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Terrestrial photogrammetry and handheld laser scanning technique in 3D modeling of small objects

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Abstract
Cultural heritage works are an important tool in shedding light on a society's past to the future and keeping its social values alive at all times. Cultural heritage; We can examine it in three different ways: concrete, intangible and natural heritage. Nowadays, there are many methods and techniques used in 3D modeling of cultural heritage works. In recent years, laser scanning and photogrammetric techniques have been used in 3D modeling of objects of all sizes. In this study, two objects of different sizes were modeled using photogrammetric and hand-held laser scanning methods and the resulting models were examined. 3D models of the objects were created using two different methods, and the lengths of the same places were compared on the resulting models. While the measurements were obtained, the places to be measured were clearly observed in the measurement values obtained from the photogrammetric method, and values close to the measurement value obtained with the electronic caliper were obtained. Since the point cloud density was not sufficient in the measurements obtained by hand-held laser scanning, the image locations obtained from it could not be selected exactly and approximate measurement values could only be taken. Of the two methods, handheld laser scanning was not affected by ambient lighting and the scanning process was completed faster. Handheld laser scanning is not an applicable technique for small-sized objects because it does not create a sufficiently dense point cloud. It has been concluded that the photogrammetry technique is a suitable technique for 3D modeling of small-sized cultural heritage artifacts and that the resulting models can be used safely in studies.

1. Introduction

Cultural heritage works are an important tool for a society to shed light from the past to the future and to keep its social values alive at all times. Cultural heritage; We can examine it in three different ways: tangible, intangible and natural heritage (Ulvi et al., 2019; Döş & Yiğit, 2023). These works are damaged and lose their properties due to reasons such as physical factors, environmental conditions and natural disasters (Cömert et al., 2012; Tercan, 2017; Döş & Yiğit, 2023). For this reason, it is very important to protect, document and record cultural heritage artifacts.

Today, there are many methods and techniques used in 3D modeling of cultural heritage artifacts (Kanun et al. 2022). In recent years, laser scanning and photogrammetric techniques have been used in 3D modeling of objects of all sizes. Common and non-invasive methods have been used in modeling objects from large historical buildings to small sculptures and much smaller objects (Viswanatha et al., 2011). In recent years, photogrammetry has been used for the reconstruction of objects and in architecture. This method can also be applied in areas where it is desired to obtain the spatial shape of an existing object outside of these areas. Laser scanning and point cloud technologies, which are data acquisition methods in documenting cultural heritage, have become quite common.

The photogrammetric method has made significant progress in 3D modeling in terms of obtaining images with lower cost than other methods and with technological developments (Prosdocimi et al., 2017; Karataş et al. 2022a). Photographs of the object to be modeled were taken superimposed from different camera angles and a scaled and coordinated point cloud

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and 3D model were created (Kaya et al., 2021; Döş & Yiğit, 2023).

The most important disadvantage of the photogrammetric method is its dependence on an experienced camera operator who can manage the camera parameters and obtain photographs accurately. If the images are not acquired correctly, they will be affected by errors caused by vibration in the 3D model formation (Rodríguez-Martín & Rodríguez-Gonzálvez 2020). If photo capture is not automatic, there will be more user error. Automating image acquisition will eliminate errors caused by the camera operator. The models created with images obtained from automatic systems will be more consistent in terms of accuracy.

Terrestrial laser scanning is a polar measurement system that directly creates 3D object points (Karataş et al. 2022b). Many existing terrestrial laser scanning systems provide color information, but are lacking in modeling small objects due to their minimum acquisition distance and limited distance sensitivity. Thanks to the developed handheld laser scanners, it has become possible to model small objects with laser scanner systems. Handheld laser scanning is a non-contact active measurement technique, just like terrestrial laser scanning. It is used in medical orthoses and prostheses, quality control, and robotic vision technologies in the film production industry. In addition to these areas, it is used to model hollow and very small objects that cannot be scanned with terrestrial laser scanning in cultural heritage documentation studies.

In his master's thesis study, Alvarez (2021) aimed to design a cost-effective photogrammetric 3D Imaging system for small archaeological artifacts. This system aims to produce high-quality 3D artwork with highly detailed textures and color information that is optimized for depth of field and serves many important purposes. The designed system creates higher quality 3D images than other cost-effective solutions. Compared to costly systems, the designed system produced 3D images of comparable quality.

In his undergraduate thesis, Prokop (2022) studied the creation of a 3D model of the Chapel of Our Lady in Brno-Líšeň using images taken from a digital camera Canon EOS 6D Mark II and a low-cost camera Xiaomi Mi 10T Pro. Mobile phone images were combined in two photogrammetric software (Bentley ContextCapture and Agisoft Metashape Professional). The accuracy of the models was analyzed using measured control points and a reference point cloud obtained from a laser scan of the chapel.

In this study, two objects of different sizes were modeled using photogrammetric and hand-held laser scanning methods and the resulting models were examined.

2. Method

In this study, a house figurine with a regular geometric structure (Figure 1a), from which measurements can be easily taken, and a vase object with an irregular geometric structure (Figure 1b), from which measurements cannot be taken (Figure 1b), were modeled using photogrammetric and hand-held laser scanning methods, and the resulting models were examined.

Figure 1a. House figurine **1b.** Vase

In the photogrammetric method, a rotating platform was designed and image acquisition was achieved automatically. The rotating platform was created in software and design. The rotating platform is ready by connecting the camera connections and power adapter. In the photogrammetric method, lighting is important for modeling. Parts with high details, lighting and the image texture of the object affect the number and angle of taking photographs (Arican et al., 2023).

In this study, lighting was provided by a photo shooting tent with a white background and 2*78 LED lights. The camera was positioned appropriately to the object with the help of a tripod (Figure 2).

Figure 2. Location of camera and photo shooting tent

Based on the size and density of the object, the focus waiting time, the number of photos taken, the photo shooting angle, and the number of photos to be taken for each movement were determined from the rotating platform hand unit and the shooting started. In this study, the number of photos taken is 20, focus waiting time; 2 seconds for the household figurine and 3 seconds for the vase object, the photo shooting angle was determined as 20 degrees and the number of photos taken was determined as 1 for each movement. Shooting started under the conditions specified for both objects and was completed without any problems.

The images were transferred to the Context Capture program and a local coordinate system was created with the help of control points on the rotating platform base. Camera positions are formed correctly for both objects. The photogrammetric process was completed with the point cloud and modeling process.

The same objects were used in the handheld laser scanning process, and the objects were placed on a table that the operator could easily turn around.

FARO Freestyle3D was used as the scanner. It is ready with the help of a tablet connected to the scanner in one hand and the printer in the other. Depending on the size of the objects, the distance to the object was determined by making a few attempts. Scanning started by pressing the button on the scanner and the scanning process was completed by making a full tour around the object. The process was repeated for the second object. Scanning data was transferred to the tablet and from there transferred to the special software Scene.

A measurement was taken from both objects with the help of an electronic caliper (Figure 5).

Figure 5. Measurements of objects with electronic caliper

Measurements of the same places were also taken from models obtained by photogrammetric method and models obtained with a hand-held laser scanner.

Lengths obtained by photogrammetric method.

Figure 6. Length measurement obtained from the vase object by photogrammetric method

Figure 7. Length measurement of the house figurine obtained by photogrammetric method

Lengths obtained by handheld laser scanning.

Figure 8. Length measurement obtained from the vase object by hand-held laser scanning method

Figure 9. Length measurement of the house figurine obtained by hand-held laser scanning method

3D models of the objects were created using two different methods, and the lengths of the same places were compared on the resulting models.

When the resulting models were considered, it was observed that the density of point finds in the models obtained by the photogrammetric method was denser than the models obtained by the hand-held laser scanning method. The photogrammetric method gave better results in displaying texture details and colors. Automation of the image acquisition process in the photogrammetric system has increased the accuracy of the obtained model and the sensitivity of the measurement value taken.

While the measurements were being obtained, the places to be measured were clearly observed in the measurement values obtained from the photogrammetric method, and values close to the measurement value obtained with the electronic caliper were obtained. Since the point cloud density was not sufficient in the measurements obtained by hand-held laser scanning, the image locations obtained from it could not be selected exactly and approximate measurement values could only be taken. Of the two methods, handheld laser scanning was not affected by ambient lighting and the scanning process was completed faster.

3. Results

In this study, models were created using the photogrammetric method and hand-held laser scanning method, which are measurement techniques used in modeling small objects in the cultural heritage, and the resulting models were evaluated.

The advantages and disadvantages of the techniques used in the obtained models were discussed and the methods were compared with each other. Handheld laser scanning is not an applicable technique for small-sized objects because it does not create a sufficiently dense point cloud. It has been concluded that the photogrammetry technique is a suitable technique for 3D modeling of small-sized cultural heritage artifacts and that the resulting models can be used safely in studies.

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