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INVESTIGATION OF THE COMPATIBILITY OF FASILLAR AND EFLATUNPINAR HITTITE MONUMENTS WITH CLOSE-RANGE PHOTOGRAMMETRIC TECHNIQUE

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ABSTRACT

There are two Hittite monuments in Konya whose names are Eflatunpınar and Fasıllar. Eflatunpınar is located approximately 25 km at the North of Beysehir town within Konya province in Turkey. Eflatunpınar monument is belonging to Hittite Empire Age, was known since XIX century. It is an open air temple of Hittite, 6.60 m wide and 7 m high, was built with large block stones. The second one known as Fasıllar Hittite monument lies on a hillside next to the Fasıllar village which is 16 km east of Beysehir town and it is a high relief monument which is made of basalt rock. It is commonly accepted that these two monuments had never been completely finished. J. Mellaart have suggested that Fasıllar monument was not in-situ position, it was moved from Eflatunpınar to Fasıllar village by the local people for decoration purposes. This means that ac-cording to J. Mellaart, Fasıllar monument is the part of Eflatunpınar monument. The objective of this study is to investigate whether Fasıllar monument was built for placing on the top of Eflatunpınar monument which is firstly raised a subject by J. Mellaart. For this purpose, three-dimensional (3D) digital model was created for each monument by close-range photogrammetric technique. By the help of the 3D digital models of these monuments, the unity between the monuments were investigated as an engineering approach.

KEYWORDS: 3D Modelling, Cultural Heritage, Eflatunpınar, Fasıllar, Photogrammetry.

1. INTRODUCTION

The Hittites were an ancient Anatolian people who established an empire at Hattusa (Hattusa was added to the UNESCO World Heritage list in 1986) in north-central Anatolia, around early 1600 BC. There are plenty of Hittites' artifacts still intact today, Fasıllar and Eflatunpınar monument is one of them.

Fasıllar monument (Sterret, 1885; Arık, 1956; Mellaart, 1962; Bittel 1976) was located at the intersection of the roads which are leading towards the south to Mediterranean. The monument has been carved on a basalt monolith block. It is a high relief monument. On the monument, there is a bearded mountain God and another young God which is bigger than the bearded one and also 2 lions on both sides of these Gods (Darga, 1992; Alexander, 1975). The young one stretches one of his arms forward, as if he is attacking, and he raises the other arm up. There are 4 horns on the hat worn by the God. The ears are rather big as it seen from the monument (Fig. 1).

Figure 1. Fasıllar High Relief Monument

Eflatunpınar monument is located approximately 30km northwest of Fasıllar monument (Hamilton, 1842; Garstang, 1910; Bittel, 1953; Arık, 1956; Mellaart, 1962; Alexander, 1968; Börker-Klähn, 1993).

Eflatunpınar is a historical open air temple remained from the Hittites (Karauguz et al., 2009). The monument is formed as a rectangular shaped pond. The most prominent part is the high wall of reliefs that stand on the north edge of the rectangular pond. It is built with large andesite stone blocks. There are some figures were carved on the façade of Eflatunpınar monument (Fig. 2). These figures may be interpreted as men whirling around themselves in Mevlana rituals (Karauguz et al., 2009).

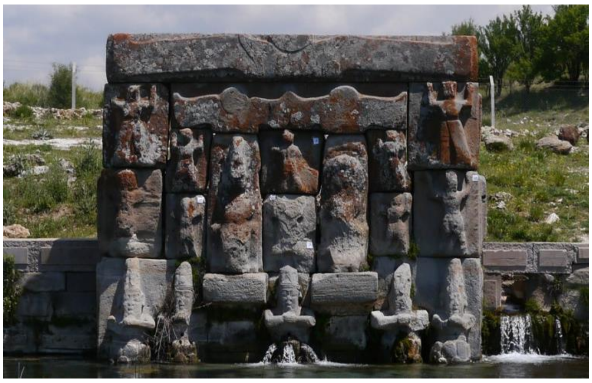

Figure 2. Some Relief Figures Seen On Façade Of Eflatunpınar Open Air Temple

Each monument is located near the main route (Karauğuz et al., 2004). Eflatunpınar is located toward the west gateway and Fasıllar is located toward the south gateway of Hittites. According to Karauğuz (2005) these monuments should have been placed on sacred open areas.

According to Mellaart (1962), Fasıllar monument is the part of Eflatunpınar monument. It was also argued that these two monuments are not representing similar features and completely independent to each other (Erkanal, 1980).

In this study, we created 3D digital model of these monuments with close-range photogrammetric technique in order to investigate the unity of these monuments as an engineering approach for the first time. For this purpose, highly accurate representative 3D models of these monuments were combined in the virtual environment to find out how compatible these monuments with each other. In the first section the materials and methods of the creating 3D model is introduced; in the second one, the comparison of the created 3D models is examined and finally the results are given.

2. MATERIALS AND METHODS

We conducted close-range photogrammetric technique to create the representative 3D digital model of Fasıllar and Eflatunpınar monument. Close-Range Photogrammetry is a scientific method which helps to determine any 2D or 3D objects' geometric proper-ties 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 (Liritzis et al., 2015). There are several stages need to be taken into consideration for completion of close-range photogrammetric process. The following stages are the two main parts: geodetic measurements, taking pictures of the object and processing of the data with photogrammetric software.

2.1 Geodetic Measurements and Taking Pictures

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 homogenously and their coordinates were determined accurately. Laser total station and GNSS (Global Navigation Satellite Systems) equipment were used to determine the three-dimensional coordinates of the control points in the order of centimeter accuracy. Control points on the monuments body are seen in (Fig.3).

GNSS surveying technique is a trilateration computing from satellites. With the help of satellites coordinates, we can compute receiver's position on the earth. Laser total station is a device which performs length and angle measurement without reflector. Two points around the monuments were determined then GNSS receiver was situated vertically over these points in order to create reference vector w.r.t the 3D ground coordinates. With the help of these points, three-dimensional coordinates of the control points on the monuments were determined by the laser total station (Selvi et al., 2014).

After the geodetic measurements, highly overlapped digital photographs of the monuments were taken from each side. All pictures were taken with Panasonic Lumix DMC-GX1 SLR, 16.2 megapixel digital camera.

Figure 3. Distribution of control points a. Fasıllar monument b. Eflatunpınar monument

2.2 Photogrammetric Processing

Agisoft PhotoScan Professional photogrammetric software was used for the processing of the taken digital photographs. 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. Iterative bundle adjustment procedure, based on the data of scenes automatically extracted from a set of multiple overlapped images (Verhoeven, 2011).

In traditional photogrammetric techniques triangulation can be used to reconstruct scene geometry with identifying control points in the input photographs and this process called 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. Camera positions derived from SfM lack the scale and orientation thus 3D point clouds are generated in a relative image-space coordinate system 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.

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 overlapping 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.

The workflow of photogrammetric processing in PhotoScan software includes aligning photos, building dense cloud, building mesh, creating model texture and georeferencing process of the model. These are fully automated step process but users can also intervene manually or change the parameters in these processes at any stage [19]. 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.

Figure 4. 3D models of the monuments

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 impose 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. PhotoScan uses 7 parameters similarity transformation. Georeferencing process is necessary to determine distance, area and volume on the model.

2.3 Comparison Of Fasıllar and Eflatunpınar 3D Digital Models

After the photogrammetric process, 3D digital models of Fasıllar and Eflatunpınar monuments were created accurately (in the order of few centimeters). Fig 5 - 6 show the produced models and the dimensions of the models.

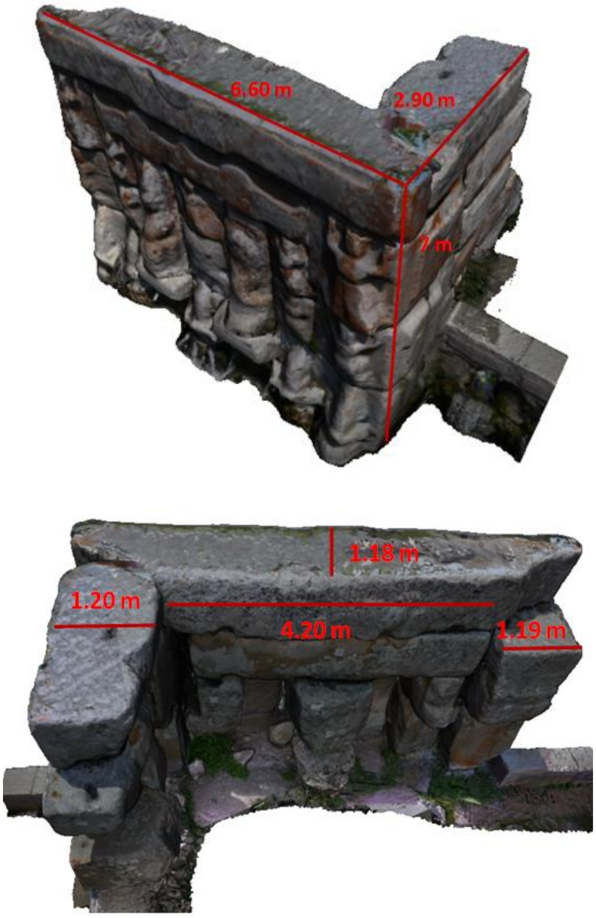

Figure 5. Dimensions of Eflatunpınar monuments
a. Front of the monument b. Back of the monument

Figure 6. Dimensions of Fasıllar monument

As it is seen from the model of Eflatunpınar, this monument is an incomplete structure (Fig 4). From the characteristic of the monument it has been considered that the completed 3D model of Fasıllar monument would be rectangular shape. For creating virtual reconstruction model, 3D model of Eflatunpınar monument was completed while taking into consideration the geometry and texture of the monument (Fig 7). This completion was done by adding the existing two faces symmetrically to come up with a rectangular structure by the help of MeshLab open source software. Thus, top surface of the model of Eflatunpınar became available to carry the model of Fasıllar monument.

Figure 7. Virtual reconstruction Model of Eflatunpınar Monument

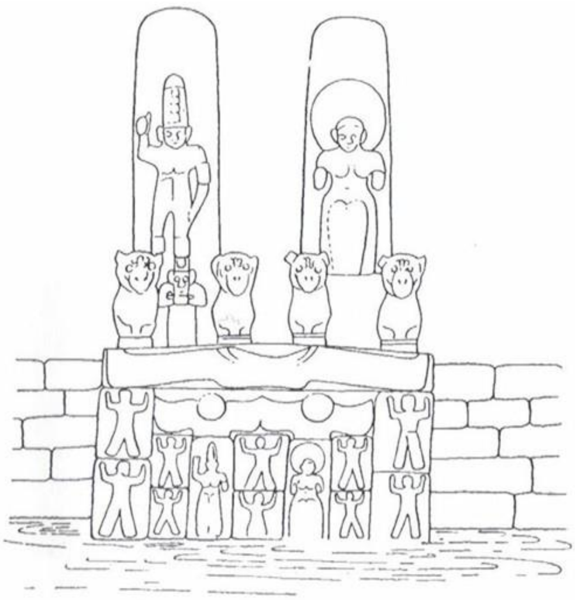

Figure 8. Composition of Eflatunpınar and Fasıllar Monuments according to J. Mellaart (1962)

Figure 9. Two identical Fasıllar monuments on the top of Eflatunpınar monument

In Mellaart's depiction (Fig 8), one goddess near the Fasıllar monument were placed on the top of Eflatunpınar monument. As it is seen from the depiction, dimensions of goddess and Fasıllar are nearly the same. In order to recreate Mellaart's depiction, we replaced the goddess with the Eflatunpınar monument because there is no any goddess monument around the region. Thus there are two identical Fasıllar monuments were placed side by side on the top of Eflatunpınar monument (Fig 9) in the MeshLab environment. To situate the two identical Fasıllar monuments on the top of the completed model of Eflatunpınar, the below part of Fasıllar monument should penetrate the space of the above part of Eflatunpınar. In our combined model, two identical Fasıllar monuments are not fitted into the space of the above part of Eflatunpınar while there was no room between them (Fig. 10). According to our calculation on the combined model, 40 cm more space of the right-left side of Eflatunpınar monument is needed to situate two Fasıllar monuments on the top of Eflatunpınar monument.

Figure 10. Two identical Fasıllar monuments are not fitted into the space of the above part of Eflatunpınar

2.4 Structural Analysis of Fasıllar and Eflatunpınar Monuments

Eflatunpınar Monument has been constructed with andesite blocks. Material characteristics of Andesite and Basalt stones are given in Table 1.

Table 1. Material characteristics of Andesite (Eflatunpınar) and Basalt (Fasillar) stones (Şimşek, 2003; Gmüşcü et al., 2012)

Material	Modulus of Elasticity	Density	Poison Ratio	Pressure stress
Basalt	50 (MPa x 1000)	2.78-3.25 gr/cm^3	0.25	97 Mpa
Andesite	20-50	2.67 gr/cm^3	0.29	48.76 Mpa

Structural analysis was conducted to investigate whether Eflatunpınar Monument can carry Fasıllar Monument. The monuments' strength and geometry are taken into consideration for structural analysis. The geo-metric information of the structures was taken from the created three-dimensional model by close-range photogrammetric technique. While determining the forces acting on the Fasıllar monument, only dead load was taken into consideration, the others such as wind, snow were excluded from the calculation (their effects are negligible in this computation). The entire volume of Fasıllar monument is approximately 15 cubic meters (m3). The density of basalt is between 2.78-3.25 gr/cm3 (Table 1). The density was taken 3 gr/cm3 as an average in this analysis. Thus, the weight of Fasıllar monument is determined approximately 45 tones. Tensile and compressive stress on the monument are directly linked to the magnitude of force and the size of the area.

Figure 11. Virtual 3D model of the monuments

The magnitude of the force is 45 tones and the size of the bottom area while Fasıllar monument is placed on Eflatunpınar monument is determined 2.12 m² from three-dimensional model. Tensile and compressive stress is determined from equation 1.

$$\sigma = \frac{\text{Force}}{\text{Area}} = \frac{45\ 000\ \text{kg}}{21200\ \text{cm}^2} = 2.12\ \text{kg/cm}^2 \quad (1)$$

Maximum stress of andesite rock σ_e is 48 Mpa (Şimşek, 2003).

As it is seen from the equation 1, $\sigma_e > \sigma$ thus we can conclude that Eflatunpınar monument can support to Fasıllar monument.

3. CONCLUSION

This study investigated Fasıllar and Eflatunpınar Hittite monuments in terms of the compatibility with each other with using close-range photogrammetric technique. By the help of high accurate 3D digital model of these artifacts we recreate Mellaart's depiction with using two identical Fasıllar monuments model rather than goddess. The models of Eflatunpınar monuments and two identical Fasıllar monuments were gathered together in the 3D environment to shed a light on whether Eflatunpınar monument can carry the Fasıllar and goddess as depicted in Mellaart's proposition. Due to the incomplete status of Eflatunpınar monument, we completed the absent parts virtually from the existing two faces without damaging the integrity of the monument. The combined models show that two Fasıllar monuments cannot be fitted into the top of Eflatunpınar monument. On the other hand the followings are some features for these monuments;

- Fasıllar monument is high-relief structure but Eflatunpınar monument is low-relief structure. (Erkanal, 1980)
- There is no esthetical integrity between the monuments.
- The carved god figures on the monuments are not the same size

Taking into consideration these distinct characteristics of the monuments and examined 3D digital models, we conclude that Fasıllar monument was not built as a part of Eflatunpınar monument. The other important function of these monuments is that they shaped the border of Tarhuntassa region (Karauğuz , 2008)

This study shows that producing 3D digital representative models of artifacts is beneficial and cost effective way for preserving cultural heritages and they also shed a light on the disagreements among the historians.

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REFERENCES

Akurgal, E.,(2000) *Hattian and Hittite Civilizations*, Ankara.
Arık, R.O. (1956) Ankara-Konya, Eskişehir-Yazlıkaya Gezileri. Türk Tarih Kurumu Basimevi Ankara.

Alexander, R. L.(1975). A Hittite Cylinder Seal In The Fitzwilliam Museum. *Anatolian Studies*,Vol 25, 111-117.

Alexander, R. L. (1975). The mountain God at Eflatunpınar.*Anatolica* II, 7-88.

Behm-Blancke, Manfred, R. D. Ritting. (l970). Der Aslantas von Eflatun Pinar. *Mitteilungen Der Deutschhen Orient-Gesellschaft* 102, 89–99.

Bittel, K.(1976). *Die Hethiter*. München.

Bittel, K.(1953). Bcitrag zu Eflatunpınar. *Bibliotheca Orientalis* X, l/2 , 2–5.

Börker-Klähn, J. (1993).*Noch einmal Iflatun Pınar. Aspects of Art and Iconography: Anatolia and Its Neighbors* (Studies in honor of N.Özgüç), Ankara, TTK. 339-55.

Darga, A. M. (l992). *Hitit Sanatı*. İstanbul.

De Reu,J.D., Plets, G., Verhoeven, G., De Smedt, P., Bats, M., Cherretté,B., De Maeyer,W., Deconynck,J., Herremans,D., Laloo,P., Van Meirvenne,M., De Clercq,W.(2013). Towards a three- dimensional cost-effective registration of the archaeological heritage. *Journal of Archaeological Science* 40 , 1108-1121.

Erkanal, A. (l980). Eflatun Pınar Anıtı. *Bedrettin Cömert'e Armağan*, Ankara, 287-301.

Gümüşçü,M., Turgut,P.(2012). Physico-Mechanical And Thermal Properties Of Karacadağ Basalt, Tr. *J. Nature Sci.* 1 (2): 25-29,Bingöl.

Hamilton,W.J.(1842).*Researches in Asia Minor,Pontus and Armenia II*.London.

Sterret, J.R.S. (1885). *Preliminary report of an archaeological journey made in asia minor during the summer of 1884*. Boston.

Garstang, J. (1910).*The land of The Hittites*. London.

Mellaart, J.(1961).Excavations at Çatal Hüyük; First Preliminary Report. *Anatolian Studies* 12: 41-65

Mellaart, J. (1961).The late bronze age monuments of Eflatun Pınar and Fasıllar near Beyşehir. *Anatolian Studies*, 12, 111-117

KarauğUz, G. (2005). Arkeolojik Ve Filolojik Belgeler IşIğInda M.Ö. II. Binde Orta Anadolu'nun GüNey Kesimi. Konya, Turkey, Çizgi Kitabevi.

Karauguz, G., Çorumluoğlu Ö., Kalaycı İ., Asri İ.,(2009).3D Photogrammetric model of Eflatunpinar monument at the age of Hittite empire in Anatolia. *Cultural Heritage* 10,269-274.

Karauğuz, G. Özcan,K.(2005).Hitit İmparatorluk Döneminde Anadolu Yerleşme Sistemine İlişkin Hipotetik Yaklaşımlar 'Tarhuntassa Eyaleti Yerleşme Sistemi'". Studı Mıceneı Ed Egeo-Anatolıcı XLIX (2007), (VI Congresso Internazionale di Ittitologia Roma, 5-9 Settembre 2005), Vol. II, 463-477.

Karauğuz, G. Doğanay,O, (2004).İ.Ö.II.Binden Bizans Dönemine Kadar Orta Anadolu'nun Güneyinden Akdeniz Kıyılarına Uzanan Yolağı Üzerine Düşünceler. Mersin University Publications of The Research Center of Cilician Archaeology ,Mersin.

Liritzis, I., Al-Otaibi, F.M., Volonakis, P., Drivaliari, A.(2015). Digital Technologies And Trends In Cultural Heritage. *Mediterranean Archaeology And Archaeometry*, Vol. 15, No 3,(2015), Pp. 313-332

Ozcelik ,Y.(2011).Determination of the regions used as facing and building stone according to the material characteristics in an andesite quarry.*Engineering Geology*, Vol 118, Issues 3–4, Pages 104–109

Selvi,H.Z., Karauguz,G., Varlik,A.,Kalayci,I., Öğütcü,S. (2014). A Cultural Heritage Belonging To Hitties: 3d Modeling And Archiving Of Fasillar Hittite Monument, *18th Symposium On Mediterranean Archaeology* April 2014, (Soma 2014), Wrocław (Poland)

Şimşek,O., (2003) "Investigation of Engineering properties of the pink Andesite Stones of Çankırı-Korgun Region",G.U.Fen Bilimleri Dergisi,16(3), Ankara.

Verhoeven, G. (2011).Taking computer vision aloft archaeological three-dimensional reconstructions from aerial photographs with photoscan. *Archaeological Prospection* 18 , 67-73.

Zedef, V., Koçak, K., Döyen, A., Özşen, H., Kekeç, B., (2007). Effect of salt crystallization on stones of historical buildings and monuments, Konya, Central Turkey. *Building and Environment*, 42, 1453-1457.