3D VIRTUAL RECONSTRUCTION AND VISUALISATION OF THE ARCHAEOLOGICAL SITE CASTELLET DE BERNABÉ (LLÍRIA, SPAIN)

RECONSTRUCCIÓN VIRTUAL Y VISUALIZACIÓN 3D DEL YACIMIENTO ARQUEOLÓGICO CASTELLET DE BERNABÉ (LLIRIA, ESPAÑA)

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Abstract:

3D virtual reconstruction of cultural heritage is a useful tool to reach many goals: the accurate documentation of our tangible cultural legacy, the determination of mechanical alteration on the assets, or the mere shape acquisition prior to restoration and/or reconstruction works, etc. Among these goals, when planning and managing tourism enhancement of heritage sites, it demands setting up specific instruments and tools to guarantee both, the site conservation and the visitors' satisfaction. Archaeological sites are physical witnesses of the past and an open window to research works and scientific discoveries, but usually, the major structures do no exist nowadays, and the general public takes long time and many efforts to elaborate a mental reconstruction of the volumetry and appearance from these remains. This mental reconstruction is essential to build up a storyline that communicates efficiently the archaeological and historic knowledge and awares the public about its conservation. To develop this process of awareness about conservation, heritage interpretation starts with the mental inmersion of the visitors in the archaeological site, what 3D reconstruction definitely helps to achieve. Different technologies exist nowadays for the 3D reconstruction of assets, but when dealing with archaeological sites, the data acquisition requires alternative approaches to be used, as most part of the assets do not exist nowadays. In this work, we will deal with the virtual reconstruction and visualisation of the archaeological site *Castellet de Bernabé* by following a mixed approach (surveying techniques and archaeological research). We further give a methodology to process and merge the real and virtual data in order to create augmented views of the site.

Key words: virtual archaeology, digital archaeology, cultural heritage interpretation, 3D reconstruction, tourism enhancement

Resumen:

La reconstrucción virtual 3D del patrimonio cultural es una herramienta muy útil para alcanzar varios objetivos: el registro preciso de nuestro legado cultural tangible, determinar alteraciones físicas en los bienes o simplemente registrar las formas y estructuras previamente a trabajos de restauración y/o reconstrucción, etc. Entre estos objetivos, cuando se planifica y gestiona la puesta en valor turístico de sitios patrimonio, es necesario establecer instrumentos y herramientas para garantizar la conservación del patrimonio, a la vez que la satisfacción del visitante. Los yacimientos arqueológicos son testimonios del pasado y son una ventana abierta a los trabajos de investigación y hallazgos científicos, pero a menudo las estructuras principals ya no existen y el público general necesita mucho tiempo y esfuerzo para elaborar una reconstrucción mental de la volumetría y apariencia a partir de las ruinas. Esta reconstrucción mental es esencial para construir una línea argumental que comunique de forma eficiente el conocimiento arqueológico e histórico, y así se conciencie al público sobre su conservación. Para desarrollar este proceso de concienciación sobre la conservación, la interpretaciñon del patrimonio empieza con la inmersión mental de los visitantes en el yacimiento arqueológico, tarea en la que la reconstrucción 3D ayuda de forma decisiva. Actualmente existen diferentes tecnologías para la recostrucción 3D de los bienes, pero tratándose de yacimientos arqueológicos, la adquisición de datos necesita enfoques alternativos, pues la mayoría de las estructuras no existen en la actualidad. En este trabajo, se trabaja con la reconstrucción y visualización virtual del yacimiento arqueológico del Castellet de Bernabé, siguiendo un enfoque mixto (técnicas topográficas e investigación arqueológica). Además, se propone una metodología para procesar y aunar los datos reales y virtuales para crear visualizaciones aumentadas del yacimiento.

Palabras clave: arqueología virtual, arqueología digital, interpretación del patrimonio cultural, reconstrucción 3D, puesta en valor turístico

1. Introduction

Cultural Heritage (CH) is a fundamental expression of the richness and diversity of our culture and therefore, its conservation, documentation and dissemination is thus considered of the utmost importance. The 3D virtual reconstruction of CH buildings and archaeological sites is of high interest for different reasons, namely the

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accurate documentation of our tangible cultural legacy, the determination of mechanical alteration on the assets, or the mere shape acquisition prior to restoration and/or reconstruction works, etc.

When planning and managing tourism of archaeological sites, setting up specific instruments and tools to guarantee both the site conservation and the visitors' satisfaction are demanded. One of the main tools to achieve both objectives (conservation and satisfaction) is heritage interpretation (Ham, 1992), as it provides archaeological and historic knowledge and awareness to the public. Among the properties included in the CH, the archaeological sites are considered physical witnesses of the past and an open window to decades of excavation, consolidation and restoration works as well as scientific discoveries. Reconstructing and understanding the past allows local people to reinforce their identity and permits the general public to access to history (Viñals, Alonso-Monasterio, & Alonso-Monasterio, 2013). Interpreting an archaeological site usually involves site mental reconstruction as a first step, process in which interpreters take long time to explain visitors the volumetry, aspect, colours, etc. of the settlement when it was inhabited. This is a key point to interpretation, which 3D reconstruction definitely helps to achieve.

Different technologies exists nowadays to deal with the 3D reconstruction of assets, mainly stereo-photogrammetry, laser scanning or structured light-based techniques, though other approaches have been investigated (Sansoni, Trebeschi, & Docchio, 2009; Granero-Montagud et al., 2013; Groves, Portalés, & Ribes-Gómez, 2014; Zhang et al., 2012; Zlot et al., 2013). The visual appearance or photometric properties is also of utmost importance. These aspects can be acquired from the use of conventional cameras, mobile phones, or cameras working in other spectral ranges, such as thermal or infrared cameras. Many works can be found in this regards, such as Dei, Mauro, & Bitossi (1998); Guarnieri, Remondino, & Vettore (2006); Pires & Cruz (2007); Navarro et al. (2009); Lerma, Cabrelles, & Portalés (2011) and Remondino (2011).

However, when dealing with archaeological sites, the 3D reconstruction and visualisation is usually not fully possible with the use of acquisition devices, because most or part of the assets do not exist nowadays. In this sense, alternative approaches have to be used that are mainly based on a rigorous documentation of the past and a survey of the current state of the site. Once this is done, the 3D reconstruction can be performed with standard 3D editing software. In Ercek, Viviers, & Warzée (2010) it is highlighted the relevance of the close collaboration between archaeologists, engineers and computer graphics designers in order to achieve a reliable 3D virtual reconstruction of archaeological sites. Following this, they report a 3D virtual reconstruction of an archaeological site in Itanos, Crete. In Garrido (2013) the research for a virtual reconstruction of an Andalusian palace is done by surveying the current state of the palace plant and formulating contrasted hypothesis on its elevations. In He, Ming, & Jin (2013), a methodology is proposed for a virtual reconstruction of an archaeological heritage in East Asia, which consists on a combination of an archaeological survey, historical photos, historical archive and artistic paintings. In Ruiz et al. (2015), drones are used in order to survey the current state of an archaeological site.

In this work, we will deal with the reconstruction and visualisation of the archaeological site *Castellet de Bernabé* by means of virtual reality technology, following a customised mixed methodology for the rigorous documentation on the former state of the site that includes on site observation, comparative research and archaeological interpretation, among others. This methodology was recently introduced in Portalés, Alonso-Monasterio, & Viñals (2016). We further show different visual materials derived from the virtual model, which includes augmented images of the site that combine real and virtual scenes. With the use of these materials we aim at enhancing heritage values by allowing the intellectual and emotional engagement to CH of the site's visitors.

2. The archaeological site

The tourism enhancement project for the *Castellet de Bernabé* Archaeological Site was developed under the framework of the Interreg IIIC European Project: Vistoria: European Historic Landscapes, carried out by several European partners in the past years, as the case study. Project partners and researchers agreed to develop a group of actions focused on recreational use of this settlement: inventory and recreational evaluation of natural and cultural resources; inventory of facilities and recreational services and proposal of new ones; study of the potential and real demand; recreational carrying capacity; design of an interpretative programme focused on cultural and natural heritage, including interpretative routes; design and production of educational dissemination materials (touristic maps, archaeological guides, kids' booklets, etc.).

The archaeological site of *Castellet de Bernabé* was first excavated in 1984, and it was restored in 1988. It is located in Llíria (Fig. 1), in the inland of Valencian Region (Spain). It is an Iberian settlement that flourished from the 5th to the 3rd century BC (Pla Ballester, 1945; Guérin, 1995; Guérin, 2003), and was a village in territory of Edeta (actually Llíria), that spread from the Mediterranean mountain range of

(a)

(b)
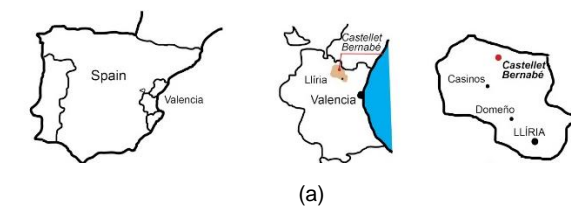
Figure 1: a) Location of *Castellet de Bernabé* and b) an overall image of the archaeological site.

Calderona to the Túria river. The Iberians were a diverse western Mediterranean civilization group that shared common cultural characteristics, including urban and trade networks.

The urban planning of the *Castellet de Bernabé* is a typical fortified Iberian village located on the top of a hill of 486 m above sea level that occupied 1000 m^2, inhabited by approximately fifty people. It has a unique central street with houses, larders, workshops, mills, furnaces, cistern, forges and stables on both sides, enclosed by a stonewall. Some of these buildings had one or two storeys and the entrances had wood doors, built with stone bases with rows of mud bricks or adobe facing on top; they had flat roofs made of beams with branches, which were then covered with thick layers of mud mixed with rosmarine straws.

This settlement is particularly relevant because the Iberians that inhabited it created the cultural landscape that nowadays defines this territory: sustainable use of Mediterranean forest combined with a dryland farming area with olives, almonds and, most important, vineyards, as wine production has deeply defined the region. The other key point with the *Castellet de Bernabé* is related to the writing, one of the most important legacy of the Iberian civilization, as there was found very representative elements of writing in this archaeological site.

The public enhancement of these values, transmitting the relevance of this archaeological site and rising awareness about this settlement is the focus of a heritage interpretation, so that people develop the sense of place and adopt pro-active conservation behaviours (Tilden, 1957). This task is supported by communication tools, both personal and non-personal, and 3D reconstruction is really useful to achieve the interpretation aims.

3. 3D and photorealistic virtual reconstruction

As it was introduced above, the virtual reconstruction of the *Castellet de Bernabé* is challenging, as most of the site is nowadays not present. Alternative approaches to those regarding laser scanning were used. In particular, the site was reconstructed by using a customised methodology in order to determine its original size, materials and colours. The methodology mainly involves a rigorous documentation of the past, gathering new data of the current state of the site. Finally, the 3D virtual reconstruction was carried out by combining all the information. In order to make correct decisions and to obtain a reliable 3D virtual reconstruction of the site, a close collaboration between archaeologists, engineers and graphic designers was required in the different stages. The collected information included:

- **Archaeological survey**: the current condition of the archaeological site is of primary importance and is used as the basis for the virtual reconstruction. In order to acquire the current shape of the ground plant of the site, a topographic map with countour lines was used, with a scale of 1:200. Additionally, an aerial image was vvsailable (Fig. 2) which was helpful for the identification of small details and artefacts.

- **On site images**: there were gathered, analysed and incorporated to the reconstruction many detailed

Figure 2: Aerial image of the archaeological site.

Figure 3: Gathering images and measuring camera locations.

images regarding colours and textures (Fig. 3). When gathering these images, the location from which they were acquired were measured with a measuring tape and marked on a map of the site, as this information was of relevance for deriving some visual materials of the site (see Section 4). Also, some parameters of the camera (focal length and field of view) were of relevance, and thus were also annotated on a notepad.

- **Bibliographic research** (digital, graphical and written materials) including: drawings and written detailed description of the original shape of the houses and the artefacts, as well as detailed description of the usage and land exploitation of the site resources. This kind of information was originally produced by archaeologists, graphical artists and art historians, and can be found in (Guérin, 1999; 2003; Guérin & Silgo, 1996)

- **Case study**: review of other archaeological Iberian sites, including Bastida de les Alcusses (Moixent), Puntal dels Llops (Olocau) or Tossal de Sant Miquel (Llíria), among others in the Valencian Region. From this review we could retrieve overall information on similar Iberian sites that shared architectonical properties with the *Castellet de Bernabé*.

- **In-depth interview**: the archaeologist expert in the *Castellet de Bernabé* excavation and leader of the study, Pièrre Guérin, was the referee along all the process of the 3D reconstruction of the site, which is here reported. His supervision and feedback was essential for the good performance of the 3D reconstruction and visual appearance of the site.

- **Comparative research**: it was also developed a field study in the area of Middle Atlas, as the project archaeologist indicated that many areas of Moroccan Middle Atlas had still very similar housing to those constructed by Iberians in Lliria. As a result,

many visual materials of these settlements (Fig. 4) were gathered, which could be incorporated to the reconstruction.


Figure 4: Moroccan Middle Atlas housing.

Once all the data was collected, the 3D virtual reconstruction of the site was carried out using commercial software. From the map with contour lines, a digital terrain model (DTM) was generated using ArcGIS v9.3, and then exported to Autodesk 3ds Max v2010 to serve as a ground basis on where to build the 3D models. The topographic map and the aerial images of the site served to draw the plant of the site. From the written texts and drawings, other issues such as the height of the houses were derived. Thus, archaeological papers (Guérin, 1999; 2003; Guérin & Silgo, 1996), revealed the dimensions and use of each department in the settlement as well as of the overall site, like which departments had one or two storeys and why. Thus, these data were used to make decisions during the reconstruction process. A sample image showing the basic shape of the site during the reconstruction process is depicted in Fig. 5. Different colours just indicate information included in different layers, such as walls, roofs, doors, small objects, etc.

Once the site was virtually reconstructed in its shape, different materials and textures were added in order to give it a photorealistic appearance. The archaeologist Pièrre Guérin, project coordinator and the most experienced researcher of the *Castellet de Bernabé*, closely reviewed the process of virtual reconstruction, explaining and putting into context each colour, texture and dimension. For instance, in Fig. 6a a grain mill is shown, which is partially missing. Thanks to the aforementioned bibliographic research, this artefact was reconstructed in its original shape (Fig. 6b to Fig. 6d).

Figure 5: Basic shapes during the virtual reconstruction of the *Castellet de Bernabé*.
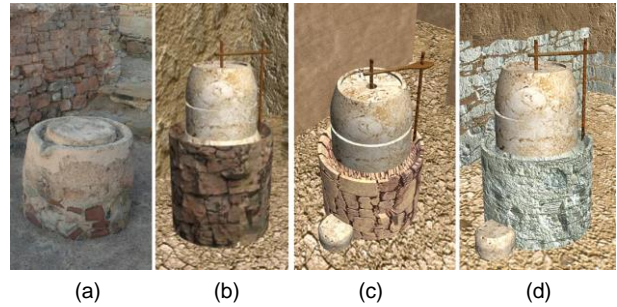
Figure 6: A grain mill in one of the houses of the *Castellet de Bernabé*: a) Image of the current state of conservation; b) 3D reconstruction of the existing and the missing part and initial proposal of the graphic designer for the textures; c) Result after the first round of review with the archaeologist advice; d) Final design approved by the archaeologist.

With the further supervision of the archaeologist, the graphic designer gave it a more accurate appearance. The final design is depicted in Fig. 6d.

Then, visits to the archaeological site allowed the virtual reconstruction team to check details such as colours, textures, natural light or the landscape. Finally, further visits to settlements in Morocco revealed details that were neither reflected in the literature nor in the remains, e.g. the aspect of the unions between walls and roofs, and the appearance that had a joist when metting a wall. The result of the 3D and photorealistic reconstruction is presented in Fig. 7, where in Fig. 7a, an overall view of the generated DTM together with the reconstructed site is depicted. In Fig. 7b, a view of the interior of the site is given, where the textures and materials (of the walls, doors, etc.) can be better appreciated. As it can be seen, the virtual environment was also completed with a mapping of the sky, in order to enhance its overall real appearance.

4. Visualisation

After the 3D reconstruction of the *Castellet de Bernabé* archaeological site, there were developed different kinds of visual materials, being part of the different interpretation materials designed for the settlement communication through different channels. Based on the 3D virtual reconstruction of the site, a total of four different visual materials were prepared: 1) a past and present book; 2) a virtual flight; 3) an explorer diary; and 4) multi-use trail. These visual materials are described in more detail in the following sub-sections.

4.1. Past and present book

The first visual material, which was the main of the interpretation materials, was a book about the past and the present of the archaeological site (Viñals, Planelles, & Guérin, 2008a), mainly focused on general public profile. Within this book, we aimed at showing to readers the augmented views of some images of the current state of the site, with the reconstructed virtual model. Thus, the visualisations included require both images of the site (which were recently acquired) and a view of the 3D reconstructed model. Additionally, in order to geometrically fit both views (the real one and the virtually generated one), the virtual camera of the 3D reconstruction must match (focal length, field of views, location, etc.) the corresponding real camera for each of the views. This information was gathered during the on

(a)

(a)

(b)
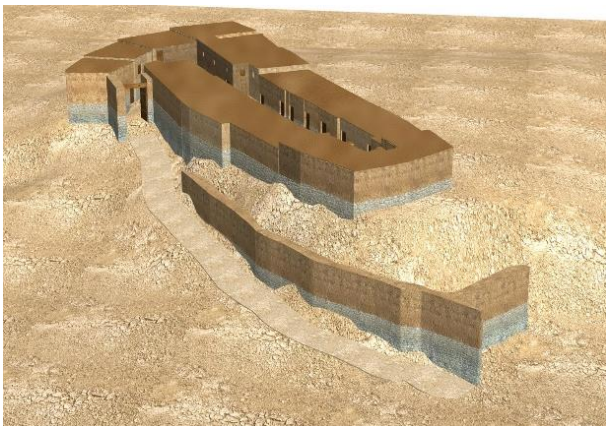
(b)

Figure 7: Virtual reconstruction of the Castellet de Bernabé: a) Overall view of the DTM and the 3D reconstructed site; b) Detailed view of the interior of the site.

Figure 8: One of the views for the book displaying the past and the present: a) Real image acquired with a conventional camera; b) Augmented image with the virtually reconstructed site.

site observation, as introduced in Section 3. A sample of the generated views is given in Fig. 8, and another sample is published in Wikipedia (2014).

4.2. Virtual flight

Another visual material of the 3D reconstruction was a virtual flight in form of a short movie developed within the 3D Studio Max software. To that end, a virtual camera was built inside the virtual environment, which moved around the site, showing first an overall view of the site from a zenithal position, and then a virtual travel inside the site from a walking position. The video can be accessed from (YouTube, 2016).

4.3. Explorer Diary

Other material produced was an explorer diary for kids (Viñals, Planelles, & Guérin, 2008b) (Fig. 9), where basically the 3D reconstruction was the support material for the illustrator that produced more kid-friendly visualisations of the *Castellet de Bernabé*.

4.4. Multi-use trail

It was also designed and implemented a multi-use trail to the settlement "Walking, riding and biking to the *Castellet de Bernabé*" (Fig. 10). Related to this facility, it

was also produced an interpretive visitor map (Alonso-Monasterio, 2014), in which were included contents and images inspired by the 3D reconstruction.

5. Discussion

As formerly introduced, interpreting an archaeological site usually involves site mental reconstruction as a first step. In this regard, the derived visualisation tools described in this paper, at different levels, have proved to be useful in generating archaeological and historic knowledge and awareness to the general public through the different dissemination and/or presentation channels (e.g. edited books, movies, etc.).

Regarding the derived visualisation provided by the past and present book (Section 4.1), it has to be mentioned that, although these views mix real and virtual objects by keeping a spatial relationship between both realms, this cannot be considered an augmented reality (AR) application, as other requirements are not met, namely, the augmentation is not interactive in real-time (Azuma, 1997). However, given the existing virtual model and aligment with the real world, it would be straightforward to build an AR application by the use of a dedicated software (e.g. ARToolKit), that allows users to visualise both environments (real and virtual) in situ by means of e.g. a mobile device or a head mounted display provided

(a)

(b)

Figure 9: Some contents of the explorer diary of the *Castellet de Bernabé*. Illustrations made by C. Maiques and layout by Aerocow.

(a)

(b)

(c)

Figure 10: Map of the route to *Castellet de Bernabé* archaeological site: a) Back side with site interpretation contents; b) Detail images showing explanations of the settlements; c) Legend.

with a live video-camera. We propose this as future work for the site. Some examples of AR-based applications for CH can be found in (Portalés, Lerma, & Pérez, 2009; Portalés, Lerma, & Navarro, 2010).

Regarding the overall 3D virtual reconstruction of the *Castellet de Bernabé*, the lack of a good conservation state of the archaeological site reveals the need to define a strategy for its 3D virtual reconstruction. The given methodology (described in Section 3), which is similar to other works referred in the introduction section, and involves the close collaboration between archaeologists, engineers and graphic designers, has proven to be efficient in the accurate reconstruction of the site. We find the aforementioned data sources as essential, though additional information can be added (e.g. other kind of documentation material) to complement the described information, whenever it is available. In this regard, we can say that the reconstruction of the site *Castellet de Bernabé* has been accomplished by means of multimodal information, which includes different kind of data, such as images,

text, interviews, etc., and remains as future work to improve the reconstruction fidelity, provided that additional information is available.

Finally, the presented reconstruction methodology and visualisation tools can be extrapolated to the virtual reconstruction of other archaeological sites, provided that enough documentation material of the site exists.

6. Conclusion

Heritage interpretation is a powerful tool that enhances cultural heritage values and allows the intellectual and emotional engagement of the visitors with the related assets/sites. This process is developed from original objects, using a variety of resources. 3D reconstruction of archaeological sites allows an easy and rapid intellectual access to heritage. Thus, visitors can expend time and energy to emotionally engage with the site, what leads to deeper connections that allow mindfulness and enriched understanding. We believe that thanks to the 3D and photorealistic reconstruction of the *Castellet de Bernabé*, visitors can develop pro-conservation behaviours and sense of place.

These virtual reality-based techniques arise as highly efficient tools to support interpretation, especially in CH interpretation of archaeological sites, where it is necessary to describe and create mental images of the sites to boost the deep understanding of the heritage and of the civilizations that created them. They provide a synoptic image upon which the interpretation discourse can be constructed.

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