Comparison of documentation cultural artifacts using the 3D model in different software

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ABSTRACT

The creation and drawing of a three-dimensional (3D) model of historical and cultural buildings have become an important issue. Especially in terms of protecting these historical buildings and transferring future generations, their importance is gradually increasing. Close-range photogrammetry is a method used for many years. With the development of computer and information technology, the classical close-range photogrammetry method has been replaced by the digital close-range photogrammetry method. Digital photogrammetry methods are easier to perform with a computer than conventional methods. By close-range photogrammetry method; it can offer many products such as orthophoto, 3D model, drawing, digital surface, and terrain. In this study, photogrammetric research was carried out for documentation purposes in Cimcime Hatun Tomb in Erzurum. In the study, the hybrid method was applied by taking photos from the unmanned aerial vehicles (UAV) and ground. The 3D model study was carried out in 3 different software (Agisoft PhotoScan, Context Capture, Photomodeler UAS). At the end of the study, the advantages and disadvantages of this software have been discussed. As a result of the study, the position accuracy (X, Y, Z) of Agisoft Photoscan, Context Capture, and Photomodeler UAS software was calculated as 2.17, 2.73, 1.73 cm.

1. INTRODUCTION

Cultural heritages not only ensure the continuity of the experiences and traditions that people have accumulated throughout history but also ensure the correct planning of the future. In addition, societies, they see their cultural heritage as defining elements of their national identity. The protection of such important monuments is regarded as equivalent to the protection of national identities. In fact, societies have embarked on scientific research activities on the origin of these elements to embrace these values as their cultural heritage. Because it enables us to increase the studies in this field and thus to reveal those who are forgotten from these values. In this context, the importance of preserving and documenting cultural heritage works has been the subject of research by different disciplines.

One of the important steps to protect historical artifacts is to make the documentation accurate and precise. Modern and technological documentation methods: It is preferred more in terms of time and cost

than traditional methods in determining deformations, measuring and drawing historical buildings, and preparing restoration projects. With the effective use of technology in this area, new perspectives have been introduced to the documentation methods. Especially in digital platforms, the use of 3D model documentation methods has increased. Different methods are used for documentation with the 3D model. Among these methods, especially the contactless data collection strategy with the photogrammetry method come to the fore.

Photogrammetry is used effectively in the documentation of cultural heritage to produce 3D models of historical buildings and artifacts (Uslu and Uysal, 2017; Uslu et. al, 2016; Zeybek and Kaya, 2020).

Yakar et al. (2018) investigated the photogrammetric method and the usability of GIS to document cultural heritage. In the study, the 3D model of a cultural structure was obtained from the images obtained by close-range photogrammetry.

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Ulvi and Toprak (2016) in their work, have touched upon the use of very different techniques in cultural heritage documentation. They mentioned that one of these methods is the close-range photogrammetry technique. They created a 3D model using this technique. At the end of the study, they documented the historical artifact on the digital platform. They mentioned that this model can be used as a base for restoration work that can be done later. They suggested that numerical data can be used by creating a tourism information system in order to introduce the artifact in terms of tourism.

Şasi and Yakar (2017) used the close-range photogrammetry technique in their documentation study. They mentioned that close-range photogrammetry was insufficient in some works within the scope of this study. They pointed out that the roofs of the buildings are missing especially in the photographs taken from the ground and that the 3D model cannot be created with exactly the required precision. They mentioned the importance of using unmanned aerial vehicles (UAVs) in eliminating this shortcoming.

The same problem was encountered in this study as stated in the documentation studies made with the close-range photogrammetry method. That's why in the study, photographs were taken both from the unmanned aerial vehicle (UAV) and from the ground. The use of UAV in documenting cultural heritage in this way is gaining importance day by day. Especially UAVs, it facilitated photographing and documenting the inaccessible parts of the structures. With the use of UAVs in different studies effectively, the definition of UAV photogrammetry has emerged in the literature.

In 3D documentation studies using the photogrammetry technique, point position accuracy is usually investigated through a single software. In this study, the point position accuracy of different software has been investigated (Ulvi et al., 2019; Yakar et al., 2016). Also, the 3D model study was carried out in 3 different software (Agisoft PhotoScan, Context Capture, Photomodeler UAS). At the end of the study, the advantages and disadvantages of this software have been discussed.

2. MATERIAL and METHOD

The study was carried out in 2 stages: A field study and office work.

In fieldwork, image data is collected, and precise measurements were made. The images were collected from two different way, aerial, and ground.

Images taken from the ground were taken with the Nikon D3100 camera shown in Figure 1. The technical specifications of the camera are given in Table 1.

Figure 1. Nikon D3100 camera

Table 1. Nikon D3100 camera specification (URL-1)

Specification	Value
Megapixels	14.20 MP
Sensor	23.1 x 15.4 mm
Sensor resolution	4616 x 3077
Sensor size	23.1 x 15.4 mm
Surface area	355.7 mm² mm
Pixel pitch & Pixel area	5 μm & 25 μm

Aerial images were taken with the Phantom 3 Pro UAV shown in Figure 2. The technical features of Phantom 3 Pro UAV are shown in Table 2.

Figure 2. Phantom 3 Pro UAV (URL-2)

Table 2. Phantom Pro 3 specification (URL-2)

Specification	Value
Weight & Diagonal Size	1280 g & 350 mm
Max Ascent & Descent Speed	5 m/s & 3 m/s
Max Speed	16 m/s (ATTI mode)
Max Tilt Angle	35°
Max Flight Time	Approx. 23 minutes
Satellite Positioning Systems	GPS/GLONASS
Sensor & Lens	1/2.3" & 20mm

In the study, the photogrammetry was used as a method.

Photogrammetry generally deals with the mathematical representation of the geometrical relations between physical objects in three-dimensional space based on their images recorded on a two-dimensional space. Over the years, photogrammetry has been used routinely in aerial photogrammetry, cartography, documentation, and remote sensing (Wolf, 1974; Ulvi, 2008).

In photogrammetry, images obtained by numerically recording electromagnetic rays reflected from objects are evaluated. It can be described as the technique of obtaining information about objects without direct contact with objects (Grussenmeyer et al., 2008; McCarthy, 2014).

The images contain all the data about the object. From these data, photogrammetric evaluation can be conducted at any time. For this reason, these images were used to document important works. Photogrammetry, which is used as a method of processing these data, is frequently preferred.

In this study, 3 different photogrammetry software (Agisoft PhotoScan, Context Capture, Photomodeler UAS) is used to obtain a 3D model from 2D images and the position accuracy of the points was calculated according to equation 1,2 and 3.

$$SXO = \sqrt{\frac{VxVx}{n-1}} \tag{1}$$

$$SYO = \sqrt{\frac{VyVy}{n-1}} \tag{2}$$

$$SZO = \sqrt{\frac{VzVz}{n-1}} \tag{3}$$

3. APPLICATION

3.1. Study Area
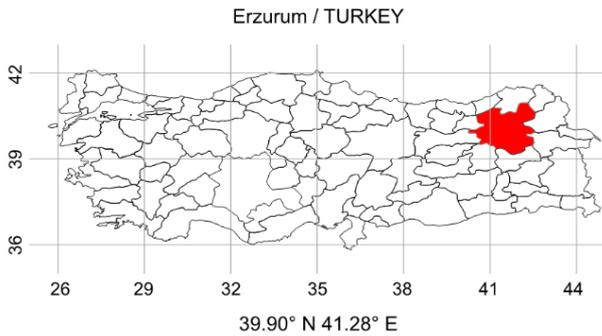
Figure 3. Erzurum location

The tomb known as Cimcime Sultan Tomb has located the Erzurum city of Turkey (Figure 3). The tomb was built in the 14th century (URL-3). The grave is in the shape of a cylinder with a conical roof. Twelve blind arches, consisting of a continuous pattern, decorate the edges of the tomb (Figure 4). The tomb is located at the latitude of 39.906257 ° N and the longitude of 41.276784 ° E.

Figure 4. General view of the tomb

3.2. Creation the 3D Model

Images were taken in different angles and distances to cover the entire object. When taking images, care was taken to the angle of arrival of the sun. Also, no contact was made to avoid damaging the object. 25 of the Tomb's specific points were measured by using Total station. 13 of them were used for orientation. 12 of them were used as checkpoints (CHP).

After the field work was completed, the 3D model was created various in the photogrammetric software. 3 different software were compared with 12 control points. 3 different software were compared with 12 CHPs. In the study, 25 UAV images and 38 ground images were used.

3.2.1. Agisoft PhotoScan Software

This software was chosen because it is the most used software in the literature. The software offers low cost and it is simple to use. It is also preferred because it contains SfM algorithms (Ulvi et al., 2020).

Camera calibration was done automatically in Agisoft software.

In the 3D model, firstly the process of "tie" and "orientation" the images with each other was executed (Align process) (Figure 5). After the "tie point" was produced, a "dense point cloud" was created (Figure 6). Last, the "mesh" and the "3D model" was produced (Figure 7).

Figure 5. Tie point (49,468) in Agisoft PhotoScan
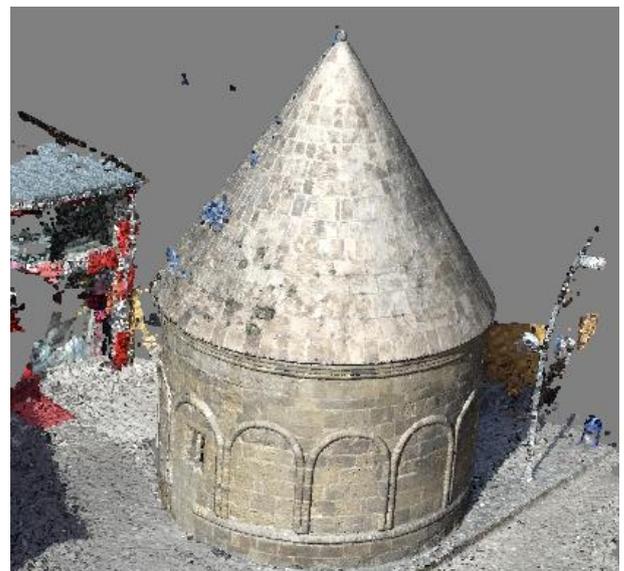
Figure 6. Dense cloud point in Agisoft PhotoScan (13,247,333)
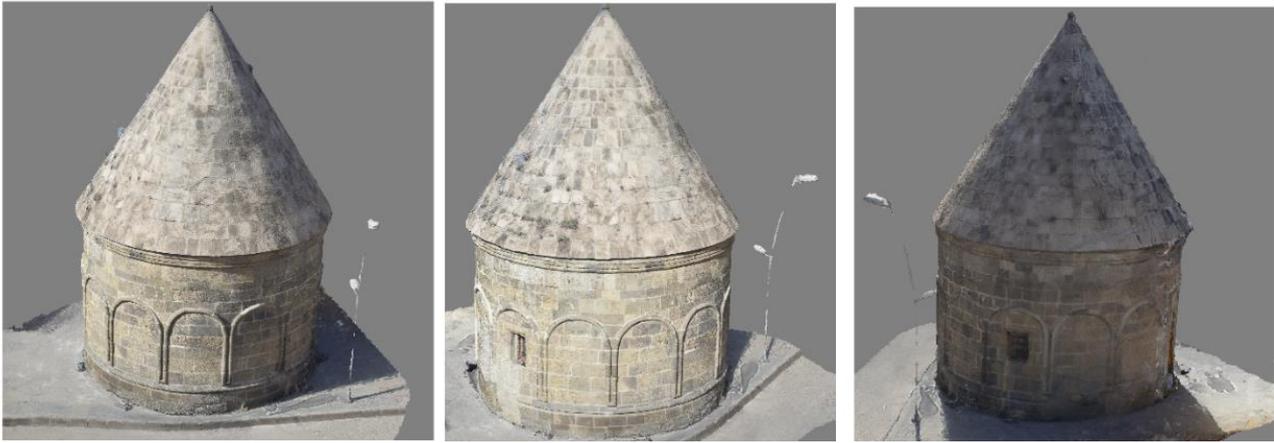
Figure 7. 3D model in Agisoft PhotScan

3.2.2. Context Capture Software

This software has been preferred because it is used less in the literature. It is more expensive than other software. But it is simple to use. Agisoft software needs to create a dense point cloud for the 3D model. Context Capture does not need a dense point cloud to create 3D models it is optional. Firstly, the tie point is created from the images and oriented (Aerotriangulation).

The created tie point is shown in figure 8. The dense cloud and 3D model are shown in Figures 9 and 10, respectively.
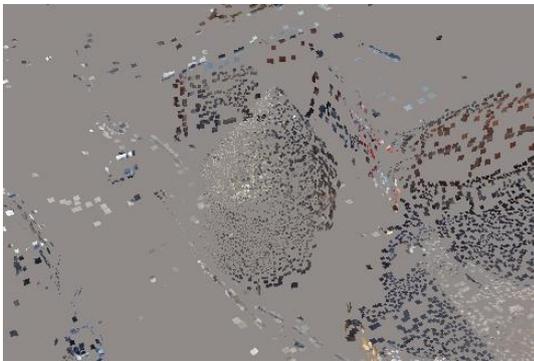
Figure 8. Tie point in Context Capture (20,919)
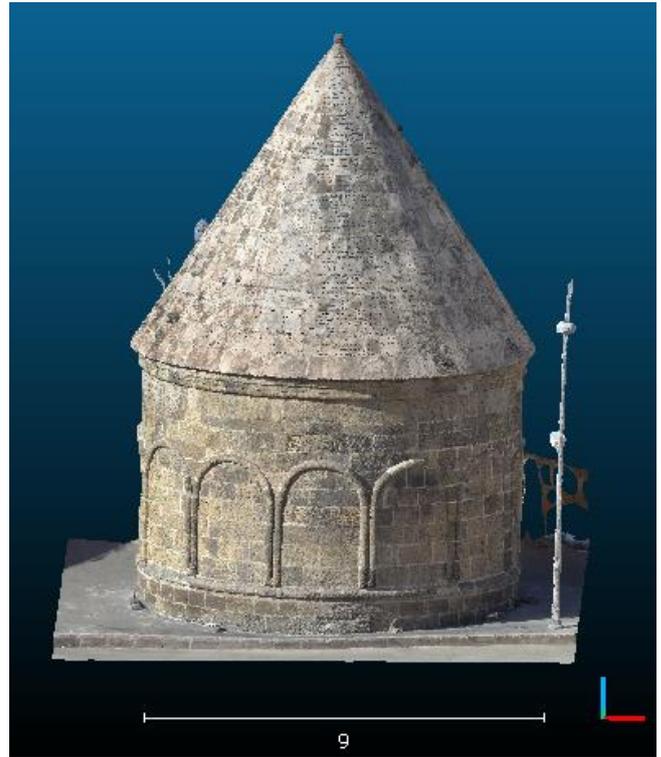
Figure 9. Dense cloud point Context Capture (173,407,269)

Figure 10. 3D model in Context Capture

3.2.3. Photomodeler UAS Software

This software is preferred because it has the feature of drawing. Due to this feature, it provides additional advantage compared to other 3D model software. It is difficult to use compared to other software.

Camera calibration is performed first in Photomodeler UAS software.

Accurate calibration parameters increase the accuracy of the orientate process. Orientation is more impeccable thanks to the beams coming from different angles and distances. For this purpose, the calibration process was performed in the study.

The template shown in Figure 11 was used for calibration.
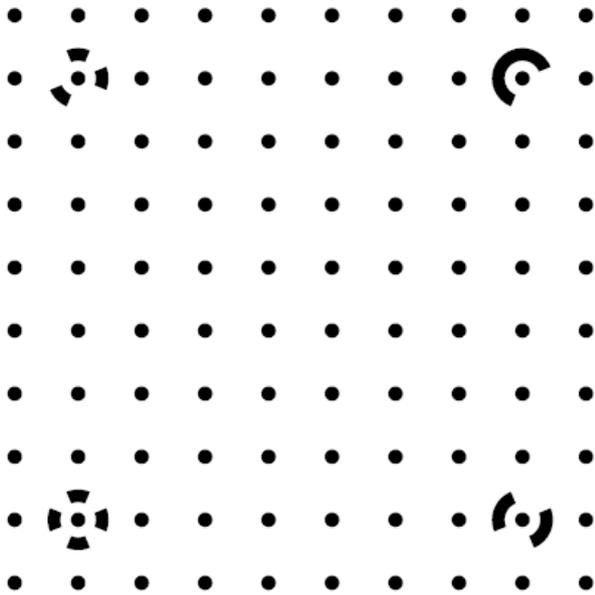
Figure 11. Calibration Paper

Figure 12 shows the calibration process performed in the software.
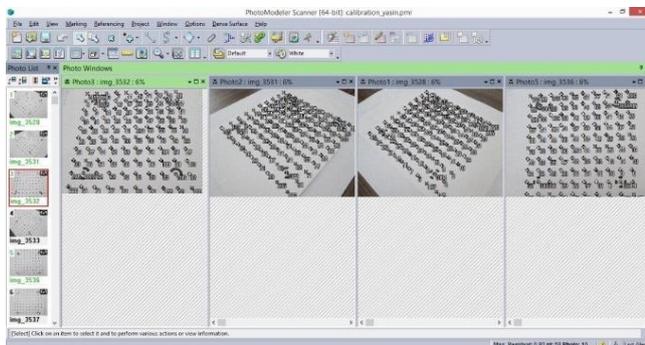
F**igure 12**. Create the calibration parameters

After the calibration process was completed, orientation was performed (Figure 13).
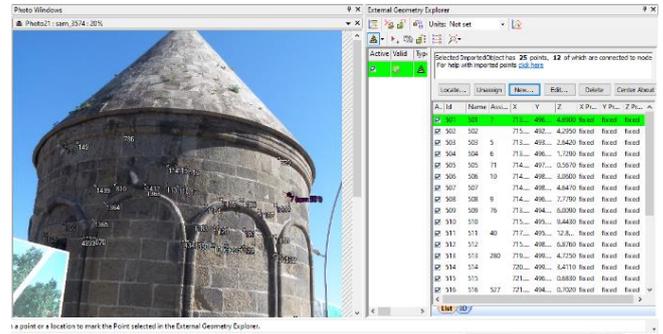
F**igure 13**. Oriented process

Drawings were made after the orientation process (Figure 14).
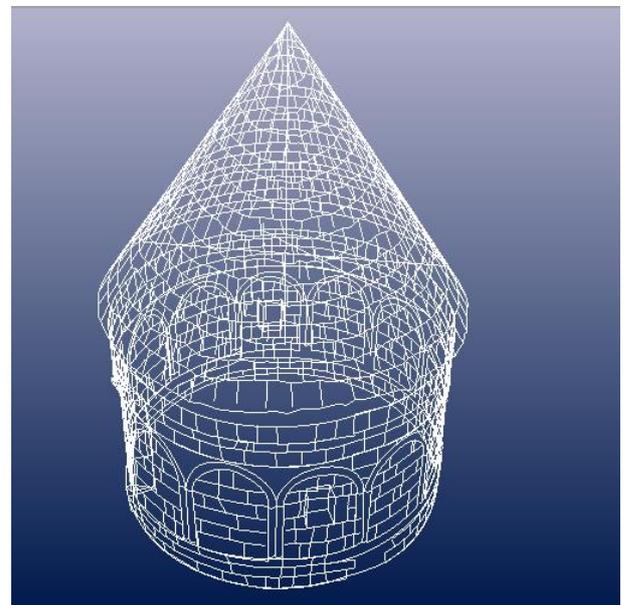
F**igure 14**. Drawing process and 3D model

During the drawing process, 1112 lines and 220 curve lines were used.

After drawing, the surface was created, and the 3D model was obtained.

After drawing, the surface was created, and the 3D model was obtained. The surfaces are covered by specifying the lines drawn in the Photomodeler UAS software. The lines covered with the surface are passed through the actual texture with appropriate images (Figure 15). At the end of the study, CHPs were compared in all 3 software (Table 3).

Figure 15. 3D model in Photomodeler UAS

Table 3. Comparison of CHPs

N.N.	Survey Coordinates			Agisoft Photoscan			Context Capture			Photomodeler		
	X (m)	Y (m)	Z (m)	Vx(cm)	Vy(cm)	Vz(cm)	Vx(cm)	Vy(cm)	Vz(cm)	Vx(cm)	Vy(cm)	Vz(cm)
501	496.137	713.669	4.690	1.6	0.9	-2.0	2.2	1.5	-0.6	0.4	0.7	-1.0
502	492.403	715.039	4.295	0.6	1.2	-2.4	1.2	2.0	-1.4	0.6	0.4	-0.8
503	496.028	713.628	1.729	-1.6	0.7	1.3	-1.8	1.7	1.7	-1.4	0.8	0.5
504	498.15	714.534	3.060	-1.1	-2.0	0.9	-1.8	-1.5	1.5	-0.9	-1.1	1.2
505	498.261	714.598	4.647	0.7	-0.6	-1.7	1.3	-1.2	-1.5	0.9	-0.9	-0.8
506	494.845	713.438	6.009	0.7	-1.4	1.4	1.4	-1.8	1.8	0.2	-1.0	1.5
507	499.476	719.23	4.725	0.3	1.1	1.8	-0.8	2.0	1.6	-1.2	1.1	1.8
508	495.591	717.788	8.861	-0.8	0.8	-1.0	-1.7	1.4	-1.8	-2.9	1.0	-1.2
509	496.027	721.901	0.683	1.4	-1.2	-1.4	2.0	-1.7	-1.6	0.4	-0.5	-1.3
510	495.439	721.896	3.669	0.2	-1.1	0.7	2.0	-1.5	1.9	-0.3	-1.2	0.9
511	493.04	721.275	4.122	0.9	1.6	-1.3	1.7	1.4	-0.4	1.0	-0.8	0.7
512	495.968	721.998	6.517	1.5	-0.8	0.8	1.3	-1.7	0.4	0.5	-0.1	0.1
				mxyz= 2.17			mxyz= 2.73			mxyz= 1.79		

4. CONCLUSIONS and DISCUSSION

All software used in the study (Agisoft PhotoScan, Context Capture, Photomodeler UAS) are frequently used in documentation studies with photogrammetric techniques. Agisoft PhotoScan software is the most preferred software. Because it has easy usage. Although Context Capture software is easy to use, it is not preferred frequently. Because it is expensive. Photomodeler UAS software is difficult to use. But it is preferred because of its drawing ability. The general assessment of the software is shown in table 4.

Table 4. The general assessment of the software

Software	Calibration	Orientation	Point Cloud	Mesh	Draw	3D Model	Usage	Price
Agisoft PhotoScan	Semi automatic Automatic	Easy	Required Medium (13,247,333)	Good	Yes (Weak)	Easy Good	Easy	Cheap
Context Capture	Automatic	Average	Optional Dense (173,407,269)	Best	No	Easy Good	Easy	Expensive
Photomodeler UAS	Manuel Semi automatic Automatic	Hard	Optional (Not Produced)	Medium	Yes (Strong)	Hard Medium	Hard	Cheap

When table 4 is examined, there are advantages and disadvantages to all software.

Calibration: Calibration is the first step of the photogrammetric process. Calibration is executed automatically in Context Capture software. In the Agisoft PhotoScan software, calibration is done semi-and fully automatically. In other words, parameters can be entered both by the operator and created by the software. In Photomodeler UAS software, the calibration process can be defined manually, unlike other software. These parameters can be determined using a calibration paper. This provides convenience to the operator, especially in the orientation process.

Orientation: Orientation is the process of determining the position and orientation of two images in three-dimensional space. In Agisoft PhotoScan

software, the images are aligned before orientation. Aligned images are completed in a fully automated using the Sfm (structure from motion) method. Manual tie points can be used if needed. Although the process is carried out fully automatically in Context Capture software, since it uses "aerotriangulation" as the basic algorithm, it is not as optimum as the Sfm method. In the situation, there is a problem in orientation the images taken from different distances. Although the process can be executed automatically in Photomodeler UAS software, the expected result cannot be acquired. So, it is more suitable to manually match the images one by one. This situation causes both a take long time and the difficulty of the process.

Point Cloud: Creating the dense point cloud in Photomodeler software is optional. This stage has not been done since the Photomodeler UAS software could not produce the expected accuracy from the point cloud. Creating the dense point cloud in Context Capture software is optional. Generally, in Context Capture software, the 3D model is produced without generating a point cloud. This is because the point cloud produced in the software is very dense. This causes the computer central processing unit (CPU) to run slowly. It is required to generate a point cloud in order to produce a 3D model in Agisoft PhotoScan software. The process takes place fully automatically. It produces sparse point clouds according to Context Capture software.

Draw: In Agisoft PhotoScan software, drawing is used only for determining straight lines. The drawing of complex lines is not at the expected level. In the Photomodeler software, complex lines can be drawn. At least two different images are required to draw a line. To increase the accuracy of the drawn line, the number of images should be increased. Every line drawn must be reorientated. This situation causes the process to be both difficult and takes a long time.

Mesh and 3D Model: The quality of mesh in Photomodeler UAS software depends on the accuracy of the lines drawn. Mesh cannot be created because some lines cannot be drawn. This results in a low-quality Mesh and 3D model. Mesh quality in Agisoft PhotoScan software depends on the point cloud. The denser point cloud is produced, the better-quality Mesh and 3D model is produced. Structures with complex and many recess-ledges are difficult to model. Context Capture software uses a very dense matching method. Therefore, the mesh and 3D models produced are of high quality. When the figures 7 and 10 are examined, the difference between the lighting post and the curves can be observed.

Usage: In Agisoft PhotoScan and Context Capture software, only CHPs are marked manually. It is easy to usage as all the other processes are fully automated. In Photomodeler UAS software, most of the process is done manually by the operator. Especially the orientation and drawing processes are difficult and take a long time. Many problems are encountered because it depends on the operator. So, it is difficult to usage.

In summary, every software has its advantages and disadvantages. It is necessary to choose the appropriate software according to the project. Therefore, good research about the software is required before starting to work.

5. RESULT

The photogrammetry method by different disciplines is frequently preferred in documentation studies. In the photogrammetry method, the images of all facades of the work cannot be taken completely. In 3D documentation of the cultural heritage, images that will see all the facades of the work are needed. All the facades of the work should be photographed to meet this need. The images of the facades which are not visible in the images taken from the ground must be taken in different locations. Especially the images of the upper facades should be taken from the air. It can be easily realized with the UAV carrier platforms that have been used for this purpose recently for the aerial images.

Images taken from both different locations were processed in photogrammetric software and a 3D model was created. In this study three different software is used for the 3D model. They are basically based on the same working principle. Some processes followed by software make a difference.

The Agisoft Photoscan software used in the study consists of 4 main processes. These are "align", "dense cloud", "mesh", and "texture", respectively. The Context Capture software used in the study consists of 2 main processes. These are "aerotriangulation", and "mesh", respectively. If desired "dense cloud" can be created in Context Capture software. The Photomodeler UAS software used in the study consists of 4 main processes. These are "calibration", "orientation", "draw", and "texture" respectively.

Tie point and dense cloud are creating in both Agisoft PhotoScan and Context Capture software. When these products are compared, for tie point: in Agisoft PhotoScan software created 49 468 and in Context Capture software created 20 919. For the dense cloud: in Agisoft PhotoScan software created 13 247 333 and in Context Capture software created 173 407 269.

When all processes of photogrammetry were examined, it took approximately 120, 100, 300 minutes respectively in Agisoft Photoscan, Context Capture, and Photomodeler UAS software.

When the orientation result was examined, the position accuracy (X, Y, Z) 2.17, 2.73, 1.73 cm were calculated in Agisoft Photoscan, Context Capture, and Photomodeler UAS software, respectively.

At the end of the study, the 3D model and documentation of the historical Tomb were made on the digital platform. In the study, both close-range and UAV photogrammetry methods were applied as hybrid methods. The integration of the photos collected by both methods has been successfully completed. As a result, these two methods are complementary methods rather than alternative methods. Both UAV and close-range photogrammetry should be used to document complex structures with the photogrammetry method. Appropriate software should be selected according to the project. The point position accuracy of 3 different software used in the study is close to each other. All three-software used in the study can be used in 3D documentation studies.

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