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A PRELIMINARY FIELD WORK ON DIGITAL HERITAGE AND THE USE OF VIRTUAL REALITY FOR CULTURAL HERITAGE MANAGEMENT

M. Hamdi KAN [1]
Department of Architecture and Urban Planning, Akdeniz University, Türkiye
ORCID: 0000-0001-7947-7140

Hava KESKİN
Tourism Guidance Department, Tourism Faculty, Akdeniz University, Türkiye
ORCID: 0000-0001-7747-7059

Nusret DEMİR
Department of Remote Sensing, Faculty of Sciences, Akdeniz University, Türkiye
ORCID: 0000-0002-2493-4583

Serdar SELİM
Department of Remote Sensing, Faculty of Sciences, Akdeniz University, Türkiye
ORCID: 0000-0002-5631-6253

Erdoğan ASLAN
Department of Archaeology, Faculty of Literature, Selçuk University, Türkiye
ORCID: 0000-0002-3437-7207

Nilgün GÜNEŞ
Independent Researcher, Antalya, Türkiye
ORCID: 0000-0002-1793-1878

ABSTRACT
This paper presents the results of a multidisciplinary research project carried on during the Covid-19 Pandemic and supported by TÜBİTAK (The Scientific and Technological Research Council of Turkey). The results are gathered from six months of field and office work, as the project was limited with this period. The archaeological site of Letoon in Muğla/Turkey has been chosen as the test area, specifically the triple temples of Leto, Apollo, and Artemis. Photogrammetric reconstruction of the current situation, as well as archaeologically accurate 3D models, have been created and converted into interactive immersive VR content to measure consumer behaviour and experience. These two different types of 3D content are integrated into the VR environment both separately and as a single content with switching from one to the other. After the creation process, the content was experienced by the visitors with different demographic characteristics and a survey was conducted to measure this experience.

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[1] Address correspondence to M. Hamdi Kan (PhD), Department of Architecture and Urban Planning, Architectural Restoration Programme, Akdeniz University, Antalya, Türkiye. E-mail: muhammetkan@akdeniz.edu.tr

INTRODUCTION

The ancient sacred site of Letoon is in Western Lycia, today's Teke Peninsula, which is located in south-western Anatolia. It is now inside the modern settlement of Seydikemer in Muğla Province of Turkey. There are three temples at the core of the site, which was indeed not a settlement but a sacred site for western Lycia, especially in the Hellenistic Period. Temples are dedicated to the twin gods of the Hellenic Pantheon, Apollo and Artemis, with the third and biggest one being dedicated to their mother Leto, who also gave name to the site Letoon.

Another significance of the site is that it has been listed on the World Heritage List of UNESCO, in 1988. The archaeological excavations started in 1950, for both Letoon and Xanthos by the French Archaeology Mission led by Pierre Demargne, and since then carried on by Henri Metzger, Christian Le Roy, Jacques Des Courtils, and Laurence Cavalier until 2011. Between 2011 and 2020, the excavations have been carried on by Sema Atik, and in 2020 Erdoğan Aslan took over the mission.

The Doric Temple of Apollo is at the east of the temenos, just beside the mother-rock shaped as a Wall (Atik-Korkmaz, 2016, p. 193). The first excavations to unearth the building has begun in 1966 (des Courtils, 2003, p. 5). Before the Hellenistic temple, which can be observed today, there was a stone based wooden temple at the same place which is the only example of Lycian woodwork on a monumental building (des Courtils, 2003, p. 143-144; Heinze, 2014, p. 78). This early temple, which could not be dated yet, could be identified by the wooden column halls that observed by excavators (des Courtils, 2003: 14). There is a mosaic in the cella, decorated with a bow, a quiver, a lyra, and sun, all of which are related to Apollo (des Courtils, 2003, p. 143). This mosaic is the only solid evidence to identify the building as a temple of Apollo. After a re-study of the columns and very few pieces of the superstructure, the building is claimed to be not a pure Doric, but a hybrid of Doric and Ionic elements (Atik-Korkmaz, 2016, p. 196). The 3D reconstructions of the building have been created in regard of this study.

The aim of this paper is to represent the methodology and results of a completed multidisciplinary R&D Project conducted in a well-studied ancient site. It is essential to carry on such multidisciplinary field projects to produce original data regarding digital heritage and its practices. As this field of digital heritage is relatively new, there are both technical and practical problems waiting to be resolved. The two most important of them are the main targets of this study: user-friendly presentation of photo-realistic VR content and the consumer adoption of this new method of presentation. The "content creation" part of the study focuses on the concomitant use of two different types of 3D immersive content; photogrammetric 3D scans and CGI 3D reconstructions. A user-friendly presentation of these in a single content provides the ground for a survey to measure the consumer experience.

Although this paper is focused on digital heritage and its use in cultural heritage management in the case of Letoon, rather than digital archaeology; another conceptual study is being prepared by the corresponding author of this paper, which is concentrated on the newly emerging concept of digital archaeology and its presentational and data productive aspects. Combining the digital heritage and data productive virtual archaeology would create a modern and deeper view of ancient sites like Letoon.

The structure of this paper is also shaped around these two main targets. Methodology and Results, each has been presented in two separate parts regarding content creation and consumer experience. Literature review is also presented in two parts as the first focuses on the ancient site of Letoon which provides the essential data to produce especially the CGI 3D content, and the second part on the technology that makes it possible.

LITERATURE REVIEW

The Ionic Temple of Artemis is the least preserved and the smallest one of the three temples. It is in the middle of the other two and should be built in "in-antis" or "prostylos". The field observations and detailed documentation show a very elaborate masonry, though it is a very small temple. With two inscriptions found inside and in front of the temple, the building is dated to the middle of the 4th century BC (Metzger, 1979, p. 14; des Courtils, 2003, p. 142-147; Çevik, 2015, p. 81; Atik-Korkmaz, 2016, p. 197). One of the most unique features of the Artemis Temple is the mother rock right in the middle of it. This rock should be considered sacred even before the temple was there, might be like an intangible cult statue of the goddess.

The Ionic Temple of Leto is the best-preserved one of these three buildings, as 80% of it is observable. It is also the biggest of the three and is located at the closest point to the water spring (Hansen & Le Roy, 2012; Heinze, 2014, p. 80-82; Atik-Korkmaz, 2016, p. 200). The architectural decoration of the temple is easily observable and the temple is built in "distylos in antis" order (des Courtils, 2003, p. 150). There is a mother rock in the cella of Leto Temple as well as the Temple of Artemis; and there are the remains of a polygonal wall dated to an earlier phase of the building (Hansen & Le Roy, 1976, p. 317). Thus, there must be an earlier (may not be wooden) temple but it was not preserved in the Hellenistic temple like the example seen in the Temple of Apollo (Laroche, 2007, p. 169-174.). The dating of the Leto Temple is controversial, as the outer architectural decoration is dated to the 4th century BC, while the inner friezes of the cella are dated to the middle of the 2nd century BC (Atik-Korkmaz, 2016, p. 200-201).

May not be digital but virtual archaeology is not new as a concept, while the conventional reconstruction and restitution techniques are in use since the beginning, and have even been the most effective presentation methods of this multidisciplinary science. On-paper reconstructions, 2D drawings, 3D drawings, scaled solid models, etc. were indeed representing some kind of virtual reality back then, of course in the means of their time and technology. By the first emergence of VR technologies in the 1990, the concept immediately took the attention of the archaeology society. The "Computer Applications and Quantitative Methods in Archaeology" meeting in Barcelona, took VR into the account and brought it to the headline as early as 1998 (CAA, 1998). This meeting was the first evaluation of VR as a presentation and documentation method by archaeologists.

The sudden eagerness for VR in the late 20th century was destined to fall, as neither the hardware nor the software was ready for a mass effect. The devices were very big, bulky, and expensive, as well as the 3D content-creating software was light years away from the "Reality" part of VR. But the fire was already lit, and the enthusiasts carry on their work on 360° photos, object, and building scanning techniques, and 3D digital reconstructions, contributing to the concept of Digital Heritage. The ICOMOS Charter in 2008, set the criteria to be followed in Digital Heritage works, as international recognition and regulation of the concept (ICOMOS, 2008).

The second and final rise of VR was in the second half of the 2010s. As relatively inexpensive mobile devices accompany the realistic 3D modelling software, technology overcame the two downsides of the 1990s attempt, rising the opportunities to use this tech in closed environments and even in the field. Following this re-emergence, Digital Heritage which has come a long way while VR was waiting the tech to catch up, could be carried to a more immersive, more effective, and more realistic platform. Multidisciplinary scientific research and studies are being realised since then, mostly in communications, archaeology, heritage management, and tourism practices of VR (e.g. Gillings, 2000; Wheatley & Gillings, 2000; Gergen, 2002; Rose & Wylie, 2006; Barcelo, 2009; Smith, 2012; Farman, 2014; Liritzis et al., 2015; Bucher, 2017; Young, 2017; Goulding et al., 2018; Kidd, 2018; Rahaman, 2018; Doğan & Kan, 2020).

A review of these studies shows that most of them are focused on immersive presentation practices rather than data production, which is obviously the most attractive use of this technology. However, even the accurate space and size perception these contents provide is solely a special contribution to understanding and data production. Also creating realistic reconstructions of entire settlements can provide a more precise view of ancient urbanistic and relations of different parts of ancient settlements (like industrial instalments, ports, etc.). Even by showing the constructional relations between individual buildings, digital reconstructions have the potential to understand the motivations that create an entire silhouette of an ancient settlement.

METHODOLOGY

The main material of the study is the ancient city of Letoon. The city is within the borders of Seydikemer district of Muğla province in Turkey. Letoon, together with Xanthos, was included in the "UNESCO World Heritage List" as a cultural heritage by the United Nations Educational Science and Culture Organization- UNESCO on 9 / 12 / 1988. Other materials used in the study are Unmanned aerial vehicle and modeling software. DJI Phantom 3 Advanced is used for the acquisition of aerial images. For terrestrial image acquisition, Sony XX SLR Camera is used. The camera parameters of the UAV and Camera can be found in Table 1. Agisoft Metashape software packages are used for the virtual modelling, and Agisoft Photoscan has been used for photogrammetric 3D reconstruction. In the literature, the photogrammetric modelling of the cultural heritage has been widely applied (Grün et al., 2004; Eisenbeiss & Zhang, 2006; Ioannidis et al., 2005; Remondino, 2011). The method of this study consists of 4 stages: (1) Photogrammetric reconstruction, (2) 3D virtual modelling of the temples, (3) virtual reality development, and (4) measuring of impacts on the visitors. Each stage is detailed below.

Table 1. *Parameters of the Drone and Camera*

Materials	Type	Image size	Focal length	Pixel dimensions
UAV	Frame	4000x3000	3.61mm	1.56 x 1.56 μm
Camera	Frame	6000x4000	28mm	6x6 μm

Photogrammetric 3D Modelling

The photogrammetric modelling phase consists of image acquisition, image correction, image processing, and 3D modelling (Figure 1). Within the scope of the study, obtaining photogrammetric images from the air and from the ground forms the basis of the modelling phase of virtual reality. A standard unmanned aerial vehicle (UAV) and an internal camera are used to acquire images aerially. A high-resolution camera is preferred for terrestrial photographs.

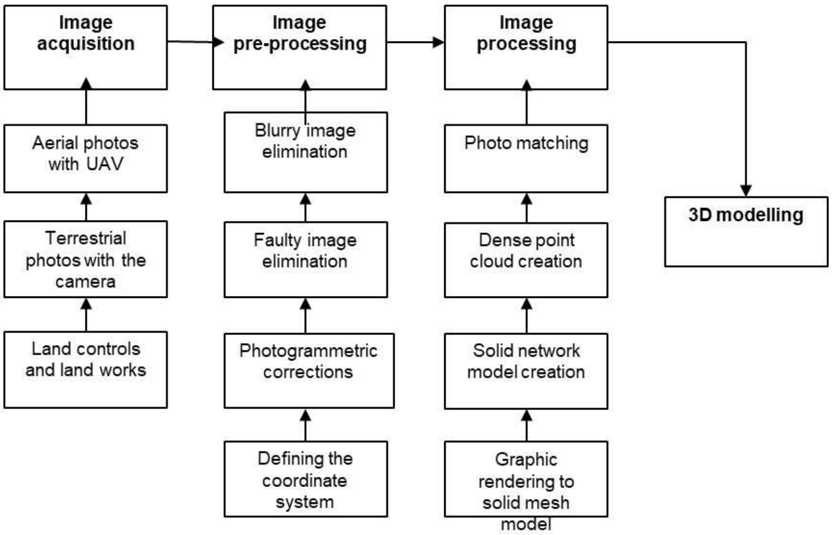

Figure 1. *Photogrammetric 3 D modelling method flow chart*

Obtaining three-dimensional metric information about an object with the photogrammetry method consists of two stages, internal and external orientation. With the interior orientation, the geometric relationships between the camera plane and the photographic plane are defined, where two important parameters are the focal point position and focal length. The cameras that these two parameters are precisely determined and presented to the users are metric cameras. In cases where these are not available, it is possible to determine these parameters with self-calibration. However, lens distortion values should also be calculated in order to eliminate these effects in modelling by considering lens defects.

In order to take aerial photographs, the flight plan, which covers the borders of the ancient city of Letoon, was planned with the use of the Pix4D interface. Five different flights have been carried out in the region. The flights are planned in 2 ways as orthogonal and oblique angles. Orthogonal images are acquired as GRID, covering an area of 200x350 m with a resolution of 3.09 cm/px from a height of 50 m. Oblique images are taken as circular with a resolution of 2.19 cm/px from 30 m height. A total of 600 images were obtained with the UAV. Terrestrial images include 3300 photographs in 6000x4000 pixel resolution.

The external orientation defines the relationship between the image plane and the modelled object. Thus, a triangle is formed with at least two images of the object, and by its solution, the 3-dimensional position of any point on the photograph is obtained. Exterior orientation has two stages: relative orientation and absolute orientation.

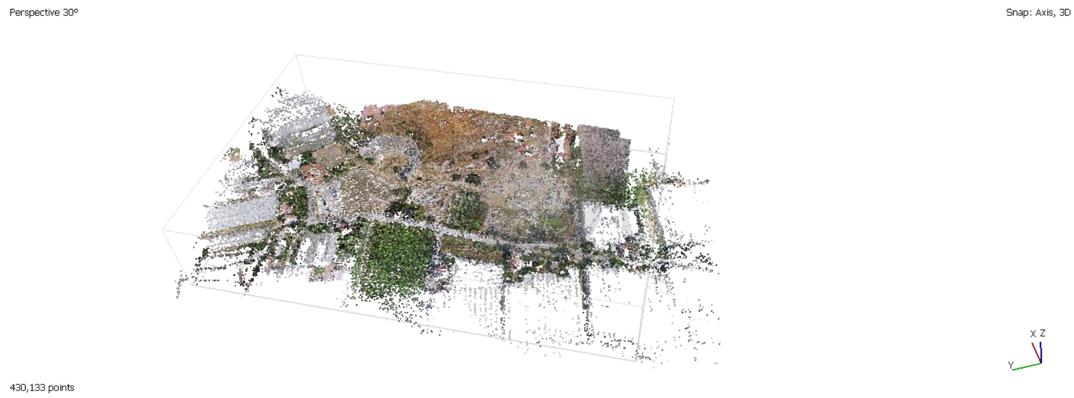

Figure 2. *Point cloud data of study area*

The relative orientation in Agisoft creates sparse points, and the absolute orientation is done with Ground Control Points, which allows calculating georeferenced dense point cloud of the temples. Figure 2 shows the sparse and dense point cloud of the area. After creating the dense cloud, a 3D solid reconstruction model is created and exported accordingly to be used in VR development (Figure 3).

Figure 3. *Reconstruction model of study area*

3D Virtual Models

For the 3D virtual model phase, the results of the observations and fieldwork of the project team have been compared with the previous virtual modelling attempts (Hansen, 1991; Cavalier & des Courtils, 2013). Although the previous works are not lacking in accuracy, presentation techniques and visual quality is limited by the competence of the time being, which is to be expected. While these works may be considered quite successful, they are much focused on the Temple of Leto and less on the other two temples of Apollo and Artemis. Thus, the previous modelling works were partly useful for our study (Figure 4).

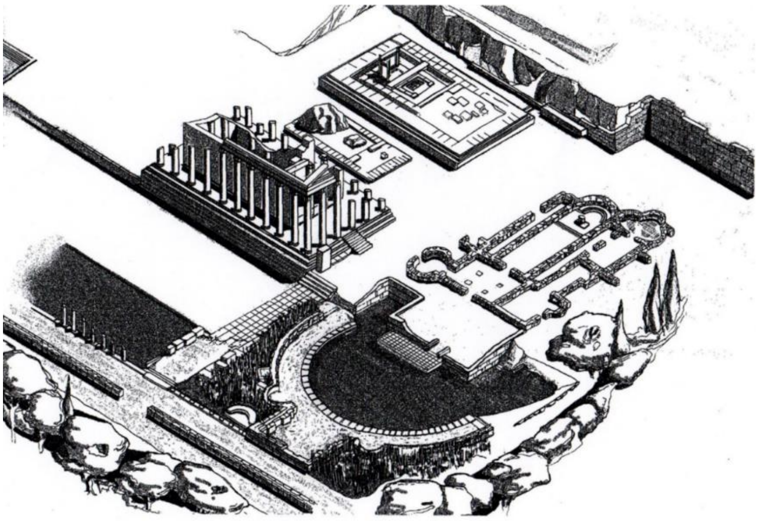

Figure 4. *Example for previous modelling attempts (Excavation archive)*

As expected, the priority is to create archaeologically accurate 3D virtual models, which are based on photographic documentation and 2D detailed drawings, as well as previously published material (Figures 5-6). Measuring, drawing, and photographic documentation are supported by a detailed investigation, in order to re-examine the whole field and answer the questions remaining from the previous works. A combination of the different previous attempts is only possible with such investigations.

While the main aim of all the content is to be applied to an interactive VR environment, there is an important choice to make. Recent VR goggles are basically mobile devices with limited technical capabilities, especially considering memory, CPU, and GPU specifications. So, the specific requirements of interactive digital content supported by high-resolution photogrammetric 3D models, are far beyond their capacity, though it is a very simple and easy task to present the content as 360° renders. At this point, there have been two choices for the project; one to compromise the academic accuracy in geometric details and create a fake perception of reality which would cause the interactive experience to lack the aesthetic and informative aspects desired, and the second to go in full detail and create a very detailed interactive and realistic content but face the technical difficulties during the presentation phase.

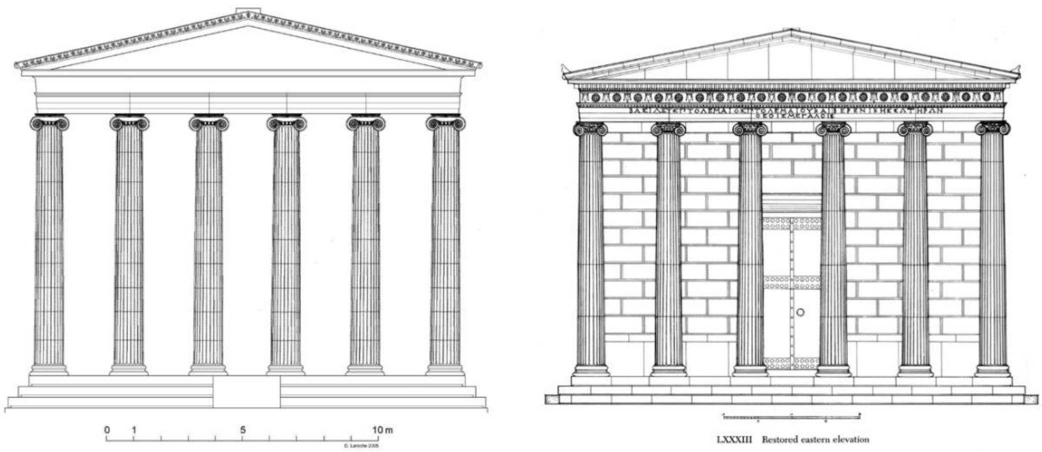

Figure 5. *Example for previous reconstruction attempts (Cavalier & des Courtils, 2013)*

Although this might be a difficult choice for a commercial content creator, it was an easy one for an academic research project, the focus of which is to face the problems and solve them. Thus, the second option is chosen, and two different kinds of presentations have been prepared. The mobile experience is set to be dependent on 360° renders as the interactive content needed to be experienced while connected to a powerful PC.

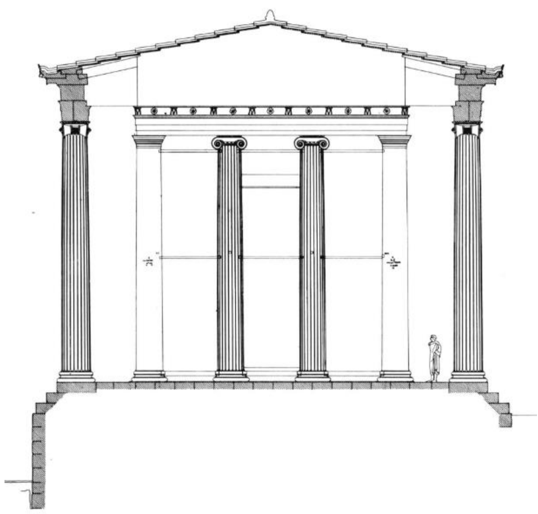

Figure 6. *Example for previous reconstruction attempts (Hansen, 1991)*

Figure 7. *Example for the 360 degree renders*

Figure 8. *Example for the combined content*

Virtual Reality Development

As mentioned above, two different options are used to present the content created. The 360° renders that have been put in order to give a walk-around feeling, have been rendered by 3DsMax and directly exported for the mobile VR goggles, while a second software, a game engine is used to combine the photogrammetric 3D reconstructions with 3D virtual models and create an interactive VR content: Unreal Engine (Figures 7-9). The final content was 28GB in size, which is obviously quite beyond the capabilities of a mobile device and needed to be experienced with the support of a powerful PC. But the uncompromising result is a perfectly realistic and archaeologically accurate 3D reconstruction of the ancient site of Letoon, which can be experienced in an interactive VR environment with complete freedom of an actual physical visit. Although the conceptional technical preparations have been made in order to carry the interactive content to the mobile experience, the period of the project was not enough to practically apply those to the content created. An ongoing new research aims to solve this problem of practicality with a combined effort of low-poly modelling and encoding.

Figure 9. *The final content*

User Impact

The effect of the produced content has been measured by a survey. The survey was conducted via questionnaire and designed to have two sections; one is to gather information demographics of the participants and the second part to include the scale developed by Rese et al. (2014, 873-4) and based on the study of Bilici and Özdemir (2019, p. 2023-4) which was the Turkish adaptation of this study to measure the experience and perceptions on the use of VR applications. The questionnaire used in the study was developed through three stages. First, researchers translated the questionnaire from English to Turkish, and then two independent researchers translated the questionnaire back into English. Secondly, two professionals from the field of tourism compared the translation-backward translation study with the original in order to eliminate idiomatic and colloquial expressions. (Netemeyer et al., 1991, p. 323-5). Finally, instructions of the survey were adapted to the VR experience of the Letoon cultural heritage site.

Random sampling method was used in selecting the study sample. Population frame obtained from the District Governorship of Fethiye. According to data obtained, the total number of visitors to the Letoon cultural heritage site has been reported as about 8655 visitors. Referring to Sekaran (1992, p. 227-9), for a given population of 8655, the sample size for a study should be determined as 368. In order to reach this sample, the potential visitors were foreseen as being tourists, the students of tourist guidance department, and the academics. However, when the trial run was ready in November, this number could not be reached due to the pandemic conditions. The visitor number to the site was very low, and the students were attending their classes online from different locations. Besides, some of the available potential participants were reluctant to participate because of the hygiene concerns related to Oculus which is used by wearing it. Despite these limitations, we have reached a sample of 102 participants between the dates of November 16th and December 9th, 2020. The data were analysed by SPSS 22.0.

Table 2. *Exploratory Factor Analysis (EFA)*

Items	**Perceived Enjoyment and Usefulness**	**Perceived Informativeness**	**Perceived Ease of Use**
The VR app invites you to discover the Letoon cultural heritage site.	.83		
It is fun to discover the scan function and its elements.	.82		
It would be beneficial for other users to experience VR app.	.80		
Using VR app is really fun.	.79		
The scan function and its elements are impressive.	.76		
It is a good idea to use VR app in the Letoon cultural heritage site.	.72		
VR app is an attractive choice for getting more information about the Letoon cultural heritage site.	.67		
The VR app showed the information I expected.		.90	
The VR app provides detailed information about the Letoon cultural heritage site.		.86	
The VR app provides the complete information about the Letoon cultural heritage site.		.84	
The VR app provides information to compare the Letoon cultural heritage site to other sites.		.81	
The VR app provides information that helps me in my decision.		.78	
It was easy to learn how to use the VR app.			.89
Handling the scan function and its elements was easy.			.80
I found the VR app to be very easy to use.			.79
The VR app was intuitive to use.			.70
Mean	4.70	3.53	4.27
Explained variance (%)	27.37	23.97	16.20
Eigenvalue	5.98	2.54	2.27
Reliability	.895	.916	.795

KMO = 0.84, Bartlett's Test = 975.563 ($p < .01$)

The scale developed by Rese et al. (2014) includes 17 items and 4 dimensions entitled perceived enjoyment, perceived usefulness, perceived ease of use, and perceived informativeness. Respondents were asked to indicate their level of VR experience with these 17 items by using a 5-point Likert scale (1= strongly disagree to 5= strongly agree). After conducting preliminary tests, we identified that one item didn't fit into the factor structure. Therefore, this incompatible item with factor structure was eliminated. Finally, exploratory factor analysis (EFA) was performed for 16 items (α=.86) and resulted in the three-factor model (Table 2). The Keiser-Meyer-Olkin overall measure was .83 which is pointing to the adequacy of the sampling and Bartlett's test of Sphericity (χ^2= 975.563, p<0.000, df= 120) was also significant at 0.01 level (Kaiser, 1974, p. 33-36).

RESULTS

Archaeology and Scientific Accuracy

Although the research based on excavations and observations has been quite productive and satisfying over the decades, it was possible to generate new information depending on observations of some stonemason signs; and complete the superstructural decoration of the temples (Figure 10).

Figure 10. *Architectural decoration of the Leto Temple*

Before the modern digital reconstructions, the archaeological reconstruction attempts suffered from the incapability of technical capacity and showed a lack of interest in details under a certain scale, just because of these limitations. However, the emergence of VR and especially the interactive contents which give complete freedom of observation to the user comes with the necessity of an indispensable elaboration on details. So, the content created in the project shows a complete attention to details like 5x5cm profiles on the krepidoma of the Leto Temple, as well as the hybrid columns of Apollo Temple with narrowing fillets (Figures 11-12).

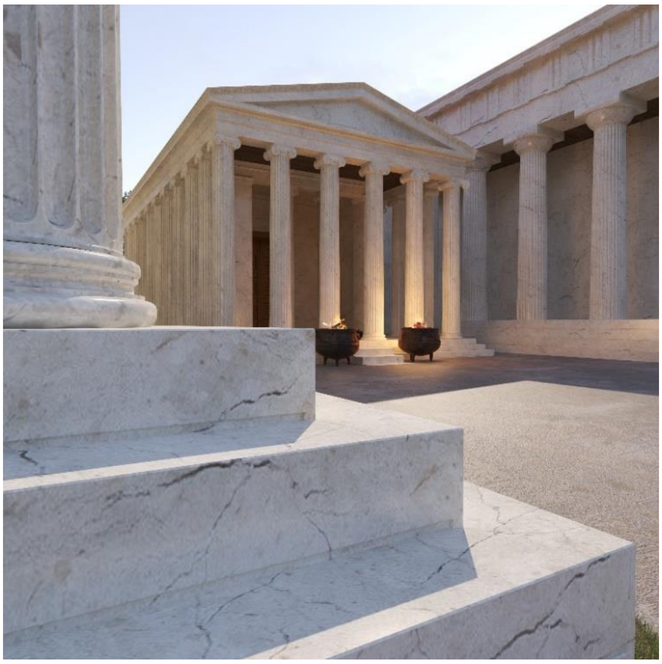

Figure 11. *The krepidoma of Leto and the hybrid columns of Apollo Temples*

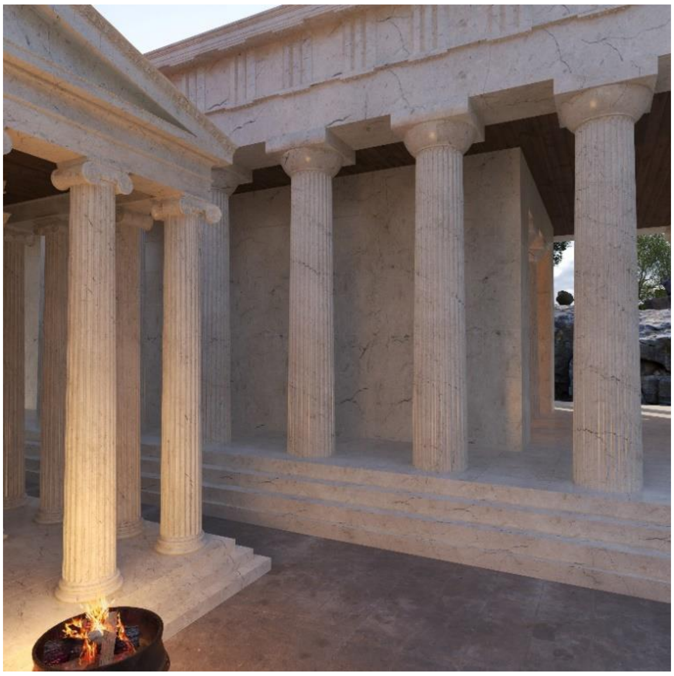

Figure 12. *The krepidoma of Leto and the hybrid columns of Apollo Temples*

Content Creation

As mentioned in the Method section, the most important result of the content creation process of the project is the technical limitations of the mobile VR devices. The dilemma of "quality vs quantity", which has been the basic issue in any mass production for thousands of years, showed itself again. The two alternative presentation methods discussed, have their own advantages and disadvantages as listed below:

- In the interactive content, the user is able to manage the whole experience of their own will and has the freedom of observing any detail, from any distance, at any time. There is no limitation of a pre-created route. Also, it is possible to add some triggers to activate certain animations like changing the time period being visited, etc. This kind of game-like experience is obviously more immersive and even more educative with the support of verbal and scripted information, as none of them is "volant" anymore. This being the upside, the downside of this method is obviously its technical requirements. The freedom earned "in the virtual environment" must be paid for with the freedom "in the real world", because the device must be connected to a PC. So, this method does not support the field experience of VR, at least not yet.
- In the content that has been created by 360° renders, the user has to move on a pre-created route and even not with the sense of walking but jumping, teleporting between viewpoints. They are limited by these viewpoints' distance and angle, which are pre-determined by the content creator. It is still possible to change the periods to be visited, but this transition cannot be supported by animations. Also, adding verbal and scripted content to these 360° renders, is only possible by converting them into a full-scale mobile application. Besides these downsides, the only but vital upside of the method is accessibility and being suitable for the field experience.

One can easily and accurately assume that this dilemma is temporary and will be left behind very soon. To get to that point, however, projects must be carried on both by academics and commercial companies. The results from the "User Impact" part of this study indicate a considerable demand for such content.

User Impact

In the scope of the study, it was aimed to reach possible visitors from different occupational and age groups. The information about the participants' demographics can be seen in Table 3.

Table 3. *The Demographics of the participants*

		n	%
Gender			
	Female	51	50.0
	Male	51	50.0
Age			
	<= 20	2	2.0
	21-30	17	16.7
	31-40	41	40.2
	41-50	25	24.5
	51-60	6	5.9
	>= 61	11	10.8
Current Education			
	Primary	3	3.0
	High school	19	18.8
	Undergraduate	39	38.6
	Graduate	40	39.6
	Missing	1	1.0
Occupation			
	Company Employee	17	16.67
	Academician	23	22.55
	Student	14	13.73
	Tourist Guide	16	15.69
	Officer	6	5.88
	Business Owner	8	7.84
	Retired	15	14.71
	Other	3	2.94
Total		**102**	**100**

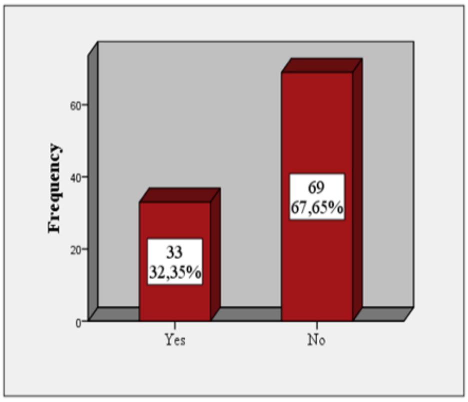

Figure 13. *Previous experience of VR use*

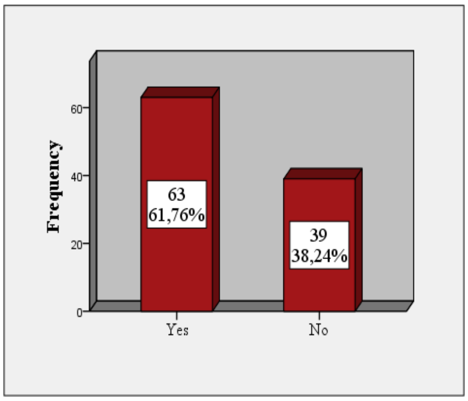

Figure 14. *Knowledge on VR app*

The survey data gathered has provided valuable information on the participants' previous knowledge and experience of VR applications. The majority of the participants (67.65%) have never used VR applications (Figure 13) but most of the participants (61.76%) have some knowledge of the subject (Figure 14). For the aim of the present study, their opinions on the potential use of VR technologies in virtual tourism were asked and 97.06% of the participants reported that VR would be used in the sector.

The participants' perceptions of the use of VR can be seen in Table 4. The data showed that they really enjoyed using the VR application for the Letoon cultural heritage site ($\bar{x}$ = 4,87) while the application was reported as not providing complete information they wanted to know ($\bar{x}$ = 3.01).

Table 4. *The participants' experience on using VR app*

Items	Mean	SD
I found the VR app to be very easy to use.	4.60	.68
The VR app was intuitive to use.	**3.55**	**1.06**
It was easy to learn how to use the VR app.	4.47	.82
Handling the scan function and its elements was easy.	4.49	.82
Using VR app is really fun.	**4.87**	**.53**
The scan function and its elements are impressive.	4.64	.67
It is fun to discover the scan function and its elements.	**4.78**	**,54**
The VR app invites you to discover the Letoon cultural heritage site.	4.68	.72
VR app is an attractive choice for getting more information about the Letoon cultural heritage site.	4.62	.61
It is a good idea to use VR app in the Letoon cultural heritage site.	4.67	.68
It would be beneficial for other users to experience VR app.	**4.73**	**.57**
The VR app showed the information I expected.	3.67	1.13
The VR app provides detailed information about the Letoon cultural heritage site.	**3.50**	**1.12**
The VR app provides the complete information about the Letoon cultural heritage site.	**3.01**	**1.26**
The VR app provides information that helps me in my decision.	3.87	1.10
The VR app provides information to compare the Letoon cultural heritage site to other sites.	3.65	1.16

Participants considered the VR application on cultural heritage sites as being valuable ($\bar{x}$ = 4.77) (Table 5). In addition, they thought that the VR application was a convenient application that carried the users out to the positive outcomes ($\bar{x}$ = 4.71). Overall, it can be concluded that the attitude of the participants is favourable.

Table 5. *The participants' attitude towards using VR app*

Items	Mean	SD
I think VR app about cultural heritage sites is a valuable application.	4.77	.53
VR app provides good creative ideas about cultural heritage sites.	4.62	.70
VR app is an inspirational tool for the creative ideas on cultural heritage sites.	4.65	.61
VR applis ideal to provide an overview about cultural heritage sites.	4.69	.53
I think VR app is an convenient application in the cultural heritage sites and it carried the users out to the positive outcomes.	4.71	.62
Total Mean	**4.68**	**.462**

The behavioural intention to use VR were also analysed (Table 6). It can be concluded that they would use the VR applications about the cultural heritage sites in the future ($\bar{x}$ = 4.67) and they would also recommend their friends to use those applications ($\bar{x}$ = 4.64).

Table 6. *Behavioural intention to use*

Items	Mean	SD
I will use the VR applications about cultural heritage sites in the future.	4.67	.68
…. download or use other VR apps about cultural heritage sites immediately.	3.66	1.18
… give the VR app priority over the books/brochures and catalogues.	3.77	1.17
… give the VR app priority over getting information on the cultural heritage sites than the other options.	3.60	1.28
I will recommend using VR app to my friends.	4.64	.74
I will use the VR app regularly in the future.	3.99	1.08
Total Mean	**4.05**	**.79**

The results of the correlation analysis (Table 7) showed that there was a moderately significant positive relation (r = .61) between perceived enjoyment and usefulness and attitude towards the use of VR. There were also somewhat lower but again positive relations between the perceived enjoyment and usefulness and perceived informativeness of the application (r = .43), and also between perceived enjoyment and usefulness and perceived ease of use (r = .20). Besides, another moderately significant positive relationship was found between the participants' attitude towards the use of VR and their behavioural intention to use the VR application (r = .61).

Table 7. *The results of the correlation analysis (n=102).*

	M	SD	1	2	3	4	5
1.Attitude towards Use of VR	4.68	.462	-				
2.Perceived Enjoyment and Usefulness	4.70	.486	.61**	-			
3.Perceived Informativeness	3.53	.996	.43**	.43**	-		
4.Perceived Ease of Use	4.27	.672	.20*	.10	.16	-	
5.Behavioral Intention to Use	4.05	.785	.61**	.44**	.37**	.26*	-

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

The multiple linear regression analysis was run to examine the effects of perceived enjoyment and usefulness, perceived informativeness, and perceived ease of use on the attitude towards the use of VR. The results showed that in the regression model (F = 24.57, p = .000), the factors of perceptions on VR use explained 43% of the variance. Both the perceived enjoyment and usefulness and perceived informativeness are significant predictors of the attitude towards the use of VR (Table 8).

Table 8. *The results of multiple linear regression analysis*

	β	***t***	***p***
Perceived Enjoyment and Usefulness	0.53	6.18	.00*
Perceived Informativeness	0.19	2.20	.03*
Perceived Ease of Use	0.14	1.47	.15
R^2 = .43 F = 24.57 p = .000			
*Dependent Variable: The Attitude towards Using VR			
The Attitude towards Using VR	0.62	7.88	.00*
R^2 = 0.38 F = 62.10 p = .000			
**Dependent Variable: Behavioural Intention to Use			

CONCLUSION

It is obvious that the available software and hardware are more than capable to produce realistic and scientifically accurate content, but the limitations of mobile viewing devices have compromised the user experience. However, by the time this paper is prepared, a new version of the primary game engine used in this project has been launched, which has been focused directly on this problem; and this indicates that the software developers are sharing the same concerns with the content creators. Considering these new game-changing developments in graphic visualisation technologies, emerging faster than a paper to be published, it would be safe to suggest that the following projects and VR attempts will be able to focus on different details, like adding more information, more user-friendly interfaces, and even more details on models.

The user effect results also prove a necessity for ever-developing content creation, as it is quite obvious that the hardware needed to view these contents is highly affordable and one thing the consumer needs is the satisfying content itself to supply the huge demand. However, the important thing is that consumer habits should be carefully examined especially during the Covid-19 pandemic. The pandemic created an ever-lasting fear of using unowned devices. Thus, cloud or even browser-based content sharing should be adopted to let the consumer use their own device without the necessity of downloading huge content.

Finally, this 6-month limited research shows that the future of cultural tourism, as well as cultural heritage management, lies in the Digital Heritage contents, which need to be developed both in quality and quantity.

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