for comparing the current state of the church with any future deformations it may undergo. The damaged interior of the Germus Church is depicted in Figure 6. The final version of the 3D model of Germus Church is depicted in Figure 7.

Figure 4. The deformed parts of the historical church

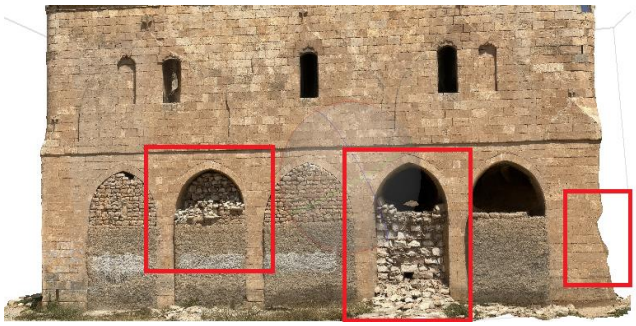

Figure 5. The deformed parts of the historical church

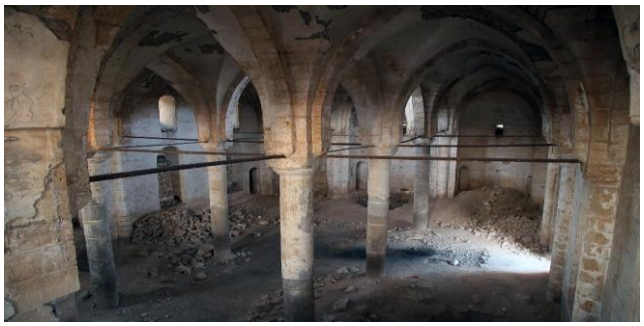

Figure 6. Interior view of Germus Church

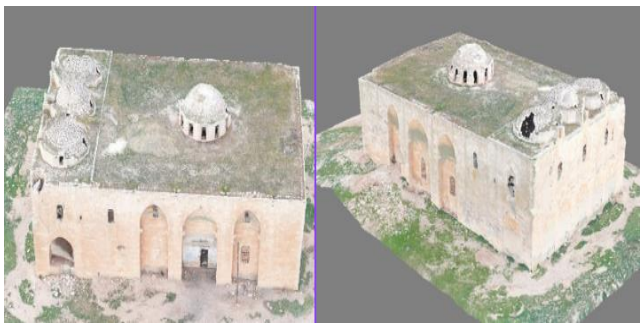

Figure 7. The 3D model of Germus Church

5. Conclusion

The modeling of Germus Church holds great importance in terms of preserving cultural heritage and passing it on to future generations. As seen in the obtained 3D model, both the interior and exterior of Germus Church have suffered various deformations due to damage and the passage of time. There are cracks on the walls, and collapses can be observed in the ceiling and dome areas. Additionally, the religious figures, mosaics, and other decorations inside the church have been damaged or lost over time. To ensure the preservation of this endangered structure and to recognize its value, efforts should be made to restore it and promote it for tourism.The three-dimensional modeling of Germus Church using UAV technology has documented the deformations of this cultural heritage and contributed to its restoration efforts, thus facilitating its introduction to tourism.

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