







FROM THE CAVE TO THE VIRTUAL MUSEUM: ACCESSIBILITY AND DEMOCRATISATION OF FRANCO-CANTABRIAN PALAEOOLITHIC ART

DE LA CUEVA AL MUSEO VIRTUAL: ACCESIBILIDAD Y DEMOCRATIZACIÓN DEL ARTE PALEOLÍTICO FRANCO-CANTÁBRICO

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Highlights:

- Despite being a transcendental cultural manifestation in the history of humanity, there are hardly any open-access virtual repertoires of Palaeolithic art.
- The numerous photogrammetric studies carried out in successive archaeological campaigns to answer scientific questions can be used in educational and dissemination projects.
- In the framework of the authors' outreach project called "*PaleoArt-3D: regreso al pasado*" a virtual museum has been created to make Palaeolithic art a more accessible and democratic heritage.

Abstract:

Palaeolithic art is a cultural manifestation of great importance to understanding the early history of our species. Through this artistic phenomenon, one can study aspects such as long-distance contacts, evidence of learning or the perception with which Palaeolithic humans were able to execute and memorise such precise details. However, there are few virtual repertoires that offer collections of Palaeolithic art. Accessibility to this type of archaeological remains is even more difficult considering conservation is prioritised over tourist visits. For these reasons, Palaeolithic art is today a type of cultural asset that is largely unknown to the population. The project "*PaleoArt-3D: regreso al pasado*" was created with the aim of democratising this heritage and making it more accessible. To this end, a virtual museum has been developed to exhibit digital models of parietal and portable art with complementary annotations for each one. The methodology includes a first stage dedicated to digitising examples of Palaeolithic art in caves or open-air stations and exhibited in Spanish and French museums. Next, the necessary infrastructure was designed to house the exhibition using specific software such as Blender. Post-processing tasks were carried out to reducing the number of polygons without losing quality. Finally, the museum has been uploaded to the Sketchfab platform to make it freely available online. It is hoped that this virtual museum will contribute to promoting and creating a more significant number of digital resources related to Palaeolithic art that are easily accessible to the public.

Keywords: virtual museum; virtual exhibition; Palaeolithic art; parietal art; portable art; photogrammetry

Resumen:

El arte paleolítico es una manifestación cultural de gran importancia para comprender los primeros momentos de nuestra especie. Gracias a este fenómeno artístico podemos estudiar aspectos como los contactos a larga distancia, las evidencias de aprendizaje o la percepción con la que podían ejecutarse y memorizarse detalles tan precisos. Sin embargo, son pocos los repertorios virtuales que ofrecen colecciones que incluyan piezas de arte paleolítico. La accesibilidad a este tipo de vestigios arqueológicos es incluso más difícil si tenemos en cuenta que se prioriza la conservación frente a las visitas turísticas. Por estos motivos, el arte paleolítico es hoy un tipo de bien cultural muy desconocido por la población. El proyecto "*PaleoArt-3D: regreso al pasado*" nace con el objetivo de democratizar este patrimonio y hacerlo más accesible. Para ello se ha creado un museo virtual donde se exponen modelos digitales de arte parietal y mueble con anotaciones complementarias para cada uno. La metodología comprende una primera etapa dedicada a la digitalización de las muestras expuestas tanto en cuevas y estaciones al aire libre como en museos españoles y franceses. Seguidamente se ha creado la infraestructura necesaria para alojar la exposición utilizando softwares específicos como Blender. Las tareas de postprocesado se han llevado a cabo con el objetivo de disminuir el número de polígonos sin perder calidad. Finalmente, el museo se ha subido a la plataforma Sketchfab para que esté disponible de forma online y gratuita. Se espera que este museo virtual contribuya a impulsar la creación de un mayor número de recursos digitales que tengan que ver con el arte paleolítico y a los que la población pueda acceder fácilmente.

Palabras clave: museo virtual; exposición virtual; arte paleolítico; arte parietal; arte mueble; fotogrametría

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1. Introduction

Virtual tourism is currently one of the most widespread cultural activities worldwide. The crisis caused by COVID-19 and subsequent social distancing has forced many people to continue visiting heritage sites from their homes, which has increased the demand for virtualised cultural resources (Itani & Hollebeek, 2021). This type of tourism has established itself as an alternative capable of simulating real experiences in a sustainable (Talwar, Kaur, Nunkoo & Dhir, 2022; Verma, Warriar, Boli & Mehta, 2022) and immersive way, thanks to novel and more accessible technologies (Cardozo & Papadopoulos, 2021; El-Said & Aziz, 2021; Zhang, Li, Ruan & Liu, 2022).

Within the catalogue of services offered by virtual tourism, one of the most outstanding is the museum, "a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment" (ICOM, 2007).

The digitisation of heritage has become one of the main activities of these types of institutions which, until a few years ago, were restricted to the inventory, documentation and storage of their collections. This procedure has increased with the emergence of cheaper and more user-friendly technology (Milosz, Skulimowski, Kęsik & Montusiewicz, 2020). For this reason, more and more institutions have a repository where they host their virtual collections, a modernising process that COVID-19 has accelerated (Gutowski & Klos-Adamkiewicz, 2020; Kim, Lee & Jung, 2020; Vayanou, Katifori, Chrysanthi & Antoniou, 2020). However, this innovative wave is not only the result of the impulse of these institutions, but also thanks to other non-profit organisations, financial support from national governments or large-scale funding such as from the European Union, and individual initiatives or small local projects (Cardozo & Papadopoulos, 2021).

1.1. Definition, advantages and disadvantages of virtual museums

The concept of "virtual museum" has evolved over time towards greater complexity. It is true that it can refer to museums and other heritage institutions that offer the public an exhibition that includes digital objects through media such as augmented reality or virtual reality (e.g. Banfi, Brumana & Stanga, 2019; Trunfio, Lucia, Campana & Magnelli, 2022). However, in this article, we speak of a "virtual museum" in the same sense as in most of the literature consulted: a digitally created environment where collections of various kinds are exhibited and can be accessed at any time and place through computing devices (such as a CD-ROM) or electronic devices (such as computers or smartphones) connected to the internet. In the latter case, the adjective "online" can be added to the term in question.

The first applications of "virtual museums" appeared in the 1990s on CD-ROM media (Huhtamo, 2010) under a multitude of synonyms that can still be found today such as "digital museum", "electronic museum", "online museum", "hypermedia museum" or "web museum" among others (Sabbatini, 2004; Schweibenz, 2019). Tschritzis & Gibbs (1991), who were among the first

authors to use the concept of "virtual museum", define this space as a place created through computer models thanks to technological innovations that may or may not be based on reality.

Today, the definition of a "virtual museum" is still being detailed. As Huhtamo (2010: 121) points out, a common denominator in this type of digital resource is the presence of collections hosted on the internet. An aspect that does not necessarily possess an identical parallel in the real world (Schweibenz, 2019), although there is a dependency since what is shown to the visitor are three-dimensional objects taken from the material world (Mintz, 1998; Sabbatini, 2004). Most authors today follow this line, trying to define the term, for example, as "a collection of digitized objects available online to an immersion experience utilizing high-tech equipment to make people feel as if they were in a museum" (Latham & Simmons 2014: 14). Apart from using the online space, when defining virtual museums, projects on heritage culture take into account other factors, such as those focused on experience, simulation, immersion, learning, open accessibility, interaction or the richness of the content (Loaiza, Morita and Bilmes, 2020; Schweibenz, 2019).

Virtual museums possess many advantages. Bandelli (1999) indicates that they are capable of creating collections with which to conceive experiences that are not possible in physical museums. Benjamin (1936) argues that the virtual museum offers the possibility of placing the original pieces in various contexts, something that may not be possible in a real museum. But undoubtedly, one of the main characteristics of this type of resource is what is known in the literature as the "democratising" and "educational" factor (e.g. Enuber, 2015; Osuna & López-Martínez, 2015; Pescarin, Cerato & Romi, 2016; Pierroux, Bäckström, Brenna, Gowlland & Wee, 2020; Rivero, Navarro-Neri, García-Ceballos & Aso, 2020). By democratising, we mean the inherent capacity of the virtual museum to allow free and equal access to all types of public, regardless of where they live and the economic means at their disposal. This democratisation represented by the virtual museum has also extended to the field of education, where culture is promoted in the classroom. Unlike traditional teaching, where learning is usually passive, the digital museum allows students to create their own experience without the excessive intervention of mediating figures such as a teacher; they are able to interact in the first person with the information on offer (Dickey, 2005).

Virtual museums have many other advantages: creating new cultural services, generating greater tourist attractions, safeguarding heritage, lower economic cost, more efficient use of time, offering new possibilities for interaction and manipulation of the heritage asset, encouraging participation, greater accessibility for people with physical or cognitive difficulties, updating content without major infrastructure changes, disseminating a type of cultural property that is little known, raising awareness of these heritage pieces when the museum is unable to display them due to lack of space or preventing the inappropriate use of pieces that are too fragile (Cardozo & Papadopoulos, 2021; Gutowski & Klos-Adamkiewicz, 2020; Milosz, Skulimowski, Kęsik & Montusiewicz, 2020; Sabbatini, 2004; Tschritzis & Gibbs, 1991; Wojciechowski, Walczak, White & Cellary, 2004).

However, other authors point to two fundamental counterparts, known in the literature as "aura" and "authenticity" (e.g. Cardozo & Papadopoulos, 2021; Jeffrey, 2015; Mintz, 1998). The former refers to the experience and feel that the real piece exhibited in a real museum is able to transmit and create in the visitor, something that for some authors can never supplant in virtual tourism (e.g. Dueholm & Smed, 2014; Falk & Dierking, 2000; Tschritzis & Gibbs, 1991). In turn, authenticity is the quality of an object that is perceived as true and made in the past (Cardozo & Papadopoulos, 2021). In this regard, Kim, Lee & Jung (2020) argue that this drawback is linked to the quality of the technology being used, a circumstance that has improved exponentially over the years. Nevertheless, Cardozo & Papadopoulos (2021) have tried to demonstrate that both aura and authenticity are in fact factors that virtual reality can achieve, provided that the heritage assets are enriched with annotations and certain contextual parameters.

Another disadvantage is related to the technical opportunities of people. Not everyone has the technology required for this type of tourism, as may occur in the developing world, the knowledge to be able to access it or the experience to be able to use it, as in the case of the elderly.

Some large important scientific projects are currently generating numerous three-dimensional (3D) restitutions. These restitutions, on which the scientific discourse published in journals is based, can also be used as a means of dissemination and didactics to promote knowledge and protection of the heritage. On occasions, the role of the virtual museum is relevant because it makes it possible to see a heritage site that is difficult to visit because of conservation issues, and which can only be accessed by specialists. One example is Palaeolithic art, a heritage asset that is increasingly necessary to bring closer to the population from an educational point of view in order to increase public sensitivity, transmit its importance and facilitate its visibility, since these archaeological sites are often closed to the general public.

1.2. The absence of Palaeolithic art in virtual museums

Palaeolithic art was a cultural manifestation created by *Homo sapiens* in the Upper Palaeolithic (40000-11500 BP). Although it is distributed all over the planet, one of the main concentrations is in southwestern Europe, in what is known as the Franco-Cantabrian sector. This type of art is highly susceptible to contamination and its preservation is one of the main fields of study in the scientific discipline of Palaeolithic research. For this reason, the use of tools to digitise and virtualise this type of art is vital. Even more so if we bear in mind that it is not exactly a type of heritage that is accessible to all audiences. It is true that there are centres and museums with an excellent collection of Palaeolithic portable art and that a large number of decorated cavities can be visited in Spain and France. However, compared to other historical periods, this one is severely restricted. It should also be noticed that in order to study Palaeolithic art, not only advanced academic knowledge is required, but also a great deal of experience to be able to recognise

and catalogue it. In addition, the small number of specialists in this prehistoric branch translates into less investment in dissemination and a widespread lack of knowledge of this cultural phenomenon among the population.

The dissemination of Palaeolithic art through the use of new technologies has been highly restricted until the present day. In the case of other historical periods, technological innovation has been used recurrently for both research and dissemination. However, in the case of Palaeolithic art, such technologies have been subordinated to the pursuit of scientific answers. It is now the time for those answers to be transferred in the form of knowledge to society.

From our outreach project "*PaleoArt-3D: regreso al pasado*", we aim to demonstrate that the resources applied to scientific research can be used in a high-quality educational and dissemination project in order to bring to the public samples of parietal and portable art scattered across the French-Cantabrian geography. The main objective is to contribute to democratising this heritage that is so unknown to the public by making it more accessible in an inclusive, alternative and visual way that is capable of creating interest in the visitor. For this reason, and taking into account the advantages mentioned in the previous section, we believe that the creation of a virtual museum is the best way to achieve the objectives set.

2. Methodology

"*PaleoArt-3D: regreso al pasado*" project has been developed by following a series of methodological phases that include two important sections: the photogrammetric recording of the heritage elements and the creation of an architectural and informative structure (Figure 1).

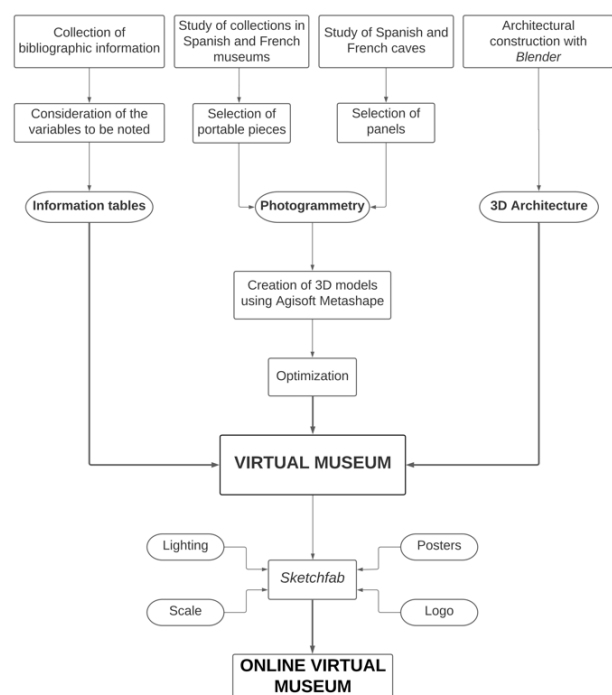
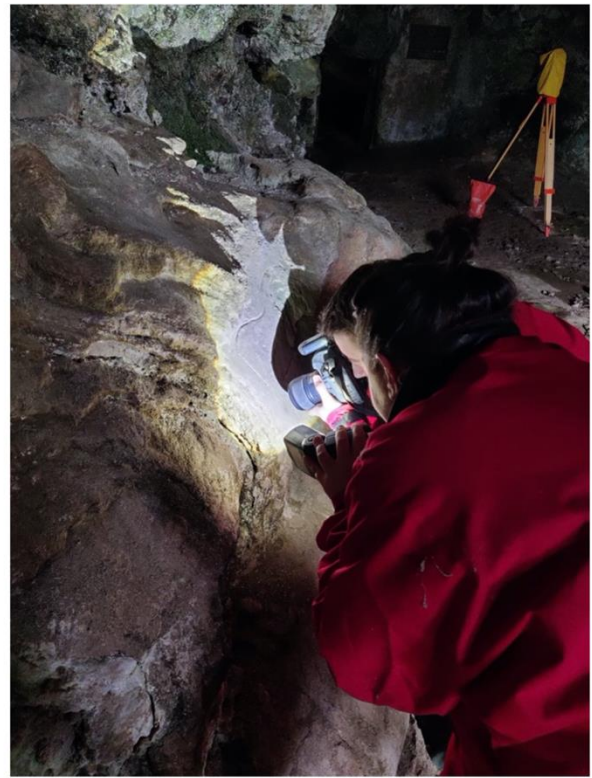


Figure 1: Outline of the methodology applied.



(a)



(b)

Figure 2: Photogrammetric data acquisition of parietal art at Hornos de la Peña: a) sector F; b) sector A.

2.1. The three-dimensional restitution of Palaeolithic Art

The definitive emergence of photogrammetry in recent years in the field of archaeology has minimised the work processes and data collection methodology. At the beginning of the 21st century, with the appearance of these new 3D techniques, the panorama of documentation, recording and interpretation of sites has evolved in such a way that they have become essential for research, particularly in prehistoric art (e.g. Bourdier, Fuentes & Pinçon, 2015: 140; Domingo, Villaverde, López, Lerma & Cabrelles, 2013; García Bustos, 2019; Plisson & Zotkina, 2015; Rivero, Ruiz-López, Intxaurbe, Salazar & Garate, 2019). Furthermore, the digitisation of the morphology of the painted and engraved walls makes it possible to understand the figure-surface relationship, offer a complete recognition of volumes, strokes and shapes and detect synchronic or diachronic relationships between the representations. Some authors point out that this technique has opened up a range of possibilities in stylistic and chronological terms, complementing traditional drawings and tracings (Gutiérrez, Farjas & Domínguez, 2014). Photogrammetry is also indispensable when dealing with panels containing engravings, as it makes it possible to study them to a greater extent in different ways (Güth, 2012).

The first objective was to build up a collection to show to the visiting public. This required the creation of 3D heritage models, "interactive digital objects that have been produced by digitising physical objects with the purpose of communicating cultural heritage to a broader audience" (Cardozo & Papadopoulos, 2021: 521). The data collection and restitution of the Palaeolithic objects displayed in the museum was carried out in two phases: one focused on portable art and the other on parietal art.

Data collection was achieved by means of close-range photogrammetry, taking into account the particularities of both types of support, such as size, limited access, human equipment, necessary material and data recording strategy (Figure 2).

The photographic documentation of the exhibited panels was carried out during numerous fieldwork seasons to document caves with Palaeolithic parietal art. In this case, the methodology has been refined to overcome the difficulties of documenting the incised engravings in order to visualise them correctly (Corchón, Garate & Rivero, 2017; Garate et al., 2020; Garate & Rivero, 2015; García Bustos, 2018; Rivero et al., 2019). The recording of portable art objects took place in the museums where they are stored.

In the laboratory, the photogrammetric model of the heritage assets was made from the images obtained using Agisoft Metashape v.1.7.3. This process must be very meticulous to avoid future errors in the virtualisation. In the models containing figures made with the technique of incised and fine engraving, digital tracings produced in the research were implemented so that the public could visualise them correctly. These digital tracings were made with Adobe Photoshop v. 20.0.3 from the photogrammetric texture obtained in the 3D process (Figure 3). Once checked, they were reloaded into Agisoft Metashape to continue with the following processes.

The next step was to simplify the mesh of all the 3D models created without losing the original quality, i.e. reduce the geometry of the objects in order to increase their viewing performance, using Instant Meshes v. 10.2 version software. In this way, around 500000 polygons were reduced in the pieces of portable art and between 4 and 2 million polygons in the parietal panels, depending on their size. Subsequently, the optimised

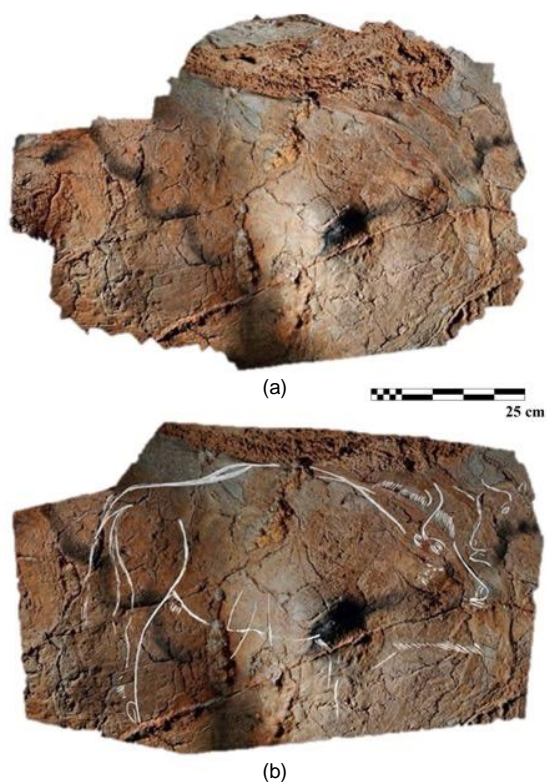


Figure 3: Extract from one of the panels of the Alkerdi cave from "Galería de los Bisontes": a) example of a fine engraving where the figure is barely visible; b) example with a tracing showing the two bison depicted.

mesh was exported to Blender v. 2.93.6 where the texture baking of the normals and textures was carried out. This process, which was applied to each of the pieces exhibited in the museum, consists of using the texture of the original mesh on the new optimised one. The result is a realistic surface with a much lower weight than the original geometry (Figure 4).

2.2. The construction of the virtual museum

The structure in which the objects are housed has been designed with the aim of distributing these vestiges in the most efficient and clearest way, as well as facilitating their viewing, understanding and immersive experience.

The museum housing the digitised prehistoric remains has also been built with Blender. This free, open-source software allows modelling, assembly, animation, simulation, rendering, compositing, video editing and 3D animation pipelining. To create the structure of the virtual museum, the extrusion method was used to configure the space, which had to have a reduced number of polygons (low poly). The wireframe, a 3D image of an object based on lines and vertices, was also used. After this process, the textures of the 3D model are projected onto a plane in 2D format through UV mapping, which makes it possible to adapt a flat surface to a 3D mesh. On the other hand, Physically Based Rendering (PBR) materials have been used. These textures allow us to calculate how light and shadows produced by objects are realistically reflected, providing information on detail (normal map), colour (Base Colour, Albedo, Diffuse), polygon displacement (Height), reflection (Specular), object details (Roughness), etc. After the construction of the 3D model and the application of the textures by UV mapping, the final renders were made with realistic lighting.

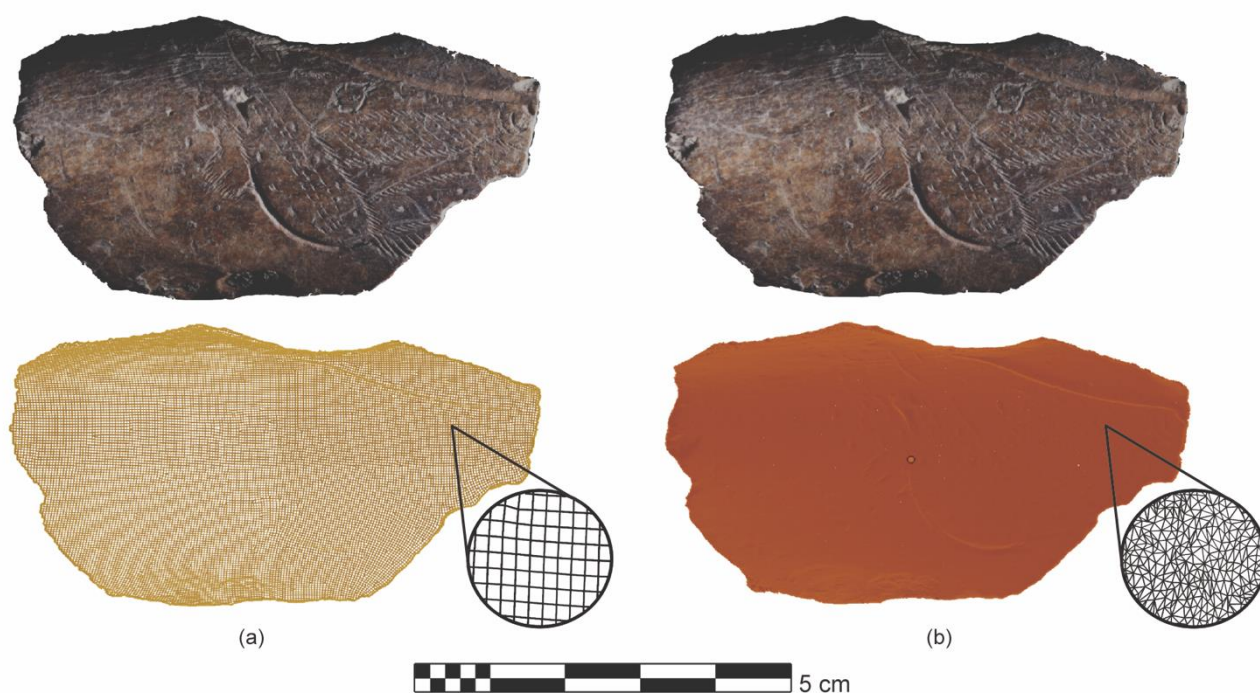


Figure 4: Comparison between meshes on a piece of portable art from Espalungue: a) low poly mesh; b) high poly mesh.

3. Results

The collection created for the virtual museum¹ includes both rock art and portable objects that can be grouped around two chronologies: Pre-Magdalenian (33000-14500 BP) and Magdalenian (14500-11500 BP). In total, more than 31 graphic units have been represented among the seven rock panels (six from Spain and one from France) and the seven portable pieces (one from Spain and six from France) exhibited in the museum (Table 1) (Figure 5).

Table 1: Franco-Cantabrian parietal and portable art exhibited in the virtual museum PaleoArt-3D.

<i>Deposit</i>	<i>Physical support</i>	<i>Iconography</i>
Alkerdi	Parietal	Bisons
Aitzbitarte IV	Parietal	Bison, reindeer and horse
Chauvet	Parietal	Rhino and felines
Domingo García	Parietal	Horses
Hornos de la Peña	Parietal	Human depictions and horses
Hornos de la Peña	Parietal	Horses and goats
Peña de Candamo	Parietal	Aurochs, bears and stags
Isturitz	Portable	Mammoths
Isturitz	Portable	Bisons
Isturitz	Portable	Horses
Isturitz	Portable	Reindeer
Espalunge	Portable	Goat
Espalunge	Portable	Horse
Las Caldas	Portable	Bison and sperm whale (?)

3.1. Architectural structure

The main objective in constructing a space to house the 3D models was to use a simple design that would not detract from the exhibits. At the same time, an open environment was sought in which to observe the greatest number of heritage assets and achieve greater visual comfort. For this same reason, a long glass window has been included both on the roof and on one of the sides of the museum, so that even from the outside, it is possible to see a general panoramic view of the internal layout.

One fundamental aspect is that the virtual museum had to adapt to the intrinsic characteristics of the heritage assets on display. For this reason, two environments have been created. The portable art is exhibited in a circular structure and the parietal art is on the walls of the museum. This separation allows the public to follow a common thread throughout the experience according to the type of surface on which the artistic motif was represented, an important characteristic to take into account when understanding Palaeolithic art (Figure 6).

¹ The museum can be viewed free of charge on the Sketchfab platform of the [Prehistoric Technology Laboratory \(LabTec\)](https://sketchfab.com/Labtec) of the University of Salamanca: <https://sketchfab.com/Labtec>.

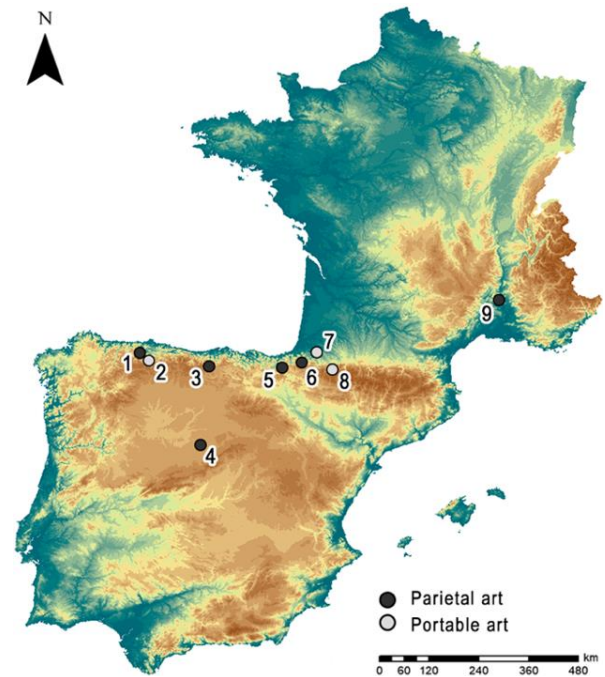


Figure 5: Map of the sites shown in the virtual museum: 1: Peña de Candamo; 2: Las Caldas; 3: Hornos de la Peña; 4: Domingo García; 5: Aitzbitarte IV; 6: Alkerdi; 7: Isturitz; 8: Espalunge; 9: Chauvet.

In short, the result has been a building that is reminiscent of a real-life museum both on the outside and inside, trying to use neutral colours that do not alter the visual perception of these assets. Likewise, a dark background colour has been selected in which both the logo and the museum itself stand out.

3.2. Addition of photogrammetric objects and information elements

Once 3D models of both parietal and portable art had been processed, they were distributed in the place assigned to each object. Special attention should be paid to the upper gallery of Aitzbitarte IV Cave, which has a semi-cylindrical shape. We believe that this shape should be preserved because it has several advantages (Figure 7). First, visitors can recognise how the animals are really arranged in the cave space. Second, the public is aware of both the dimensions of the cave and the space available to the archaeologist for documentation. Therefore, a part of the museum has been adapted to this gallery so that visitors can enter it to observe the three animals represented.

All the pieces on display are accompanied by two elements: a scale and an information panel. The former, always located at the bottom of the object on display, is important to give the viewer an idea of the size of this type of heritage object. The information panel, located to the right of each piece, seeks to situate the artistic motif represented chronologically and spatially. The information it contains tries not to be too specific as it is aimed at a non-specialised audience. Aspects such as location, chronology, support material, iconography represented, the technique used and a brief commentary on the work on display have been included in order to highlight the importance of each object on display of the virtual museum. These panels have also been used to include the logos of the institutions that have collaborated in the creation.



Figure 6: Architecture of the constructed virtual museum: a) front view; b) zenithal view; c) side view; d) interior view facing south; e) interior view facing north.

3.3. Using the Sketchfab platform and adding annotations

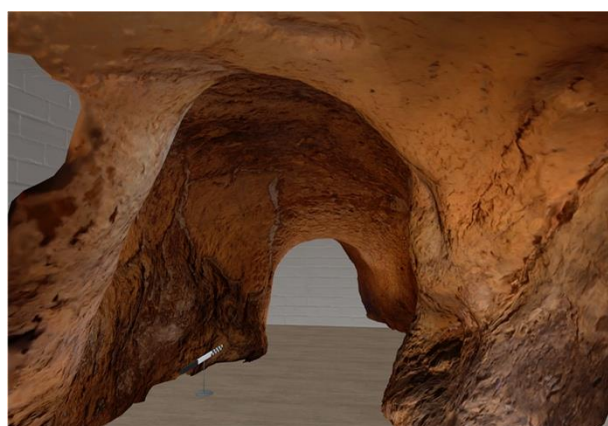
The Sketchfab website is a free 3D model viewer. This platform has been chosen out of all the existing ones (Champion & Rahaman, 2020) for several reasons. First, because its editor is easy to use; secondly, it is a social platform widely used at the user level and allows the visualisation of heritage through computers and smartphones in a professional way. And most importantly, it allows annotations to be added to the models, which the visitor can access interactively.

Some studies consider the annotations of each model an essential complement to obtaining a higher quality educational and informative experience within the virtual museum (e.g. Abbot, Bale, Gowigati, Pritchard & Chapman, 2011; Albus, Vogt & Seufert, 2021; Cardozo & Papadopoulos, 2021; Lloyd, 2016). For this reason,

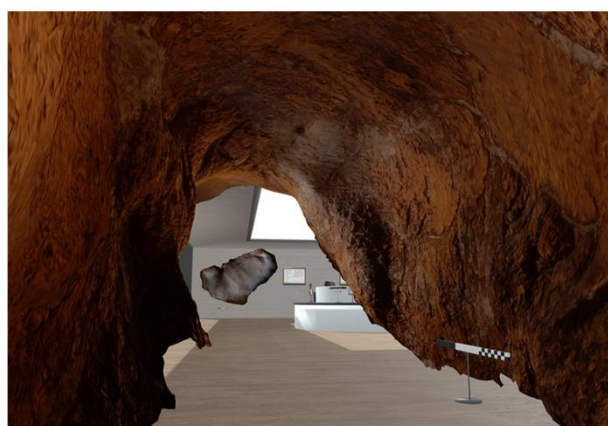
information panels have not only been included for each heritage asset on display. Using the "tags" tool provided by the Sketchfab platform, we wanted the user to be able to create their own experience at the click of a button, with which the visitor is able to move freely throughout the space created in a simple way. Taking advantage of this resource, we have proposed a route through a pre-established order, starting with the cave art and ending with the portable art. It should be noted that this tool has also been useful to point directly to the parietal figures that do not have tracing and which may be challenging to locate, as in the case of the Candamo or Domingo García panels.

4. Discussion

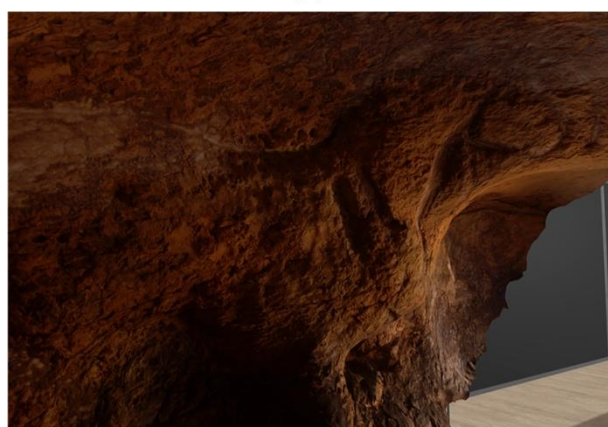
This type of resource makes it possible for the population to access archaeological heritage that is sometimes difficult to see *in situ* for two reasons.



(a)



(b)



(c)

Figure 7: Gallery of Aitzbitarte IV in the virtual museum “Paleoart-3D: regreso al pasado”. Its semi-cylindrical shape allows the user to appreciate how the Palaeolithic artist used the walls to represent a horse, a reindeer and a bison: a) north view of the entrance; b) south view of the entrance; c) horse moulded and incised in clay.

Firstly, Palaeolithic art is a very delicate vestige whose conservation can be seriously compromised during a visit in person. Secondly, such visits can be of little use because the spectator does not recognise figures that are deteriorated, and difficult to decipher or access. “PaleoArt-3D” exhibits examples that the public can see on a tourist visit, such as the Domingo García, Peña de Candamo and Hornos de la Peña panels. However, the museum houses numerous examples that cannot be physically visited, such as the panels in Chauvet, Alkerdi and Aitzbitarte IV.

Additionally, a 3D museum can promote respect for these archaeological remains. The greater democratisation of these assets increases citizens' awareness of the duty to care for and protect them. At the same time, [Cardozo & Papadopoulos \(2021\)](#), [El-Said & Aziz \(2021\)](#) and [Sabbatini \(2004\)](#) show that after the virtual experience, one of the main virtues of this type of resource is to encourage people to visit the real heritage property; that is, the objects exhibited in a virtual museum “can remind the user how stimulating the visit can be” ([Sabbatini, 2004: 225](#)). Therefore, the virtual museum is not a substitute for the real one, but an ideal complement when it comes to promoting cultural tourism. The virtual resource presented here can arouse the interest of the public to get to know Palaeolithic art in person. In this way, the visit to the virtual museum is only the starting point that leads to future excursions to the sites open to the public.

New viewing platforms have improved not only outreach but also the educational field. Resources such as “Paleoart-3D” allow the viewer to interact with the object so that he or she can focus on the aspect that interests him or her most. The application of such methodologies in the current educational system must be a matter of discussion. However, it is increasingly felt that projects of this type should be introduced into the classroom. Numerous studies on the application of virtualisation in educational environments have shown that it is not only effective in terms of teaching, but that this system stimulates interest in the subject, allowing students to develop new ideas or reformulate old ones (e.g. [Christou, 2010](#); [Elmqaddem, 2019](#); [Fabola et al., 2016](#); [Kavanagh et al., 2017](#)). In the same way, the education system has been affected by the global pandemic, demonstrating that e-learning is also possible, and that projects such as the one presented here have a place in schools.

The pandemic caused by COVID-19 has given the final push to virtualisation as an effective method of heritage dissemination and learning, while complying with mandatory standards imposed by health agencies and institutions ([El-Said & Aziz, 2021](#); [Sigala, 2020](#)). Some research (e.g. [Itani & Hollebeek, 2021](#); [Sarkady, Neuburger & Egger, 2021](#); [Talwar, Kaur, Nunkoo & Dhir, 2022](#)) indicates that in no case does the use of virtual tools (e.g. virtual reality or virtual tours) during the health crisis affect or reduce tourist intention to use them again during the post-pandemic. Furthermore, the study conducted by [Zang, Li, Ruan & Liu \(2022\)](#) shows that there was a general positive feeling toward virtual tourism among its consumers during the pandemic. Therefore, at least in times of crisis, the use of virtual tools is a competent alternative to get to know or maintain contact with Palaeolithic art when conventional tourism is not available, while hardly altering the cultural perception of the consumer.

5. Conclusion

The implementation of virtualisation of heritage is increasingly necessary, especially when working with something as unknown and delicate as Palaeolithic art. Not all caves have the appropriate conservation parameters to be visited and in many cases access to them is very complicated. Through the combined use of various methodologies that include photogrammetric documentation and the use of digital 3D tools, it is possible to create an attractive, high-quality and

low-cost online virtual museum that democratises Palaeolithic art and makes it more accessible. This work also shows that the technological resources used to obtain scientific answers are also useful when it comes to transferring the results to the public.

Besides, this type of museum makes it possible to offer a collection of pieces that are difficult to gather and exhibit in conventional museums. It also avoids the overcrowding of this type of fragile heritage and, at the same time, encourages citizen participation in its conservation and valuation by using this type of resource not only from an informative but also an educational point of view. In this aspect, the Sketchfab platform is fundamental, as it has made it possible to reach a large number of people who otherwise would not have been able to access this type of cultural manifestation.

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