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VIRTUAL ARCHAEOLOGY: FROM ARCHAEOLOGICAL EXCAVATION TO THE MANAGEMENT AND DIFFUSION OF HERITAGE. *LES CASES DE LA CATEDRAL* (TORTOSA) AND THE PROTOHISTORICAL SETTLEMENT OF *LA CELLA* (SALOU), TARRAGONA

LA ARQUEOLOGIA VIRTUAL: DE LA EXCAVACIÓN ARQUEOLÓGICA A LA GESTIÓN Y SOCIALIZACIÓN DEL PATRIMONIO. LES CASES DE LA CATEDRAL (TORTOSA) Y EL YACIMIENTO PROTOHISTÓRICO DE LA CELLA (SALOU), TARRAGONA

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Highlights:

- Photogrammetric technique saves the real information that emerges and prevents much of it from disappearing, a common occurrence in archaeological excavations.
- Virtual reconstruction is an effective method of presenting the results in an educational way for the general public.
- The final product needs to show the result of a scientific hypothesis in an attractive and understandable way.

Abstract:

This article reports how the new information technologies are used in two practical examples in the field of archaeology from the early stages of excavation up to the reporting of the results. The first example is an urban settlement focused on the process of documentation and recording, the presentation of the archaeological remains and the resulting museum discourse in Tortosa, Tarragona (Spain). The second example is a settlement near the coast with no urban problems or conditions, which is more focused on the diffusion of research results through a variety of virtual communication channels (*La Cella*, Salou). In this regard, we present a variety of techniques and systems that we apply to achieve our objectives. Photogrammetry is now an essential tool for recording archaeological data because it facilitates fieldwork, provides extremely accurate measurements and considerably increases the quality of the result. It also enables archaeological and heritage research to be socialized and the results target scientific and interpretative analysis. If it is combined with the appropriate software, the remains of artefacts and buildings recovered at the sites, and which in some cases cannot be conserved, can be displayed in 3D. Finally, it can be used to make recreations and virtual interpretations that can present all these archaeological data to a non-specialized public in the form of a virtual museum, an immersive virtual reality experience, or can be applied to improve scientific research, through 3D modelling and virtual experimentation.

Keywords: dissemination; 3D reconstruction; virtual recreation; photogrammetry; virtual reality; heritage.

Resumen:

En este artículo presentamos una metodología de trabajo basada en la aplicación de las nuevas tecnologías de la información y la comunicación en el campo de la arqueología desde las primeras fases de excavación hasta la exposición final de los resultados mediante dos ejemplos prácticos, un yacimiento arqueológico en un contexto urbano, centrado o bien en todo el proceso de documentación y registro o bien en la propia presentación y discurso museístico de los restos arqueológicos en Tortosa, Tarragona (España); y un poblado justo al lado de la costa, sin ninguna problemática urbanística o condicionantes urbanos, centrado más bien en la socialización de los resultados mediante diversos canales de difusión virtuales (*La Cella*, Salou). En este sentido, presentamos algunas de las técnicas o sistemas utilizados para conseguir estos objetivos: en primer lugar, la fotogrametría se ha convertido en una herramienta imprescindible para el registro de datos arqueológicos (agiliza el trabajo de campo, tiene una gran precisión métrica y aumenta considerablemente la calidad del resultado final), y su uso permite una socialización de la investigación arqueológica y del patrimonio sin olvidar que se trata también de una herramienta de trabajo que permite analizar los resultados obtenidos a nivel científico e interpretativo. En segundo lugar, la combinación de esta técnica, con el uso del programa adecuado, permite el crear modelos tridimensionales (3D) de los restos muebles e inmuebles recuperados en yacimientos que en algunos casos son imposibles de conservar. Finalmente, se pueden efectuar recreaciones e interpretaciones virtuales que acerquen todos estos datos arqueológicos a un público general, no especializado, ya sea en forma de museos virtuales ya sea en forma de experiencias inmersivas de realidad virtual, y que además sirvan para avanzar en la investigación científica, mediante el modelado 3D y la experimentación virtual.

Palabras clave: divulgación; reconstrucción 3D; recreación virtual; fotogrametría; realidad virtual; patrimonio

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1. Introduction

The *Rovira i Virgili* University's Protohistory and Archaeology Research Group (GRESEPIA, *Grup de Recerca Seminari de Protohistòria i Arqueologia*) has been carrying out much of its research in the south of Catalonia for many years now. Of particular interest are the archaeological excavations in the protohistoric site of Assut (Tivenys, Baix Ebre), which has been underway since 2000, the urban dig in the city of Tortosa (2004) and the excavation of the protohistoric site of *La Cella* (Salou, Tarragonès) since 2010. The main purposes of our work are not only to document our findings and further the bounds of research but also to communicate the results. To do so, we have always tried to use innovative instruments that are the most appropriate for each situation.

Our research group now makes extensive use of the new information and communication technologies to carry out the research itself and make subsequent explanations attractive. The main challenges our group now faces are the use of photogrammetry, the three-dimensioning of archaeological structures and small finds and the three-dimensional (3D) virtual model of the sites where we work. The work methodology described in this article is based on a variety of virtual archaeology techniques. Photogrammetry is a system that streamlines all documentation processes, especially graphs and planimetries. It minimises distortion errors from the lens and more traditional drawing techniques, and generates a model with relative measures that can be transformed into real measurements by using ground control points/marks (Caro & Hasen, 2015). Another technique is the virtual reconstruction or virtual recreation of archaeological sites. This technique is used to interpret our work and is based on the analysis of the results obtained during the excavations.

One of the challenges our team faces is to apply photogrammetric methods to specific sites in order to solve specific problems. Urban sites tend to have problems of working dynamics, preserving and presenting archaeological remains, and integrating them into modern museum discourse. More natural sites, on the other hand, tend to have problems with the diffusion of results. Specific communication channels need to be used to convert the heritage into tourist attractions that the local authorities maintain and conserve.

2. Archaeological drawings

All archaeological excavations need to be documented graphically and photographically. A planimetric process, using an architectonical approach, is important in horizontal stratigraphy. Vertical stratigraphy and its documentation provide means to understand the sequence of occupations (Harris, 1989).

Advances in computing, the introduction of design programs and the implementation of photogrammetry have obviously greatly facilitated all archaeological processes, especially data collection and fieldwork, but the rapid rate of progress requires professionals to be constantly trained.

At present, data can be acquired by two basic systems that enable the cultural heritage to be digitalised and objects to be displayed in 3D. On the one hand, there is a digital image-based system (Image-Based Modelling, IBM) which obtains data by matching photographic images that are subsequently processed by specialised software using algorithms (Remondino & El-Hakim, 2006). And on the other, Range-Based Modelling (RBM) uses active sensors to geometrically document materials and structures, mainly by means of laser scanning devices (Lo Brutto & Spera, 2011). The final choice of the methodology to obtain data depends on a variety of factors which, in our case, were economy (Kersten & Lindstaedt, 2012) and the speed of processing of the IBM system. Initially, it was not very competitive because of its computation demands, but it is now one of the quickest and cheapest ways of modelling archaeological objects and structures.

Once the archaeological remains have been digitalised, orthographic images are obtained which are then processed by computer-assisted design (CAD) programs to create the appropriate planimetry. This part of the process (plans, elevations and sections) is generated with programs such as Autodesk AutoCAD or DraftSight. The graphics drawings that contain all the constructive, chronological and stratigraphic information are created always using a real scale. Subsequently, it is scaled to generate specific plans. For materials such as ceramics, metals, coins or fauna the programs Adobe Illustrator or Inkscape can be used.

Although the human eye is a unique and precious tool, and various methods of drawing are still used, it is evident that archaeological documentation has extra value, if orthographic images that are sharper and contain more information are applied. Consequently, planimetric drawings must increasingly focus on providing information that complements these images (for example, historical information about different construction phases and the urban evolution of a particular settlement) evinces the constructive techniques of the surface of the walls, which can indicate possible reforms, and observes stratigraphic relationships between walls so that they can be interpreted (Fig. 1).

2.1. Photogrammetry as a method for obtaining data

The photogrammetric technique discussed in this paper aims to create a 3D geometrical model of structures and materials documented during an archaeological excavation. The process is fast, accurate and reproduces their tangibility, and, in so doing, preserves sizes and the data of the archaeological record.

We photograph the structures, stratigraphic levels and materials of the archaeological site from different angles in accordance with a pre-established mental order, taking a sketch of different control points or reference distances on the ground. In this way, we obtain a detailed vision of the site and its structures. Lighting control is of the utmost importance because photographic documentation processes in archaeological excavations depend on sunlight whether images are taken outdoors; artificial light indoors. Consequently, when outside, photographs can only be taken at certain times or on cloudy days, when the sunlight is not too bright and there are no shadows.

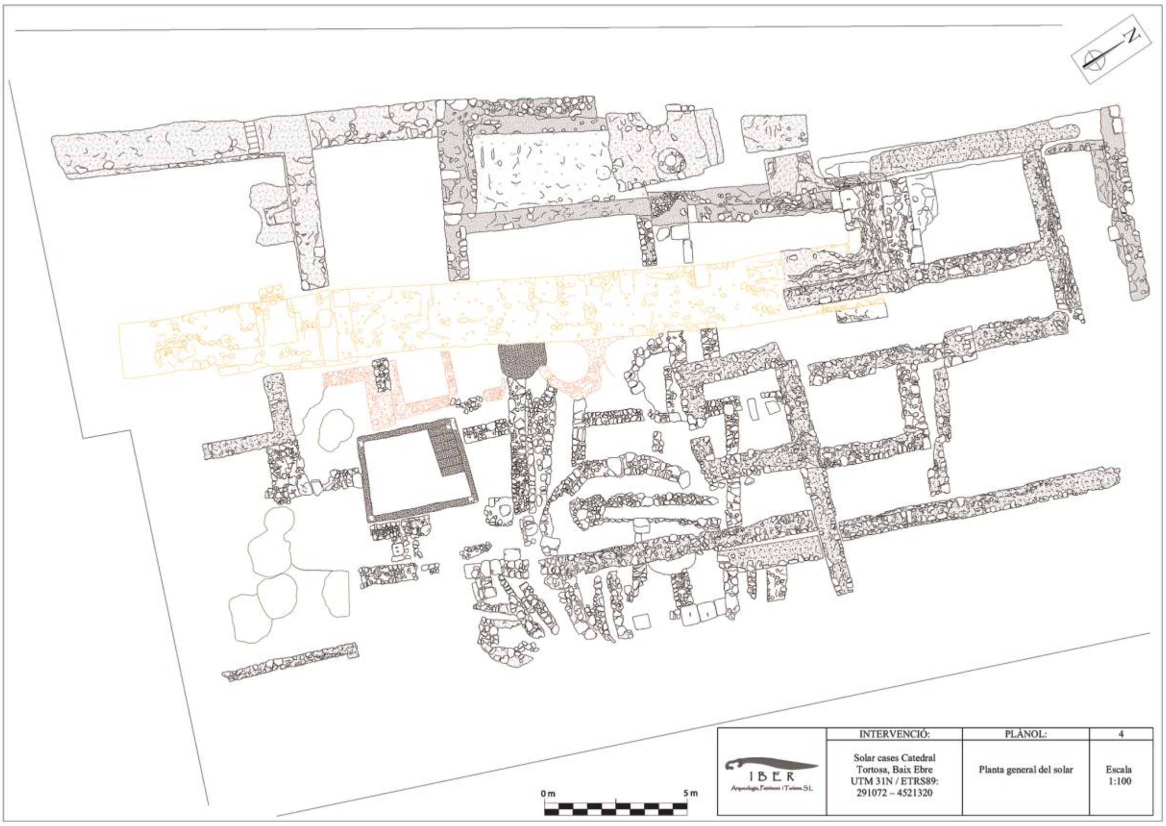


Figure 1: Planimetric floor plan of the archaeological excavation at *Les Cases de la Catedral*, Tortosa (Tarragona).

However, if the aim is to document parts of the excavation to produce archaeological drawings (floor plans, elevations and sections) but not a complete model, light control can be minimised and some shadows can be accepted. The effect of reflections, transparencies or camera flash on the documentation of archaeological materials must be minimised in a controlled interior.

One advantage of this documentation system is that it saves the real information that emerges and prevents much of it from disappearing, a common occurrence in archaeological excavations. With this documentation procedure, we can reinterpret the work carried out and retrieve the archaeological context that has disappeared, making it unnecessary to rely on interpretations by archaeologists and 2D planimetry.

Once the photogrammetric documentation has been obtained, the data is processed using the appropriate software. Nowadays, there is a wide variety of software, most of which does not require specialised technical knowledge, to make photogrammetric 3D modelling. Particularly important programs are Arc3D, Photomodeler Scanner, Phyton Photogrammetry Toolbox and, in our case, Agisoft Photoscan, which we use largely because of its measurement accuracy and the speed with which it processes models. This program can be used to create a cloud of 3D points for the archaeological structures or materials documented. Later algorithms are used to generate a polygonal mesh that models the surface so that images can be located in the 3D space. At this point, the measures, coordinates and scale references taken during the excavation process are applied to obtain accurate measurements in the final model. Finally, textures can be added and a high-quality 3D model is obtained (Fig. 2) which can be integrated into other design, animation, edition or presentation supports by exportation in various formats (.TIFF, .PDF, .OBJ, .3DS, .DAE, .PLY, .DXF, .U3D, etc.) depending on its use, its intended audience or the degree of detail that is required (Moya-Maleno, Tormejón, Vacas, & Losa, 2015).

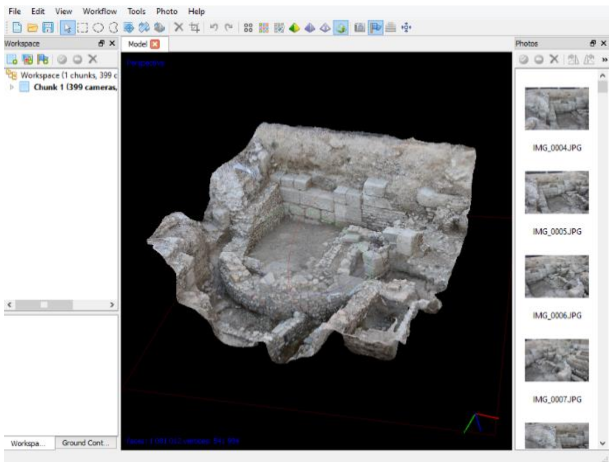


Figure 2: Photogrammetry carried out in the apse discovered during the excavation of *Les Cases de la Catedral*.

So the structures, materials and stratigraphic levels excavated during archaeological excavations can be documented using this data collection system. Measurements and geometric comparisons can be made, which can then be exported, modified or studied in detail.

We should make special mention of the features that make photogrammetry one of the best archaeological recording systems nowadays, if properly executed. First, the photographs are top quality and the whole process is meticulously planned. Secondly, it is cheap and portable, since it only requires a camera to record and document objects and spaces. We should also point out the quality of the textures generated, which always depend on the type of camera used. Finally, the whole process –the taking of the photographs and the subsequent processing with the software– is very quick, which reduces the time spent on documentation processes in fieldwork (Dueñas, 2014).

2.2. The process of orthographic creation (floor plans, elevations and sections) and how 3D models can be processed with Blender software

Once the archaeological documentation process has been completed using photogrammetry, the model generated in Blender, which is free software designed for editing 3D models and meshes, is exported. This software makes it possible to carry out such procedures as presenting the results obtained from either archaeological excavations or future exhibitions on different supports. However, at first, this 3D modelling program is used to produce orthoimages (orthophotographs) that will subsequently be used to make archaeological drawings of excavated structures.

The work is organised as follows. The 3D model (.OBJ file format first developed by Wavefront Technologies) is imported into Agisoft Photoscan v. 1.4.0. Once it is recovered, the entire model is properly oriented and the mesh is cleaned of unconnected points or alterations that may have appeared during the preparation of the photogrammetric survey. Then, the model is set in the appropriate position: in the frontal mode for elevations and sections, or in zenith mode for floor plans. The camera is aligned with the view to be used and, within the camera's options, the orthographical mode is selected by regulating the scale factor (Fig. 3). For sections, the camera option known as clipping is used to move the orthographical view to the exact point where the section is to be obtained and the remaining part of the model is automatically removed. Once the image the user wants to draw has been obtained, it goes into rendering mode which regulates all the characteristics of the final orthoimage, such as the resolution of the image (1920x1080 pixels, 4096 x 2160 pixels, etc.), the output format (.JPG, .PNG, .TIFF) or the type of background.

Once the model has been cleaned, it can be used to socialize the project through various communication channels. In this case, we provide the mesh obtained with a texture and we use Blender's node system to introduce the texture that incorporates the .OBJ file generated by Agisoft Photoscan. This node system also makes it possible to improve the quality of the texture with numerous options that give greater relief, correct the colours, improve the luminosity, etc.

Finally, the finished model and its texture can be exported to various supports for viewing 3D models, presented as images or videos or viewed with virtual reality glasses.

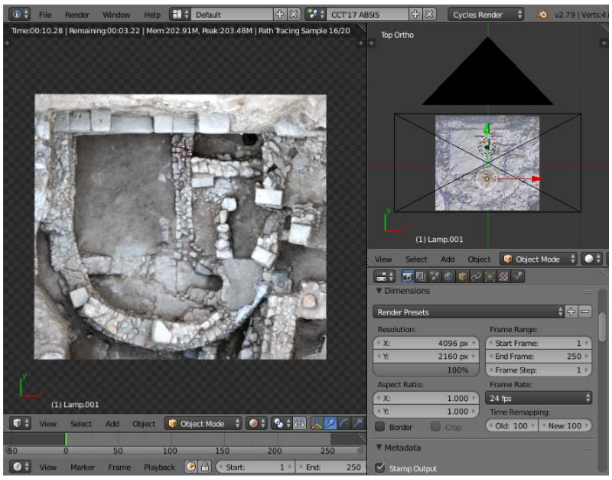


Figure 3: An orthoimage (floor plan) created by the Blender software as a photorealistic 3D model.

2.3. The reconstruction and virtual recreation process

We understand virtual reconstruction as a process of recovering a construction or object made at a specific time in the past on the basis of existing physical evidence and scientific hypotheses (Lopez-Menchero & Grande, 2011). The objectives of this reconstruction will always depend on the final function of the project. In our case, we use reconstruction to socialize heritage through various channels of communication (social networks, 3D viewers, exhibitions, etc.), immersive tourist guides or material that improves the understanding of archaeological structures and remains (posters, museums, etc.).

The methodology used to reconstruct and recreate archaeological sites and restore materials and objects goes through several phases (Portalés, Alonso-Monasterio, & Viñals, 2017), all of which subject the conserved evidence to scientific analysis and compare it to archaeological, chronological and technical parallels. Hence, a scientific hypothesis is advanced that is duly confirmed and generated by historical and archaeological documentation (Rascón & Sanchez, 2009). The initial analyses involve experimental archaeology studies and the search for ethnoarchaeological parallels that prove previously reconstructed hypotheses, because at *La Cella* there is little archaeological evidence on elevations and roof systems in Iberian architecture (Peña, 2015).

Alongside the study of the archaeological and ethnographic record, dimensions are calculated and measuring systems determined so that the structures can be optimally restored. Thus, once all the data has been obtained, a work schedule or hypothetical elevation from which we begin our work of the structures or the drawing of the materials is obtained.

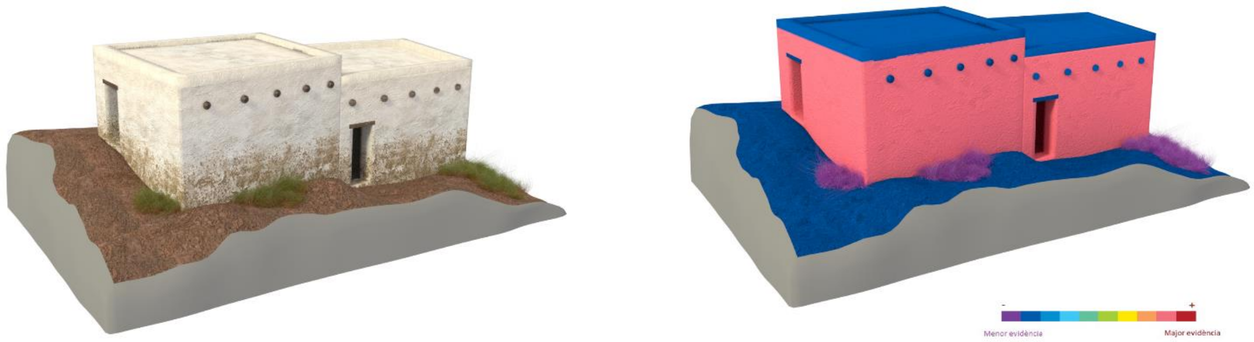
The second part of the process is the 3D elevation of structures from the previously prepared floor plans, elevations and sections. Once this base has been created, it is moved as a scaled image to the Blender software that contains free source tools that enable all the phases of digital anastylosis to be carried out (Fabregat, Tejerina, Molina, & Frías, 2012).

Once the 3D model has been made, materials and textures are assigned to all objects or structures to reproduce their real appearance. To do so, two systems are used to obtain textures. On the one hand, photographs can be taken of the original models, mostly of pavements, large walls or fragments of amphorae, which are subsequently treated and edited with special software (Crazy Bump) to obtain mappings of the image (with relief information, shadows and shine) that will be applied to the 3D modelling to increase realism. On the other hand, online repositories can be used free of charge or purchased, for access to large banks of downloadable textures that may be suitable for the elements to be reconstructed. These textures add information that increases realism and prevents subsequent editing. It should also be pointed out that there is specialised software, such as Allegorithmic Substance Painter, that can texture 3D models later.

Once all the materials have been obtained, our modelling objects will be UV mapped or unwrapped so that the textures can be applied. Outside Blender, the mapping is transferred to image processing software (GNU Image Manipulation Program –GIMP– 2 or Adobe Photoshop) and the textures are applied to each object or structure. Once the process has finished, the mapping is imported again into Blender and the 3D models are provided with information about relief, brightness and shading.

Afterwards, the reconstruction is moulded and textured and the process of recreation or setting of the scene is started if necessary. The lighting procedure should be mentioned at this point. By working on lighting, we can improve volumetric objects and structures by enabling them to reflect and project shadows. The realism of reconstruction can be improved, for example, by adapting sunlight to latitude, time of day or season. Likewise, interiors can be illuminated with artificial light or with light coming from the outside (Pastor, 2001).

Once the reconstruction and recreation process has been completed, the model can be exported. When doing this, it is important to apply the scale depicting the historical-archaeological evidence of the virtual reconstructions (Aparicio & Figueiredo, 2016). A simpler parallel texture must be applied to the final mouldings and the amount of evidence accumulated after the whole analytical process is indicated by colour (Fig. 4). The features represented by cold colours are less likely to have been reconstructed as well as those represented by warm colours because less evidence has been found.



(a) (b)

Figure 4: Virtual reconstruction of an Iberian house in *L'Assut* (Tivenys, Tarragona) dating from the 3^{rd} century BC, and the scale of historical-archaeological evidence.

3. Communication and diffusion tools

3.1. Virtual museums

Our group has applied virtualisation to construct virtual museums. Different types of artefacts or archaeological sites have been organised into collections and some elements have been virtually reconstructed. The great advantage of this type of museum is that a variety of accessories can be added to the objects on display (for example, links to documentation, photographs, plans or videos), which greatly enhance the visitors' experience and increase the level of information. Likewise, these interaction and visualisation tools in combination with distant communication, facilitate communication and enable results to be accessed anywhere in the world. Photogrammetry makes it possible to make 3D representations of the settlements where we work, the material recovered and virtual reconstruction, by which we can show what they were when they had been in use. Among the software options that can be used to publish 3D models are Sketchfab[1] or p3d.in (Fig. 5), among others (Scopigno, Callieri, Dellepiane, Ponchio & Potenziani, 2017).

3.2. Virtual reality

Virtual Reality (VR) is quickly becoming one of the most important tools for explaining and socialising archaeological heritage. It can be used in numerous ways and the technology is advancing so quickly that improvements are being made almost on a daily basis. We are now using it to pilot archaeological guides created by GRESEPIA. The aim is to give visitors the chance to see the buildings they are visiting –and particularly the interior areas– as virtual reconstructions, so that they can compare the material reality with what they see through VR glasses. The Sketchfab platform allows users to view in VR all the models available after it is configured and the menu adapted.

[1] GRESEPIA virtual museum www.skethfab.com/gresepia

This pilot test has shown that visitors who do not have much experience of archaeology greatly appreciate this type of application because it helps them to understand.

The rendered images made by Blender, created by projecting a rectangular camera in image or video format depending on the particular needs of each case, are then exported (Fig. 6). Once exported, they must be moved to a mobile device so that they can be watched in VR glasses. At present, there are numerous applications for Android and iOS mobile devices that enable users to display 360º virtual reconstructions or recreations, which reduces the price of hardware, so we can enjoy 3D immersive environments with a very low budget if mobile devices are incorporated into the VR glasses. Nowadays these glasses are readily available on the market. In our case, for the moment, visitors share two Ivargo mobile phones and virtual VR Box glasses.

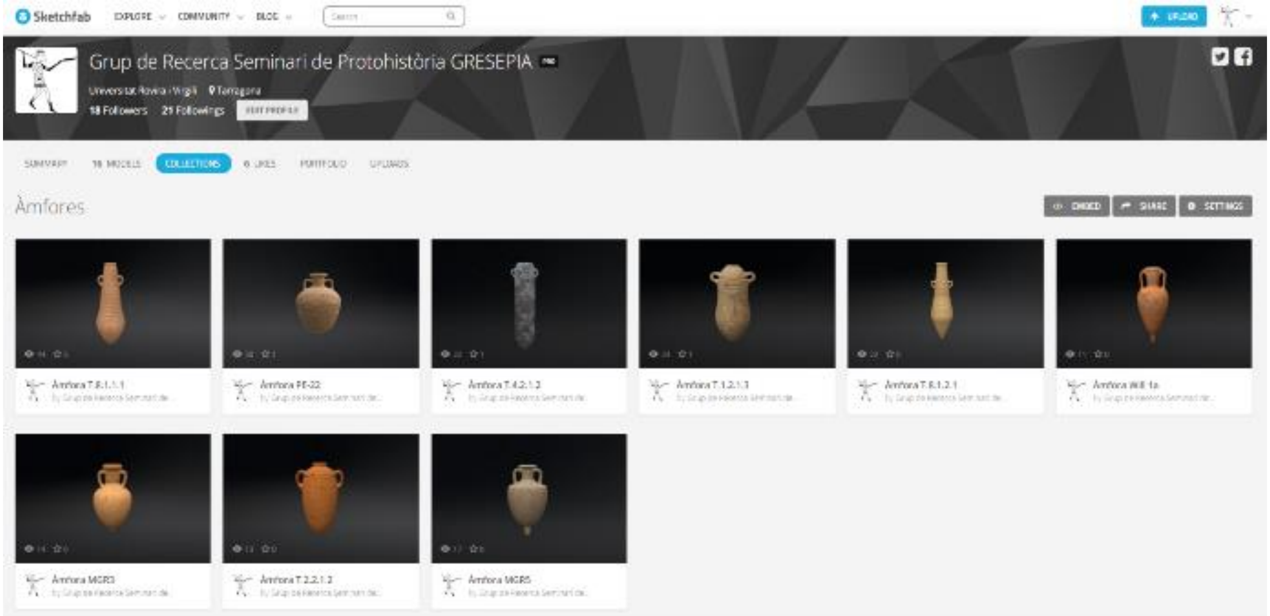


Figure 5: Virtual museum of GRESEPIA where the virtual reconstruction of the amphora fragments recovered in *La Cella* (Salou, Tarragona) is on display.

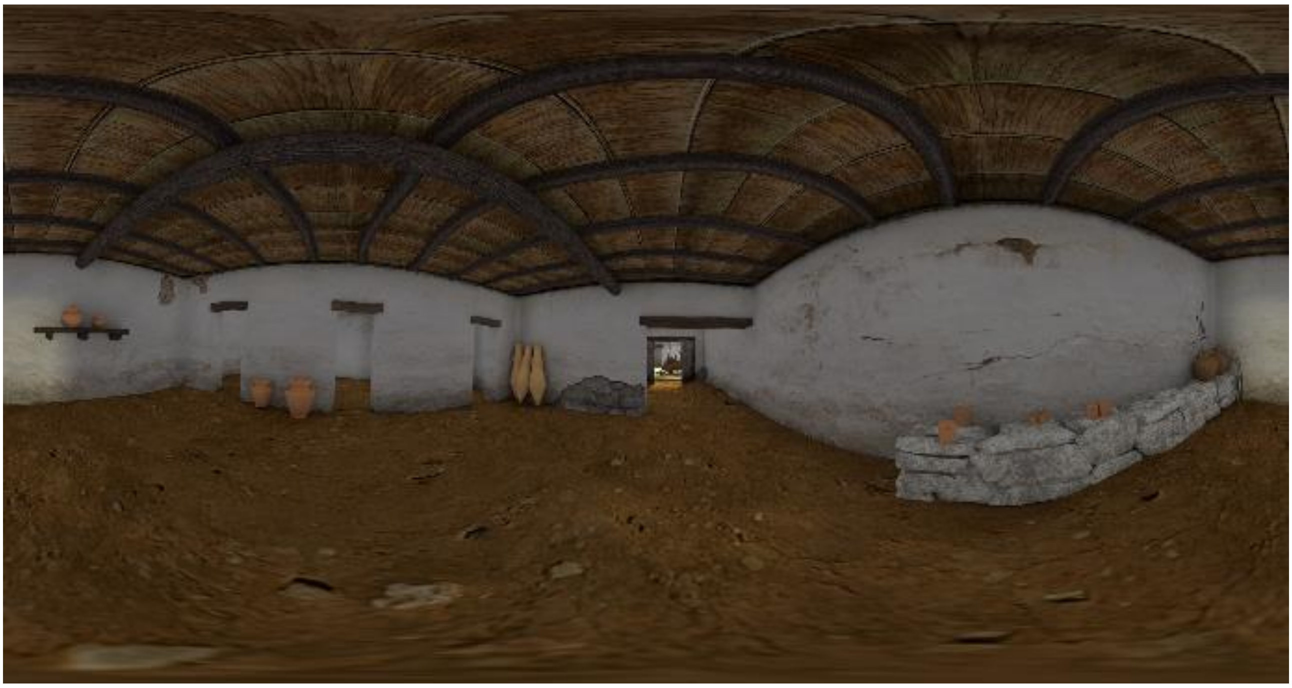


Figure 6: 360º virtual reconstruction of an Iberian house from the protohistoric site of *La Cella* in an equirectangular projection which is prepared for display on VR glasses.

3.3. Video and image

The images and videos from image-based 3D modelling are all obtained in the same way. Once the models have been created and corrected, we do all the editing work on meshes and modelling using the 3D creation suite in Blender v. 2.79. This program has a large number of rendering options which enables a final file to be obtained as a high-quality video or image.

In this section, however, we do not want to discuss the features of the software but how the output is used. Videos or images of these modelling processes and virtual recreations of archaeological sites have become the fastest, most inexpensive and efficient way to socialise the results of our work. The ease with which these types of file can be inserted into social networks, including 360º views in the case of Facebook and YouTube, has made them the main channel by which our work is communicated. The visual impact generated and the speed at which these platforms run lead to very high levels of the diffusion of research in heritage and archaeological excavations. This is, therefore, a very appropriate way of promotion and returning what belongs to society. By mixing visual impact with scientific explanation through these communication techniques, we may increase interest and plant a seed of what may subsequently lead to consultation and/or reading scientific articles and, above all, more visits to archaeological sites and museums.

4. Examples of the documentation and diffusion of heritage

4.1. A tool applicable to urban archaeology. The example of the plot of *Les Cases de la Catedral* (Tortosa)

The archaeological excavation on the site of *Les Cases de la Catedral* (Tortosa, Baix Ebre, Tarragona) presents many of common problems in urban archaeological excavations, especially when they are located in the historical centre of a city with a history that goes back to protohistory. Structures from different historical periods are superimposed, the urban dynamics of a living city have destroyed a great deal of evidence and the interpretation of complex stratigraphic relationships greatly hinders both the dynamics of archaeological work and the subsequent comprehension, interpretation, communication and diffusion of the results. These problems, which are clear to the professionals who work in archaeology, are greater when the results of the research need to be communicated to the general public, who are not used to these dynamics.

In the specific case of *Les Cases de la Catedral* in Tortosa (Fig. 7), the site concentrates 18 centuries of history. If we were to make a diachronic study of the various historical stages or the most important archaeological evidence; we would find a section of the Roman wall, the defensive structure of the old Dertosa, which until now has remained almost totally undocumented, and a large platform of *opus caementicium* from the Early Roman Imperial Period, which is related to a large public square and probably a part of the forum of the Roman city. Likewise, there is also evidence of a salt factory from the Early Roman Imperial Period, which consists of the remains of two large cubes, along with some habitat structures corresponding to a building from the same period. Another noteworthy element from this period is a large apse that may be related to a Christian building for worship. There is clear evidence of the urban fabric of the Islamic city from later times. We can find its sewage system, some of the fluvial port structures of the medieval city of the 13th and 14th centuries, which is a large rectangular building, and the remains of two Late Medieval buildings that could be linked to the residences of the canons of the Cathedral. Finally, more recent findings are a small 18th century intercity cemetery and the foundations of modern 19th century houses[2].

Figure 7: Aerial view of the site of the archaeological excavations at *Les Cases de la Catedral*.

It is essential to exploit all the advantages and possibilities that the information and communication technologies (ICT) provide to urban archaeologists who are working with such structural and historical complexity. These technologies facilitate the compilation of the archaeological record and the graphics documentation process, and more accurately presents the results for the communication and diffusion of the whole excavation process for both specialists and the general public.

4.1.1. Archaeological record and graphic documentation

One of the main problems of urban excavations is graphic documentation, especially of certain structures. In this particular case, there is a Roman wall that is more than 40 m long and, in some parts, more than 4 m deep. A wall such as this can only be graphically documented by photogrammetry, which can superimpose many photographs. It can also generate an orthorectified representation that minimizes the errors of the lens, and generates a joint image that can be used for planimetric documentation (with centimetre accuracy and minimisation of errors) and for presenting the results (more didactic and understandable for the audience). A representation of this sort cannot be obtained in any other way (Fig. 8). In this regard, a general orthographic floor plan of the site makes it possible to obtain sections in any sector more quickly and accurately.

[2] This study, which is pending publication, was carried out by GRESEPIA of the Universitat Rovira i Virgili and the company IBER, Arqueologia, Patrimoni i Turisme.

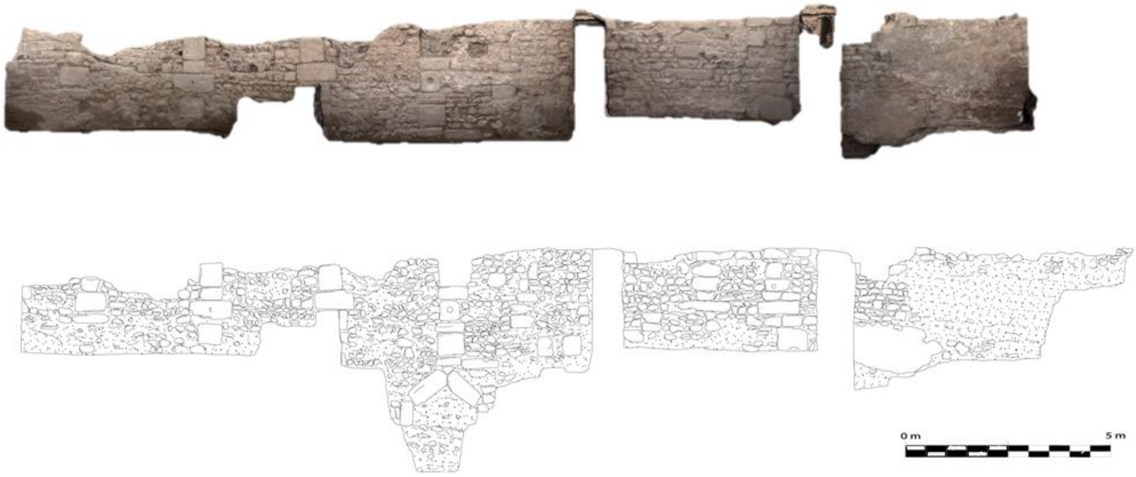


Figure 8: Aerial photogrammetry and archaeological drawing on the Roman wall located at *Les Cases de la Catedral*.

In many cases, this type of excavation requires the most modern phases or walls to be dismantled so as to reach the oldest levels or structures. In this case, much of the sewage system from the Islamic period had to be dismantled and removed in order to document the apse from the Early Roman Imperial Period. All the structures were positioned on the floor plan using photogrammetry. The data were preserved virtually so there was no need to preserve the physical structures. This made it possible to draw up virtual floor plans of all the historical phases at the site.

4.1.2. Communication and diffusion of archaeological results

As we have pointed out above, one of the great advantages of photogrammetry as a system of archaeological documentation is the diffusion of the results and of the remains themselves, especially if these must be conserved, visualised or integrated into the re-urbanisation of the space. Modern, educational museumization does not allow for the overall conservation of all the existing historical phases and we tend to eliminate some of them so that the others can be interpreted correctly. Photogrammetric documentation and the virtualisation of this heritage must be part of this new museum discourse in urban archaeological sites. They provide an approach to the archaeological remains that clarifies the various historical periods, or simply reproduces and virtually models some of the excavated structures. It combines a material archaeological vision and a virtual vision.

Finally, the application of these new techniques to the archaeological record and virtual reconstruction has allowed us to create a virtual museum of some of the most outstanding structures of the site. It can be consulted on-line and can be visualised with virtual guides (Fig. 9) at fairs or for educational sessions for all kinds of audience.

Although we have only used photogrammetry for the structural archaeological remains to model the whole archaeological area, floor plans, elevations and sections have been delivered to preserve structures that have subsequently been disassembled, our aim is to extend its use to record a variety of the materials recovered. A new virtual museum will be set up to display some of the materials, especially the wide variety of coins recovered during the excavation.

4.2. A heritage and tourism promotion tool. The case of the protohistoric site of *La Cella*

The protohistoric settlement of *La Cella* in Salou (Tarragonès, Tarragona) is located at the top of a hill that rises above a cliff near the coast. The site has undergone important natural and anthropic modifications, especially due to the extraction of stone and urbanisation activities. Even so, in spite of these adverse conditions, more than half of the site is conserved and it covers an area of more than 1 ha (Fig. 10).

This protohistoric settlement that dates from between the 4th century BC and the middle of the 3rd century BC, has characteristics that make it a *unicum* on the coast of the ancient Iberian *Cessetania* because the whole settlement was the result of previous planning: the streets are not of the habitual size and the architecture of the buildings is complex. The size of the homes documented so far varies between 100 and 200 m² (Diloli, Vilà, Ferré, Cots, Bricio, & Sardà, 2016).

Setting aside the uniqueness of its structures, one of the added values of the site is its location because it is not in a natural environment that is difficult to access –a common problem of sites from these periods– but rather in a coastal urban environment that is easy to access and has a considerable tourist impact.

The new ICTs are vital for conserving and communicating a site such as this. They can be used for two purposes that may initially seem contradictory, but can end up complementing each other: the interest in sustainable tourism, and global diffusion aimed at making it a tourist attraction for the town.

If we want to prioritize the most sustainable aspects, we should use the new technologies to protect and conserve the archaeological remains. The site is one of the weak structures that were built with stone and mud, in a space that is not prepared or appropriate for a high volume of visitors. If the new technologies are used to design routes around the site or create immersive, virtual reality experiences in certain domestic domains, tourists will be able to visit and understand the site and without having to be physically there. In this way, we can prevent a large number of visitors from having to come and limit access only to those who are interested in archaeological sites.

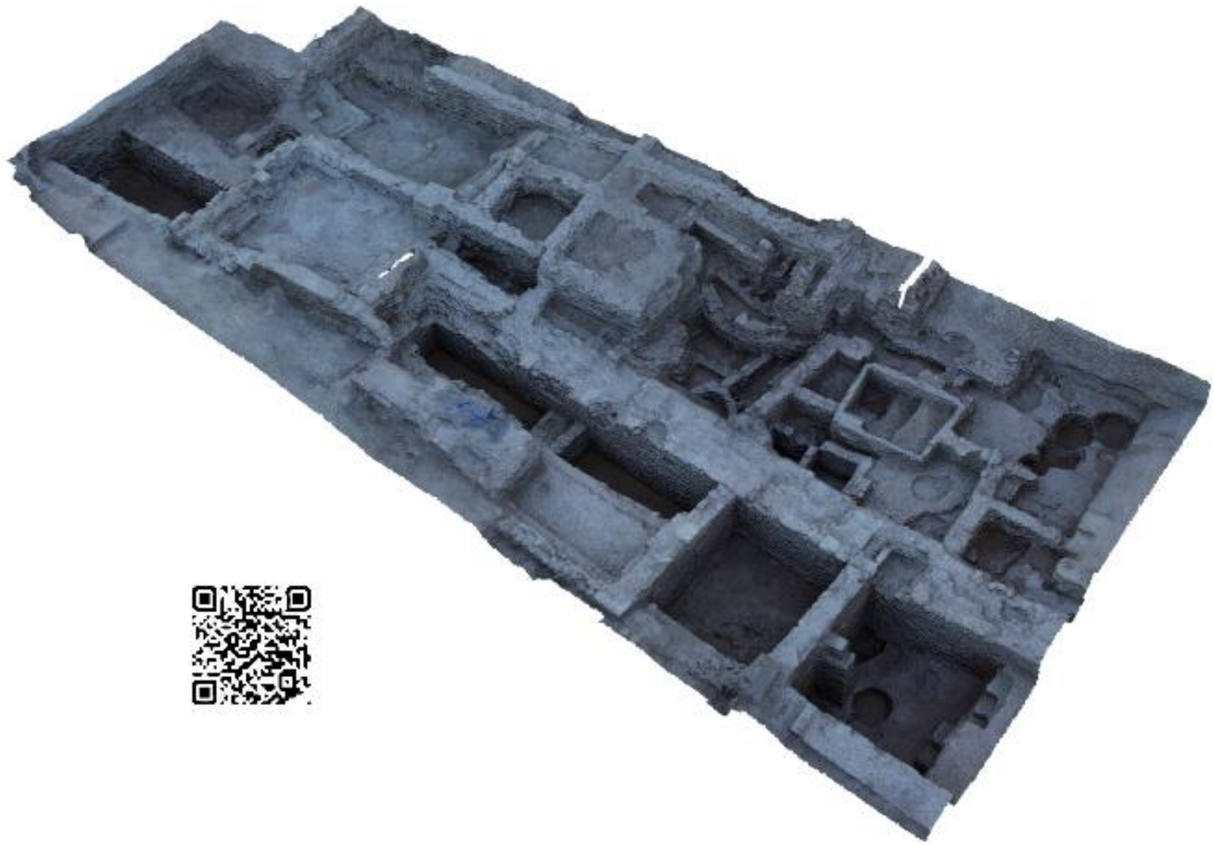


Figure 9: Photogrammetric documentation of the site at *Les Cases de la Catedral* and QR with a virtual visit to the site.

Figure 10: Aerial image of the protohistoric site of *La Cella* (Salou, Tarragona).

Figure 11: A virtual recreation of the interior of Building C of the protohistoric site of *La Cella* and QR to watch it in the video.

However, the commitment of our research group (GRESEPIA) to *La Cella* is to take advantage of these new ICTs to give impetus to the diffusion of this archaeological heritage and turn it into an innovative tourist attraction for all kinds of people without losing the most educational and scientific aspects. From this point of view, we are working to provide virtual visits to the site and offer immersive experiences with guided routes that give visitors an overall understanding of the settlement without jeopardising the structures. Visitors will be able to stroll virtually along some of its streets, enter some of the buildings (Fig. 11), move around the different areas in a house or enjoy a general virtual restoration of the settlement, all integrated into the natural environment and the Mediterranean landscape of the Iberian Period.

An initial virtual recreation of one of the best-preserved houses in the entire site was provisionally designed and four guided tours organized with the aim of publicizing and socializing the settlement of *La Cella* in collaboration with the Council Town of Salou. The recreation consisted of a theatrical tour, a small historical home with several characters inside (Fig. 12) and an immersive experience with virtual reality glasses in another building. The response from the attending public was very positive and all the input we received from the youngest to the oldest visitors for this heritage experience has been favourable.

In summary, new ICTs have become an essential tool for communicating archaeological heritage. Our team has prioritized two essential aspects in the case of *La Cella*. Firstly, we adapted and applied these new technologies to the site by combining and comparing virtual recreation with the current state of preservation of the archaeological remains themselves and providing visitors with an educational awareness of this type of heritage. Secondly, we used the results of the research to carry out all sorts of recreations and virtual reconstructions at the site. Our aim was not to give a spectacular vision of the site but to find an effective way of presenting the results in an educational way for the general public, and finding solutions to questions or work hypotheses that had arisen during the archaeological campaigns for a more scientific or specialized audience. It is archaeological experimentation 2.0.

Figure 12: A theatrical visit to the protohistoric site of *La Cella* (Salou, Tarragona).

5. Discussion

By means of an interdisciplinary dialogue between traditional archaeological techniques and the new technologies in the virtualization of heritage, we can improve the documentation and archaeological record of excavations and provide the general public with a greater understanding of the structures and materials found (Serrano & Andreu, 2015).

Our scientific fieldwork has fulfilled the twofold function of creating pedagogical material and a tourist attraction. Of course, from the very beginning of the project, our work had been planned with clear objectives in mind, and a narrative that reflects the underlying scientific hypotheses (Rovira, 2010). Therefore, our 3D models, reconstructions, recreations and virtualisations have been created with the utmost scientific rigour, quite unlike the constant proliferation of high-quality infographic reconstructions that show fictitious speculation with no explanation of the level of veracity or the background study.

We are aware that there are several types of heritage, each of which has its own specific problems. In this article, we wish to present some reflections on the protohistorical archaeological heritage. The line that separates the scientific results (the archaeological remains themselves, their interpretation or their protection) of the informative results (their presentation in society) is very thin: we should not convert an archaeological deposit into a closed plot for scholars only, but on the other hand, a mass and uncontrolled attendance can cause irreparable damage to both the archaeological heritage and its environment.

Indeed, this problem can be solved by using a correct application of ICT, but an incorrect application can also be problematic: the main protagonist in an archaeological site must be their own remains, while ICT should be only a tool that allows to present them or explain them in a more didactic way, but never substitute them. The combination of real evidence with virtual recreation in the same space has been a satisfactory experience: the visitors did interact with the site; they ceased to be spectators to become active actors. The interaction between the real world and the virtual reality, without a subjection of both worlds to the other, helps the visitors to think and understand for themselves, and thus, they acquire a greater sensitivity to protection and preservation of the archaeological heritage. And, last but not least, the ICTs can be used as a useful tool that should help us to prove or deny work hypotheses and clarify doubts. In summary, they are valuable and effective tools in the field of archaeological experimentation linked to constructive, architectural and urban aspects of ancient towns and sites.

6. Conclusions

The aim of this article was not simply to describe how the new ICTs are used in archaeology, but to report a work in process, a methodology that goes on from the capture of data at archaeological excavations up to the final display of the results. In addition, this methodology can facilitate fieldwork and also be very useful for diffusion. The capture of data by digital image-based modelling systems enables archaeological structures and materials to be recorded and documented quickly and cheaply, and can be used to provide 3D models that will subsequently disclose the information. The models generated can also be used to initiate a process of virtual reconstruction and recreation that will make the process of diffusion more informative and provide greater insight into the archaeological remains unearthed. All this work, from the very beginning to the very end, must go hand in hand with a rigorous scientific investigation. The final products need to show the result of a scientific hypothesis in an attractive and understandable way that will encourage people to visit archaeological sites. Nevertheless, it should not be an alternative to a personal visit but can awake the public's interest in heritage.

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