3D Model of Hittite Yalburt Monument

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Abstract. The objective of this paper is Yalburt plateau which is located 16km north of Ilgın. Height of this plateau is 1300m. There are hieroglyph stone blocks located in the foot of mountain constitutes a pool. This pool was first discovered in 1970 and archaeological dig has been carried out during 1970, 1972, 1973 and 1975. As a result of these archaeological studies, there is a rectangular pool surrounded by the hieroglyph stone blocks with its three sides was discovered. There were no Hittites’ remnants found inside and outside of the pool but plenty of ceramics were found from Rome, Byzantine and early Hellenistic era. The total length of hieroglyph stone blocks of the pool is 12.70 m, their thickness is 1.20 m and the width of the pool is 8.30 m. The condition of 18 hieroglyph stone blocks is quite well except a few of them. One tablet describes the family tree of Tuthaliya IV and also describes the king of Hittite’s campaign to Lukka lands which consist of Wiianawanta and Pinali countries.

1. Introduction

After the battle of Kadesh, Hittite empire called the up country and down country for the upper parts of Red River (Kızılrmak) and the lower parts of Red River stretches along the Mediterranean. After the short-term riot following the death of Muwattalli II, Hattusili III became the king. He got responsible for taking care of his brother’s son, Kurunta, and he used every facilities of the empire for the future of his son Tuthaliya IV and Kurunta. He also assigned Kurunta as a governor for the down country known as Tarhuntassa. After the death of Tuthaliya’s father, Tuthaliya needs to run the empire consisting of capital Hattusa, up country and down country. A bronze tablet was found in Boğazköy Yerkapı which shows the agreement between the two cousins. It is concluded from this agreement that Kurunta claimed the throne. It is also inferred from this agreement that Kurunta captured Hattusa for a particular time period. After this agreement, Tuthaliya IV conceded the three main regions within the empire to his cousin Kurunta. These three regions consist of Mediterranean stretches between Silifke and Antalya, eastern part of the empire includes hieroglyph inscriptions of Kurunta known as Emirgazi region and western part of the empire includes the region surrounded by 18 hieroglyph stone blocks known as Yalburt region or monument.

In this study we created 3D digital model of the Yalburt Monument with close-range photogrammetric technique in order to preserve this historical site for the future generations, [1].

2. Work Flow

Archaeological practice within Turkey in terms of heritage management is facing huge challenges such a way of recording and reproduction of ex-situ preserved sites. Archaeological remains constitute a
considerable part of the cultural heritage. Archaeological investigations require detailed, high resolution registration and documentation techniques, in order to increase the chance for future reproduction of the structural historical monument. In the last decade, 3D applications have found their way into archaeological heritage and documentation research. We conducted close-range photogrammetric technique to create the representative 3D digital model of Hittite Yalburt monument, [2]. Close-Range Photogrammetry is a scientific method which helps to determine any 2D or 3D objects' geometric properties by taken digital pictures with different angles and positions. This technique has been widely used for many applications. Cultural heritage recording and documentation are among them. Three dimensional visualization techniques as preserving cultural heritage are becoming more and more important. The 3D modeling is a ubiquitous technique for the identification, monitoring, conservation, restoration and enhancement of archaeological objects [1]. In order to obtain the representative 3D model of the monuments, georeferencing process which is required to define the objects in the ground-based coordinate system is necessary. Hence, control points over the monuments’ body were situated homogeneously and their coordinates were determined accurately. GNSS (Global Navigation Satellite Systems) equipment were used to determine the three-dimensional coordinates of the control points in the order of centimeter accuracy. GNSS surveying technique is a trilateration computing from satellites. With the help of satellites coordinates, we can compute receiver's position on the earth. We used TUSAGA-AKTIF Continuously Operating Reference Stations (CORS) Network to determine the coordinates of the monument. Only one geodetic receiver is necessary to use this system. Cm level accuracy can be obtained during the measurement. With this system there is no additional control point whose coordinates are known before are necessary. There are several stages that need to be taken into consideration for completion of close-range photogrammetric process. The following stages are the two main parts: taking pictures of the object and processing of the data with photogrammetric software.

2.1 Primary Sub Heading
2.1.1 Taking Pictures
Highly overlapped digital photographs of each hieroglyph stone block were taken with Panasonic Lumix DMC-GX1 SLR, 16.2-megapixel digital camera. Spending some time planning the shot session might be very useful. The considerations for good shot for any object can be summarized as follows;
- More photos are better than not enough.
- Number of "blind-zones" should be minimized since PhotoScan is able to reconstruct only geometry visible from at least two cameras.
- Each photo should effectively use the frame size: object of interest should take up the maximum area. In some cases, portrait camera orientation should be used.
- Do not try to place full object in the image frame, if some parts are missing it is not a problem whereas these parts appear on other images thus alignment of the photos can be possible.
- Good lighting is required to achieve better quality of the results, yet blinks should be avoided. It is recommended to remove sources of light from camera fields of view.
- If you are planning to carry out any measurements based on the reconstructed model, do not forget to locate at least two markers with a known distance between them on the object. Alternatively, you could place a ruler within the shooting area for georeferencing the model Agisoft LLC, [3].

Agisoft PhotoScan Professional photogrammetric software was used for the processing of the taken digital photographs. This software was released in mid-2010 by the Russian manufacturer Agisoft LLC. PhotoScan uses Structure-from-Motion (SfM) algorithm which is the low-cost photogrammetric method for high resolution reconstruction. This technique differs significantly from conventional photogrammetry approach in a way that the geometry of the scene, camera positions and orientations are solved simultaneously and automatically without the need to determine control points on the ground. The workflow of photogrammetric processing in PhotoScan software includes aligning photos, building dense cloud, building mesh and creating model texture. These are fully automated step processes but users can also intervene manually or change the parameters in the processes at any stage [4].
photogrammetric resection. In SfM approach, position and orientation of the camera and scene geometry are reconstructed simultaneously through the automatic identification of matching objects in multiple highly overlapped images, [5, 6]. Camera positions derived from SfM lack the scale and orientation, thus 3D point clouds are generated in a relative image-space coordinate system (Figure 1) which must be oriented to a real-world coordinate system. In most cases, the transformation of SfM image space coordinates to a real world coordinate system can be performed using 3D similarity transformation. Camera positions w.r.t. the monument is shown in Figure 2.

![Figure 1. 3D point clouds](image1)

![Figure 2. Camera station w.r.t. the Yalburt monument](image2)

2.1.2 Photogrammetric Processing
In the alignment process, PhotoScan finds the camera position and orientation for each photo and builds a sparse point cloud model. Internal and external camera orientation parameters are also computed after the alignment process. The following conditions should be taken into account to produce representative 3D digital model by close-range photogrammetric technique;
Stereoscopic image pairs (two or more over-lapping photos) should cover the object which is supposed to be modelled.

Three-dimensional coordinates of at least three control points should be known in the model to perform seven parameter similarity transformation (3 parameters for translation, 3 for rotation and 1 for scaling) for georeferencing process of the model. This transformation enables to transform image coordinates of the model into the ground (object) coordinates.

Internal and external camera orientation parameters should be estimated with enough accuracy.

2.2 Transformation and finalization
There is no need to determine the camera internal calibration parameters before the photogrammetric process. If these parameters are determined precisely by using metric camera, they should be entered in PhotoScan software prior to the photogrammetric process. In the dense point cloud process, PhotoScan calculates depth information for each camera based on the estimated camera positions to be combined into a single dense point cloud. This process imposes heavy computational burden on CPU. The computation time depends on the resolution and quantity of photos and also CPU's power. The output of the dense point cloud process is a polygonal mesh. The polygon faces are created during the building mesh process. Building texture process calculates a so called texture atlas from one or more source of photographs. This step enables to provide a rich texture for each polygon in the 3D model. To perform georeferencing process of the model, the reference distances or reference coordinates on the object can be used. When using coordinates, either control points' coordinates or coordinates of the camera positions can be used. In this study, only control points' coordinates were used. Control points on the monument are determined by GNSS system which is explained in section 2. PhotoScan uses 7 parameters similarity transformation. After this transformation, the accuracy of the transformation can be controlled. Georeferencing process is necessary to determine distance, area and volume on the model.

3. 3D Digital Model of Yalburt Monument
After the photogrammetric process, 3D digital models of Fasillar and Eflatunpinar monuments were created properly. Figures 3-6 show the sections of the produced 3D model of Yalburt Monument.

![Figure 3. Front side view of the 3D model of Yalburt Monument](image)
**Figure 4.** Upper side view of the 3D model of Yalburt Monument

**Figure 5.** Hieroglyph stone blocks of the monument

**Figure 6.** Close view of one of the Hieroglyph stone blocks model
4. Conclusions

The 3D model discussed in this article was created by close range photogrammetric technique. Low investment and equipment requirements of close range photogrammetry are appealing to researchers. Thanks to PhotoScan SfM approach, highly overlapped pictures can be processed effectively to cover 3D model of the monument efficiently. This structure is deteriorating day by day; therefore, it is important to preserve this Hittite monument as a historical site for the future generations.

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