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3D modeling of historically significant columns

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Abstract

The Anatolian region has been home to countless civilizations throughout known history. As can be imagined, this region is also home to various buildings that differ in size and type. There are many essential cities where these structures were built. However, many of the artifacts in these cities have been destroyed due to natural or unnatural causes. Various analyzes can be made by modeling and digitizing the parts of the buildings. Especially the 3D models of the parts of the buildings in the digital environment can provide information about the rest of the building and the urban structure of the city where it is located. In this study, the stunning part of a building was modeled in 3D using the photogrammetric modeling technique. It is thought that this study will be helpful in terms of guiding future studies.

1. Introduction

Anatolia, also formerly known as Asia Minor, has been home to numerous civilizations throughout history, and each has secured its position in history by leaving corresponding traces on this land. This region's fertile lands have witnessed the rise and collapse of many empires, including the Romans, Byzantium, Seljuks, and Ottomans. Due to their geopolitical significance, the cities, which are located in a first-degree seismic zone, have been affected by both natural disasters, such as earthquakes and wildfires, and manufactured disasters. Due to these damages, most of the structures and artifacts from these ancient civilizations have not survived to the present day. Those who have made it to the present day are protected through restoration. Most of Amasya's extant structures date back to the Seljuk and Ottoman empires. Religious and civil architectural structures, such as bridges, inns, hammams, mosques, madrasas, mansions, and clock towers, remain from these eras. Preserving these historical structures for future generations is of the utmost importance. Even though factors such as war do not exist in the region, the city is still susceptible to earthquakes. Similarly, to other types of structures in the region, earthquakes pose the highest threat to such structures. Therefore, it is essential to identify historical and valuable structures susceptible to these factors and take the necessary precautions.

The photogrammetry technique, an excellent alternative to traditional methods in documenting cultural heritage, can take photographs of the object and create a 3D model with the help of specific mathematical models. Ulvi et al. (2019) conducted a study on modeling historical fountains using close-range photogrammetry. Yakar and Dogan (2018) examined the use of the SfM method in different fields of study and reported consistent results in archaeological areas. Nowadays, due to the relatively cheap and portable nature of digital handheld cameras, terrestrial photogrammetry is frequently used in archaeological areas (Ulvi et al., 2019). Digital handheld cameras used in terrestrial photogrammetry can be calibrated before and during the mission and store the necessary information for 3D modeling. In this way, 3D models can be obtained with calibrated cameras. Using motion-based structural sensing (SfM), a 3D model of the object can be created using superimposed photographs. Nowadays, with the development of photogrammetry and computer vision disciplines, image-based modeling techniques have become a serious competitor to laser scanning

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(Remondino et al., 2011). Some crucial advantages of image-based modeling are its low cost and include color information, calibrated or uncalibrated cameras are acceptable (Colomina et a., 2008), and it can produce a denser point cloud than a laser scanner. This is where the SfM approach, different from classical photogrammetry, is widely used (Polat et al., 2020). SfM works under the same primary conditions as Photogrammetry. Overlapping images are used to obtain the 3D structure of the object of interest. Much commercial software, such as Agisoft Photoscan, is also widely used for 3D modeling. In general, photo matching allows the production of many products, such as sparse and dense point clouds, three-dimensional models, digital elevation models, and orthophotos. Image processing steps can take considerable time. For this reason, it is recommended to use exceptionally high-performance computers to produce a full-performance 3D model (Siebert & Teizer, 2014). In this study, a column fragment of a historical building was 3D documented using photogrammetric techniques.

2. Method

Using stereo vision principles, photogrammetry as a mapping technique attempts to convert two-dimensional images into three-dimensional coordinates (Alptekin and Yakar, 2021). While such concepts were initially implemented empirically, as with analog photogrammetry, mathematical relations were quickly devised to facilitate an analytical approach to the 3D reconstruction problem. The collinearity and coplanarity conditions were crucial in establishing a relationship between 2D and 3D space (Alptekin & Yakar, 2020). Photogrammetry has focused on the issue of precision for the majority of its history and continues to do so today. This is consistent with photogrammetry's original remote sensing mapping instrument purpose. The prevalence of Structure-from-Motion as a solution to image pose estimation (Karataş et al., 2022a) demonstrates that significant advances were made almost simultaneously in computer vision. This advancement, along with other advancements in imaging sensors and computational technologies, facilitated the unprecedented automation of the traditional photogrammetric workflow, albeit occasionally at the expense of stringent quality control (Kuşak et al., 2021; Ünel et al., 2020). Image matching algorithms reduce the need for manual measurements, such as the conventional six Von Grüber points (Yılmaz & Yakar, 2006).

Bundle adjustment refers to the simultaneous computation of image exterior orientation parameters (also known as extrinsic parameters in computer vision (Karataş et a., 2022b) and point coordinates in the 3D space. It evolved from previous solutions for the problem of aero triangulation, i.e., the densification of ground controls (Yılmaz & Yakar, 2006) in analytical photogrammetry. Typically, it requires a nonlinear optimization calculation based on collinearity or coplanarity equations. This simultaneous "block" modification of the entire system offers a rigorous solution to the exterior orientation issue (Kanun et al., 2021a). In a process known as self or auto-calibration (Kanun et al., 2021b), the bundle adjustment may also comprise the resolution of the camera's internal parameters. In addition, modern bundle adjustment solutions may employ attenuation techniques (e.g., the Levenberg–Marquardt algorithm) to aid the classical Gauss–Newton least-squares method in achieving final convergence (Karataş et al., 2022c). This is the case, for instance, with the Agisoft Metashape software utilized in this investigation.

The invention of dense image matching was an additional significant advance in photogrammetry. Patch-based Multi-View Stereo (PMVS) and Semi-Global Matching (Yakar et al., 2015) may be two of the most significant advances. Dense image matching is a crucial development for photogrammetry, as it generates dense point clouds comparable to those produced by lidar. This enables photogrammetry to compete with lidar systems, although, in practice, they are frequently complementary, particularly for large-scale applications. There are numerous commercial and open-source photogrammetric solutions available on the market today. A traditional photogrammetric workflow begins with image acquisition. Certain principles must be followed to ensure excellent photogrammetric results, such as sufficient image overlap, image network configuration, and photographic quality. Before proceeding with dense image matching in order to generate dense point clouds, image orientation with bundle adjustment is typically conducted. However, these point clouds represent the object in question primarily from a geometric standpoint.

2.1. Material and Method

In the study, a mobile phone camera was used for photogrammetric photography. The sfM algorithm and photogrammetry technique were used to produce 3D models. 3D models were produced in Agisoft Metashape software.

The technical specifications of the phone camera used are given in Table 1.

Table 1. Samsung M31 technique specification

Parameters	Value
Focal Lenght	35 mm
Aperture	F 2.0
Camera Resolution	32 MP

The representation of the photogrammetric picture attraction centers of the object is given in Figure 1.

Photogrammetry is a method in which a 3-dimensional geometric model is created through photographs, allowing us to measure these models. The photogrammetry technique is frequently used when measuring environments. The principle we take as a basis in the photogrammetry technique is to pay attention to the photographs of a point taken from at least two different angles. This technique is used in many areas, including indoors and outdoors. It should be said that the photogrammetry technique has a wide application area. In many fields, such as architecture and engineering, 3D measurements can be made with the photogrammetry technique and photorealistic models of spaces and objects with this method. Photogrammetry, which has become an important technique, especially in the measurement of open areas, is a technique that is valid for many different sectors. The best use of this technique is the most critical factor in increasing the accuracy of the measurements. Agisoft Metashape produces reliable solutions with years of experience in photogrammetry. Agisoft Metashape, which performs photorealistic, coordinated 3D model analysis using photogrammetry and high-resolution photographs, is among the software experts in its field. It is a method in which we produce photorealistic 3D models by photographing the structure or object to be modeled. We can throw these models into virtual and augmented reality environments.

As a result of the photogrammetry study, the 3D point cloud data of the object is obtained. A 3-dimensional point set where you can examine all the details of the object is given in Figure 2. The 3D model of the object is given in Figure 3.

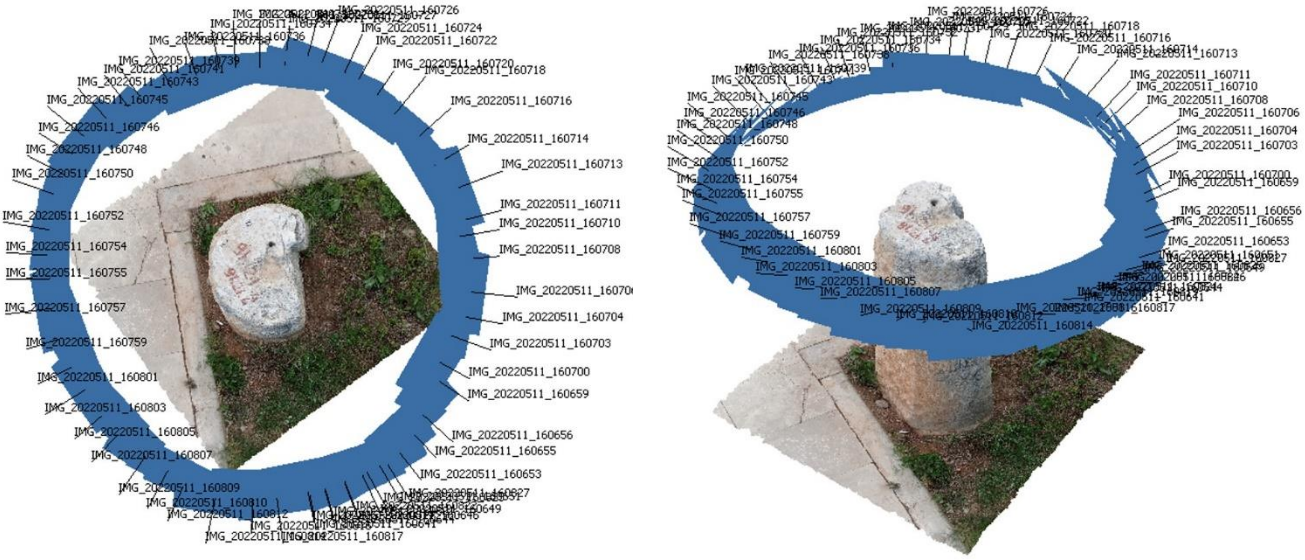

Figure 1. Photogrammetric photography method and camera positions based on the SfM algorithm

Figure 2. Point Cloud of object

Figure 3. 3D model of the object. Top left Solid model, Top suitable wireframe model, bottom 3D model (different angle).

3. Discussion and Conclusion

In order to transfer cultural heritages to future generations, they need to be protected from natural and artificial dangers, but these dangers cannot be avoided altogether. For this reason, it is necessary to document not only the external and internal structure of the cultural heritage but also the entire historical texture, including the broken parts, for the repair and reconstruction of the damaged structures. This study has tried to document a column fragment broken off from a historical artifact using digital photogrammetry tools. In the study, the point cloud and 3D model of the column piece were produced by photogrammetric methods. The modeling process was done by taking terrestrial photographs. As a result of the study, more than 5 million points were produced by terrestrial photogrammetry. Documentation of archaeological artifacts is essential because of their reaching future generations and the restoration work that can be done on them. Documented archaeological artifacts will also shed light on future generations.

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