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Stone material damage detection in restoration using Virtual Reality: The case of Virgin Mary Church and Patriarchate in Midyat, Türkiye

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Abstract

With the advancements in technology, various methods are being used for documenting cultural heritage. However, three-dimensional (3D) documentation techniques have some drawbacks. For instance, terrestrial laser scanning techniques are not widely used due to their high costs and the expertise required. Photogrammetry can generate point clouds at a lower cost but involves managing large data files, which require additional time. In this context, the aim of this study is to present a method that integrates photogrammetry and virtual reality technologies to examine a stone building in three dimensions in a cost-effective and timely manner, and to investigate stone material deterioration on the obtained 3D model. The virtual 3D environment of the structure can be created using the proposed method from global panoramic photographs on various open-source platforms at a reasonable cost and within a short period. The results of the study demonstrate that stone material deterioration can be easily identified in these environments consisting of a three-dimensional virtual tour of the structure.

1. Introduction

Using 360-degree panoramic images to conduct virtual reconstruction and damage assessment in historical buildings is an important method for digitally recreating buildings and identifying potential damages. Scientific studies highlighting the significance of virtual reality-based damage assessment in historical buildings and the benefits of the techniques used in this field indicate significant progress in the processes of identifying structural damage, planning restoration, and making conservation decisions. These techniques have provided important advancements in the assessment of structural damage, restoration planning, and decision-making for the preservation of historical buildings. Zhang et al. (2020) conducted research on how 3D laser scanning and virtual reconstruction can be used in the damage assessment of historical buildings, and it was determined that significant benefits were achieved in damage assessment. Gül & Özşahin (2019) emphasized the importance of virtual reality applications in the damage assessment of historical structures and highlighted the usability of virtual reality technology in areas such as structural analysis, restoration processes, and conservation decision-making. Ioannidis & Soile (2019) emphasized the benefits of virtual reality technologies, particularly in the preservation of cultural heritage, in areas such as damage assessment of historical buildings, restoration processes, and visitor experiences. Costa et al. (2017) examined how virtual reality technology can be used in the preservation of historical buildings through a case study, highlighting that augmented reality technology is an effective tool in areas such as damage detection, restoration processes, and visitor interaction.

The stage of restoration and restitution proposal is the most important step carried out before applying interventions to a structure. Building upon the positive findings obtained in previous literature studies, this paper presents a case study of the Virgin Mary Church and Patriarchate. Within this scope, the identification of stone material issues will be discussed through virtual reconstruction of the building. Located in the urban conservation area of Mardin, the Virgin Mary Church and Patriarchate are historical monuments with distinct

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characteristics influenced by factors such as topography, materials, climate, and surrounding cultural elements. In this study, a virtual simulation was created from 360-degree panoramic photographs of the historical monument, which is of great necessity for the sustainable preservation of cultural heritage, and stone material deteriorations were attempted to be identified through this virtual reconstruction.

1.1. The history and significance of the structure

The Virgin Mary Church and Patriarchate are located in the district of Midyat, which is part of the Mardin province in Türkiye. Midyat is situated in a region surrounded by the fertile lands of Mesopotamia and has a significant historical background. The district is renowned for its rich cultural heritage and historical structures (Abdulgani Efendi, 1999).

The Virgin Mary Church is one of the most important religious structures in Midyat. It has a history that dates back to the 4th century and belongs to the Syriac Orthodox Church. The church is believed to have been built on a site where the tomb of Mor Şleymun (Saint Simon), one of the apostles of Antioch, is located. The architecture of the Virgin Mary Church bears resemblance to traditional Syriac churches in the Middle East, and it serves as a significant religious and touristic attraction in the region (Alioğlu, 2000).

The Midyat Patriarchate is the central location of the Syriac Orthodox Church. This building was relocated from the Deyrulzafaran Monastery in Mardin to Midyat in 1994. The Midyat Patriarchate serves as the residence of the Syriac Orthodox Patriarch, who is the religious leader of the Syriac Orthodox Church. The Patriarchate building is a beautiful example of Syriac church architecture and holds significant importance as a tourist attraction for visitors to the region (Altun, 2011; Ahunbay, 2005) (Figure 1).

Figure 1. Images of the Virgin Mary Church and Patriarchate

2. Method

Steps for Virtual Reconstruction and Damage Assessment in Historical Buildings Using 360-Degree Panoramic Imaging:

2.1. Capturing panoramic images

To capture 360-degree panoramic images that encompass the entire surroundings of the historical building, special equipment such as dedicated 360-degree cameras, cameras with a 360-degree shooting mode, or smartphones with 360-degree capabilities can be used. It is important to carefully capture the shots to obtain high-resolution and sharp images. Sufficient photographs should be taken to capture all the details, both indoors and outdoors of the building (Karataş, 2022a; b; c). In this study, the selected structures were visited, and panoramic images of the buildings were captured using a panoramic imaging device (NCTech iris360º Model) (Figure 2) for the creation of three-dimensional virtual environments (Figure 3).

Figure 2. The NCTech iris360º Model is a panoramic imaging device used for capturing 360-degree panoramic images. (TMMOB Jeoloji Mühendisleri Odası ,2023).

Figure 3. 360-degree panoramic images of the Virgin Mary Church and Patriarchate taken by the NCTech iris360º

2.2. Image stitching and virtual reconstruction

360-degree panoramic images are stitched together using specialized software or online platforms. In this step, the captured photographs are merged to create a complete 360-degree image. The image stitching process involves analyzing the overlapping points of the photos to ensure perspective alignment and create a seamless panoramic view (Karataş, 2022).

In recent years, with the advancement of technology and the widespread availability of open-source software, it has become possible to generate virtual models from 360-degree panoramic photographs for the 3D examination of historical structures. Even on open-source platforms, various studies have been conducted in this regard. Examples of open-source software and platforms include Matterport (https://matterport.com/), Kuula (https://kuula.co/), Roundme (https://www.roundme.com/), 3DVista (https://www.3dvista.com/), and Mozilla Hubs (https://hubs.mozilla.com). These platforms can be used to upload, edit, and create virtual tours using 360-degree photographs.

Within the scope of the study, the obtained panoramic images were transformed into navigable 3D environments within structures by leveraging the capabilities provided by various open-source virtual reality platforms. These platforms offer the ability to convert panoramic images into 3D environments, allowing users to navigate within the structures.

Within the scope of the study, a 3D virtual environment was created based on the 360-degree panoramic photographs of the building, and the damages occurring in the structure were identified. The virtual environment of Virgin Mary Church and Patriarchate was generated using the Mozilla Hubs program from the 360-degree panoramic photos. The details of the building can be perceived clearly in the virtual environment, allowing users to navigate and zoom in or out using avatars to view detailed information about materials and material deterioration. The virtual tour images conducted through avatars for damage assessment in the virtual environment are presented as shown in the figures (Figure 4).

2.3. Damage assessment

The created virtual model and tour were utilized to detect material damages in Virgin Mary Church and Patriarchate structure. Through analyses conducted on the virtual model, cracks, wear and tear, structural issues, or other signs of damage could be identified. Additionally, comparing the virtual model with historical records or photographs will aid in determining changes that have occurred over time in its current condition.

3. Results

According to the findings, the facade walls of Virgin Mary Church and Patriarchate structure have experienced surface loss, voids, and color changes due to the damaging effects of moisture and sunlight on the stone material. Surface loss and color changes are the most common problems observed in monuments located in Mardin (Karataş, 2016; Karataş et al., 2022d, e, f, g, h; Karataş et al., 2023a, b, c, d, e).

Based on these results, it can be concluded that the material issues identified in Virgin Mary Church and Patriarchate located in Midyat, a district of Mardin, are similar to historical structures in Mardin. Improper material repairs are partially present due to the failure to use original materials resulting from the deterioration of the original material. Plant growth and moss formation have been detected in the flat courtyard. Wear and tear are observed on the stairs. Cracks, deformations, wear, and color changes are found in the frames and wings of the wooden windows. Wear is observed on the thresholds. No material deterioration has been detected in the arches. Decorative elements on the building facade show loss of form and surface contamination.

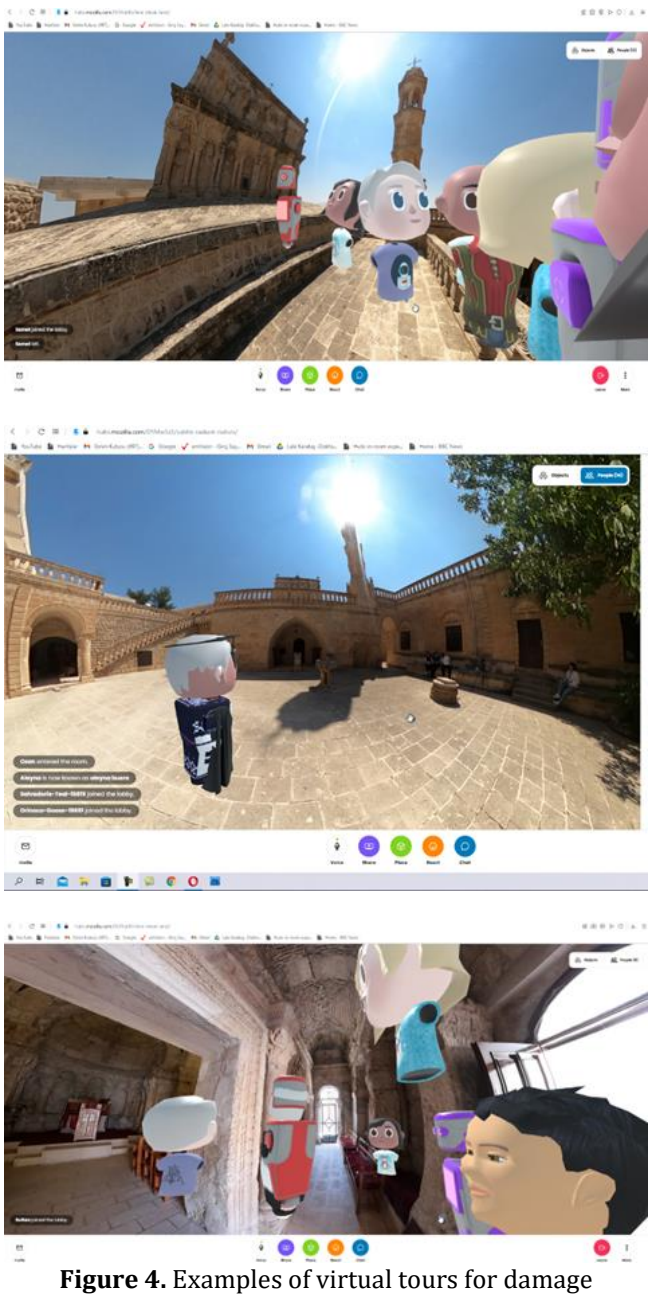

Figure 4. Examples of virtual tours for damage assessment

4. Conclusion

The study presents a method that integrates photogrammetry and virtual reality technologies to obtain a virtual tour containing a 3D model of a stone building in a cost-effective manner and within a short timeframe. The detectability of stone material deterioration was investigated within the obtained 3D virtual environment. As a result of this study, it was concluded that the proposed method enables the creation of a virtual 3D environment of the structure from global panoramic photographs in a cost-effective and efficient manner. It was also found that stone material deterioration within the structure can be easily identified using avatars in this virtual environment.

In future studies, it is recommended to use the systematic approach followed in our research to create virtual environments of historical structures from different countries and share them on open platforms such as Sketchfab (https://sketchfab.com) on the web. This would allow for the creation of an open-source library on stone material deterioration and provide individuals from anywhere in the world with the opportunity to freely view, explore, and examine all documented historical buildings in this environment.

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