# Unmanned Aerial Vehicle Data Documentation of Cultural Heritage Availability: 1001 Church

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**ABSTRACT**

Photogrammetry technique is a method used for documentation of historical artifacts with measurements of archaeology for many years. Cultural heritage are common spiritual values of past and future generations. Documentation and preservation of historical monuments without damaging the natural texture are essential elements for their transfer to future generations. Cultural heritage documentation, using photogrammetric methods with the help of UAVs, increased possibilities for taking photos and therefore allows the work to be more comprehensive, reliable and realistic. This work was modeled using three different software with data from 1001 church UAVs reflecting medieval Byzantine art over Karabağ, which was considered a sacred center in the northern province of Karaman and also during the Hittites, and is thought to have been used as a Diocesan Center in ancient times. On 3D models produced using photogrammetric techniques with UAV, $m_{xy}=\pm3.01$ cm in Agisoft Photoscan Professional software, $m_z=\pm3.68$ cm in height error, $m_{xy}=\pm2.26$ cm in Pix4D mapper Pro software, $m_z=\pm1.15$ cm in height error and $m_{xy}=\pm11.18$ cm in Visual SFM-Meshlab software, $m_z=\pm8.11$ cm in height error. it was seen to be. Agisoft Photoscan Professional and Pix4D mapper Pro have concluded that location and height errors are acceptable in terms of Large Scale Map and Map Information Production Regulation.

## 1. INTRODUCTION

When it comes to cultural heritage, man-made works (paintings, sculptures), historical buildings and archaeological sites come to mind. However, the expression of cultural heritage is not limited to this; that is, it is thought to include photographs, books, documents and manuscripts. Cultural heritage is not limited to be expressed only by the concrete objects we see. There are also abstract elements that contribute to the formation of these heritages; traditions that passed from generation to generation in a society, practices and ceremonies in society. All societies contribute to world culture. For this reason, it is very important to protect all cultural heritage with laws and international agreements. Photogrammetric methods can be easily applied in cultural heritage documentation; it is seen that it is a suitable method to avoid the destruction of time, cost and historical artifacts, and that it will shed light on

this subject if it is thought that, in the following periods, relief, restitution and restoration works are considered (Uysal et al., 2013).

The techniques that are considered to be applied in the documentation of cultural heritage are based on more than one parameter; They can be classified as required precision, accuracy and time factor, object accessibility, method permits, and procurement of measuring instruments for required work (Çelik et al., 2020).

Since it uses the latest technology, it is important to use the photogrammetric method more actively in order to understand the importance of our cultural heritage and to pass it on to the generations, since it can obtain data in any format, archive it in the given digital media, and reach the result quickly with minimum error (Yakar et al., 2005).

Unmanned Aerial Vehicle (UAV); It is a kind of aircraft that does not have a pilot and passenger,

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carries a suitable camera and performs its duty by using smartphones and tablets as a control unit (Eroğlu, 2013).

Firstly, the researches carried out in the 1001 Church, which is the subject matter, were examined in detail. Afterwards, the necessary control points were established in the area where the 1001 Church, which is the subject of the study, was located, and the necessary control points were established, and the flight operations were carried out in the field by preparing the UAV flight plan. The field work was completed by measuring the coordinates of the control points with the help of Total station. With the data obtained, office work was initiated, the data was transferred to a UAV software, and the necessary photogrammetric operations were performed, and the three-dimensional model and documentation of the study area was made. In this way, the usability of UAV data in such applications has been examined.

In this study; The history of the Three-Dimensional Modeling and Documentation Process of UAV Data in the Documentation of Cultural Heritage has been carried out on 1001 Church, by utilizing today's advancing technology opportunities to transfer many historical and cultural heritages left to us from our past to the next generations of culture.

## 2. MATERIALS AND METHODS

### 2.1. Study Area



**Figure 1.** 1001 Church

Karadağ is an extinct volcanic mountain rising between the Çumra and Karaman plains and the Hotamış Swamp in the north of Karaman. Karadağ is an extinct volcanic mountain rising between the Çumra and Karaman plains and the Hotamış Swamp in the north of Karaman. There is a 1001 Church in this region which is called Değle Ören, located within the borders of Karaman Üçkuyu Village. Değle Ören,

located in Karadağ, a volcanic mountain in the north of Karaman, is approximately 35 km from the center. It is believed that 1001 church were used as the bishopric center in ancient times (Kurt, 2013). Figure 1 shows the location and view of 1001 Church in Turkey.

Among the regions listed village of Byzantine forward in terms of faith tourism in Turkey is one of the most important religious center. There are many churches and residences from the Byzantine period in the area. The churches and residences located here were established after St. Paulos, who came to Anatolia to spread Christianity, after coming to Derbe, one of the oldest settlements in Karaman. It is very important in terms of faith tourism that it is one of the places where Saint Paulos passes in Anatolia (Eyice, 1971; Kurt, 2013).

### 2.2. Coordinating Operations

By going to the 1001 Church located in the borders of Üçkuyu Village of Karaman Province, the area to be flight was determined. five control points and one intermediate facility, six ground control points 25 uniformly distributed locations and detail points have been established in the area to be flying, and the land direction has been completed.



**Figure 2.** Control points in the work area

Details were taken from the walls and side naves of the church structure to be used in aerial photographs to extract the three dimension (3D) model of the building, which is an important church structure and was used as a house and folder for a period of time.

### 2.2.1. Aerial imaging process

When the flight is made to the flight destination, the final checks of the UAV have been made and made ready for the flight.

**Figure 3.** The points where the detail is measured on the work area



**Figure 4.** The building control points and the distribution of control points of the side facade of the building

When the flight was finished, the UAV was lowered and the images acquired by the UAV were transferred to the computer.

### 2.3. Office Work

Within the scope of the study, different software studies were carried out to model cultural heritage sites in 3D with the UAV photogrammetry method. Necessary studies were carried out by using Agisoft Photoscan Professional, Pix4D mapper Pro and Visual SFM-Meshlab software.

The raw data from the total electronic distance meter were transferred to the computer. Subsequently, "x, y, z" coordinates of the detail points were calculated by using the control points with NETCAD software.

The coordinates of the points obtained were made ready for use in the software to be studied and saved in .txt format.

### 2.4. Creating a 3D Model with Agisoft Photoscan Professional Software

The Agisoft Photoscan Professional program was provided and the photos obtained from the field were transferred to the PC and made ready by transferring the facade and the processes were

started in Agisoft Photoscan Professional software, which is the first stage of the photogrammetric study.

While preparing the project in Agisoft Photoscan Professional:
-Entering projection values by entering raw images and GPS / IMU data of these images into the software
-Tiepoint collection process
-Entering ground control points and balancing process
-Point cloud creation process
-Mesh model creation process
-Texture dressed 3D model creation
-Provide Point cloud, 3D model and Orthophoto under the Agisoft File tab.

as the evaluation process has been completed.

Ground control points were measured with Total station and the values measured in the field were accepted as absolute values in the sensitivity survey. After this process, coordinates were obtained from the pictures produced by using UAV photogrammetric techniques.

As a result of the evaluation, images of the mesh model and orthophoto image of the old church in 1001 Church Figure 5 and 6 is also shown.



**Figure 5.** The texture of the resulting mesh model (texture covered)



**Figure 6.** As a result of the evaluation, orthophoto image of the old church in 1001 Church

### 2.5. 3D Model Production with Pix4D Mapper Pro Software

In this application, it has a specific workflow as in Agisoft Photoscan Professional software. We can express this order as follows.

While preparing the project in Pix4D mapper Pro:

-Opening the program and selecting the folder and giving the name

-Opening a new project

-The process of adding the pictures we take from the field

-Setting the picture coordinate system

-The process of selecting the model coordinate system

-The process of selecting the required (3D maps) data from the process options template

-The process of making the process settings

-The process of formation of the point cloud

-Adding the control points we selected

-The process of receiving reports from the system after the check points

-Obtaining orthophoto in the light of the last entered data

as the evaluation process has been completed.



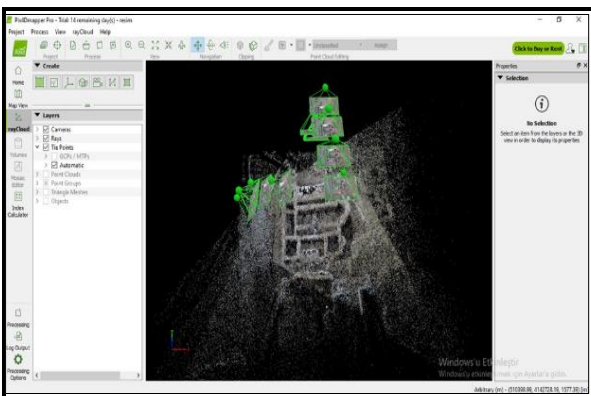**Figure 7.** Orthophoto and digital surface model (DEM-DSM) of the study area



**Figure 8.** Orthophoto image of the workspace created with the help of Pix4D mapper Pro



**Figure 9.** The area where orthophoto map is created in Pix4D mapper Pro

### 2.6. Generating a 3D Model with Visual SFM-Meshlab Software

Visual SFM is free software and an open source software program. SFM stands for building a structural model from the image, and Visual SFM, an open source software for the production of 3D models of objects, has a general public license.

At first, the photos to be used as in Agisoft Photoscan Professional software were transferred to the software and matched with each other. This process is based on finding common details between photos using the Scale-Invariant Feature Transform combination. Then, the image-to-image mapping process automatically performs bundle balancing performed by the program, and as a result, the sparse point cloud and dense point cloud operations. Visual SFM; It also allows an open source material such as CMVS / PMVS to work integratedly. After creating a dense point cloud in Visual SFM, the model can be saved in "ply" and "nvm" formats. The recorded model has been transferred to Meshlab software, an open source software, for mesh processing and texture creation operations. By making necessary operations in the meshlab software, orthophoto image was obtained.
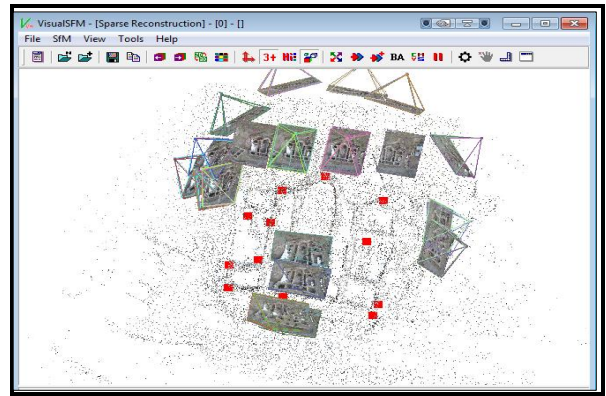


**Figure 10.** Point cloud that occurs after entering control points in Visual SFM software

**Figure 11.** Orthophoto image produced in Meshlab program

## 3. RESULTS

As a result of the experience obtained in the field study, the selection of UAV and digital camera is of great importance. For this reason, considering the flight sensitivity and camera resolution in our work in the 1001 Church, it was envisaged to fly with the DJI Phantom III Advanced Series and an average flight of 26 m was made. In our office, orthophoto image and DSM production processes were completed by using the package program Agisoft Photoscan Professional and Pix4D mapper Pro software, and open source software VisualSFM-Meshlab software, taking into account the drawing capabilities and other features of the software.

If we are to recover as a result of these transactions; The $m_{xy}$ and $m_z$ position and height errors of Agisoft Photoscan Professional and Pix4D mapper Pro software, titled "Detail Measurement Accuracy" of Large Scale Map and Map Information Production Regulation 46-1. It is seen that the detail points in the article are within the limits of location and height accuracy. This proves the accuracy of the transaction.

Using the same computer, Agisoft Photoscan Professional software completed orthophoto image and DSM production in 1 hour 55 minutes and Pix4D mapper Pro software in 24 minutes. Compared to accuracy, $m_{xy} = \pm 3.01$ cm in position error and $m_z = \pm 3.68$ cm in height error is obtained with Agisoft Photoscan Professional software, $m_{xy} = \pm 2.26$ cm in position error and $m_z = \pm 1.15$ in height error with Pix4D mapper Pro software. An accuracy of 1.15 cm was obtained. When we add Visual SFM-Meshlab software, which is an open source software in addition to both software, it was observed that there was an error of $m_{xy} = \pm 11.18$ cm in the position error obtained in our sensitivity research and $m_z = \pm 8.11$ cm in the height error.

As a result of the evaluations made according to the data obtained from these three software, Pix4D mapper Pro and Agisoft Photoscan Professional software are considered to be more suitable software than Visual SFM-Meshlab software in terms

of accuracy, time and ease of use (being a package program).

As a result;  The "Detailed Measurement Accuracy" of the Large Scale Map and Map Information Production Regulation (BÖHHBÜY) in force. Using the projection coordinates and heights of the detail points, electronic tacheometry, GNSS, LIDAR or other techniques and methods; The position accuracy will be measured better than ± 7 cm (inclusive) and Helmert orthometric height accuracy will be better than ± 7 cm (inclusive) ". As can be seen from here; In the light of the data we obtained from Agisoft Photoscan Professional and Pix4D mapper Pro software, it is seen that the documentation of cultural heritage using UAV and photogrammetric techniques is one that provides detail measurement accuracy. However, it is seen that the work done with Open Source Visual SFM-Meshlab software does not provide the desired accuracy according to BÖHHBÜY provisions. Documentation and three-dimensional modeling studies of historical and cultural heritage with UAV data respond to expectations using appropriate software and accuracy data can be obtained in accordance with the provisions of the regulation.

## 4. DISCUSSION AND CONCLUSION

In this study, the errors in the y, x and z directions obtained from Agisoft Photoscan Professional, Pix4D mapper Pro and Visual SFM-Meshlab software are given in Table 1.

**Table 1.** The resulting position and height errors

| Software Used | $m_{xy}$ (cm) | $m_z$ (cm) |
|---|---|---|
| Agisoft Photoscan Professional | ±3.01 cm | ±3.68 cm |
| Pix4D mapper Pro | ±2.26 cm | ±1.15 cm |
| VisualSFM-Meshlab | ±11.18 cm | ±8.11 cm |

When Table 1 is examined, in the sensitivity research performed on the 3D model produced by using the photogrammetric techniques with the Agisoft Photoscan Professional program, the sensitivity of the position is $m_{xy} = \pm 3.01$ cm, the height error is $m_z = \pm 3.68$ cm, and the sensitivity research done on the 3D model produced with the Pix4D mapper Pro software using photogrammetric techniques. position error $m_{xy} = \pm 2.26$ cm, height error $m_z = \pm 1.15$ cm. Finally, in the sensitivity research conducted on the model produced in Visual SFM-Meshlab software, which is open source software, the position error was found $m_{xy} = \pm 11.18$ cm, and the height error was $m_z = \pm 8.11$ cm.

According to the calculated results, it is seen that by using UAV with photogrammetric techniques,

sufficient location accuracy is provided in archaeological documentation. In this way, it can have the feature of producing litter in excavation works, modeling before and after excavation, monitoring the development of excavation phases, determining the work area and carrying the qualities that may be litter in restoration projects.

With the archaeological documentation that provides great advantage in terms of time, the desired dimensions and values can be obtained precisely on the 3D model.

When comparing our previous academic work using Agisoft Photoscan Professional;

Toprak (2014); In the study of documentation application of cultural heritage by using UAV with photogrammetric techniques; In this research, he accepted the coordinates of the location and building control points measured by the total station device as an absolute value. Coordinate differences in the y, x and z axes were taken between the coordinate values of the ground and building control points, which are accepted as the absolute value and calculated from the documentation of the cultural heritage using photogrammetric techniques, and the average position sensitivity was calculated as ± 5.01 cm by calculating the average mean errors by using these differences. seen.

In this study, it is seen that the average position sensitivity is ± 4.75 cm in our sensitivity research that we performed on the 3D model produced by using UAV with photogrammetric techniques.

As a result of the modeling we made with Pix4D mapper Pro and Agisoft Photoscan Professional programs with the same data, the following comments can be made about the results obtained when a comparison is made in terms of ease of use, time and accuracy;

Using the same computer, Agisoft Photoscan Professional software completed orthophoto image and DSM production in 1 hour 55 minutes and Pix4D mapper Pro software in 24 minutes. Compared to accuracy, position error $m_{xy}$ = ± 3.01 cm and height error $m_z$ = ± 3.68 cm are obtained in Agisoft Photoscan Professional software, while position error $m_{xy}$ = ± 2.26 cm, height error $m_z$ = ± 1.15 cm with Pix4D mapper Pro. an accuracy has been achieved.

In addition to both software, in the study made with Visual SFM-Meshlab software, an open source software, the position error was obtained as $m_{xy}$ = ± 11.18 cm, and the height error as $m_z$ = ± 8.11 cm.

## ACKNOWLEDMENT

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