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DESIGN AND IMPLEMENTATION OF AN AUGMENTED REALITY APPLICATION FOR ROCK ART VISUALIZATION IN COVA DELS CAVALLS (SPAIN)

Present/permanent address:

Photogrammetry & Laser Scanning Research Group (GIFLE), Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, 46022 Valencia, Spain.

Author names and affiliations:

Silvia Blanco-Pons
Universitat Politècnica de València, Photogrammetry & Laser Scanning Research Group (GIFLE), Department of Cartographic Engineering, Geodesy and Photogrammetry
silblapo@doctor.upv.es
ORCID: 0000-0003-0764-2199

Berta Carrión-Ruiz
Universitat Politècnica de València, Photogrammetry & Laser Scanning Research Group (GIFLE), Department of Cartographic Engineering, Geodesy and Photogrammetry
bercarru@doctor.upv.es
ORCID: 0000-0001-5965-8833

José Luis Lerma
Universitat Politècnica de València, Photogrammetry & Laser Scanning Research Group (GIFLE), Department of Cartographic Engineering, Geodesy and Photogrammetry
jllerma@cgf.upv.es ORCID: 0000-0001-9443-9214

Valentín Villaverde
Universitat de València. Departament de Prehistòria, Arqueologia I Història Antiga.
valentin.villaverde@uv.es ORCID: 0000-0002-2876-0306

Corresponding author:

Silvia Blanco-Pons, silblapo@doctor.upv.es

Abstract

Prehistoric rock art paintings, specifically rock-shelters exposed to environmental and anthropogenic factors, are usually faint and severely damaged, being them difficult to identify and understand by visitors. Augmented Reality (AR) supplements reality with virtual information superimposed onto the real world. This sensor-based technology in smartphones/tablets can improve the paintings experience displaying the 2D digital tracings overlapped onto the real scene (rock with faint paintings). This paper presents an AR application (app) developed in Cova dels Cavalls that shows a recreation of a possible original composition full of motifs with descriptive information to improve current guided tour user experiences. This case study aims to evaluate the rock art AR app targeting non-expert visitors as a means of improving rock art knowledge and sensibility of a fragile archaeological UNESCO Work Heritage site. To achieve this, a variety of participants with different backgrounds and interests tested the AR app on site and answered a complete questionnaire about the use of AR mobile apps. Overall, the results showed great acceptance of this AR app, mainly because in addition to adding new information interactively, it helps to identify the rock art motifs, as well as to recognise them quickly, improving their understanding.

Keywords: Archaeology, Augmented reality (AR), Dissemination, Levantine rock art, ARToolKit, Cultural heritage, Mobile application.

1. Introduction

Tangible cultural heritage such as historical buildings, archaeological sites and artefacts is a fundamental expression of the richness and diversity of a group or society from the past. Wars, natural disasters, anthropogenic factors seriously endanger heritage, hence many technicians, curators and researchers are focused in its preservation, documentation and dissemination. Over the last two decades, technological advances have significantly improved the process of documentation and dissemination of cultural heritage, obtaining accurate 3D models in a short time and their dissemination through different forms of digital deliverables.

The advent of both image-based technology (photogrammetry) and range-based technology such as terrestrial laser scanning (TLS) meant a radical change in 3D documentation. Both techniques provide dense point clouds through automatic processing. TLS has been used in many cultural heritage projects in order to obtain an accurate documentation of complex monuments or sites [1–3]. However, this technique requires expensive equipment and long time to process data. Unlike TLS, photogrammetry provides a low-cost method to produce high quality 3D models [4,5], although the final quality is not always guaranteed (depends on multiple parameters such as number of images, image network, texture…) and must be validated by the user. The 3D models obtained through these techniques can assist in the conservation, preservation, and documentation, as well as dissemination for both scholars (experts) and the general public (non-experts).

Next to the development of data acquisition methodologies with low and high end imaging and ranging sensors, new technologies and advances in 3D virtual reconstructions, semi-immersive environments, serious games [6] or AR [7] have offered new ways of performance. These new approaches are being widely applied in the cultural heritage field, improving user experience and serving as a tool to show how heritage was in the past. There are numerous examples of 3D virtual reconstructions of archaeological sites [8–10] and monuments [11]. Furthermore, in some cases the 3D reconstruction provide the basis for the development of virtual reality applications (apps) [12,13] which allow users to plan, visit, analyse and experience an archaeological park [14], even know how a lost site was [15] through immersive visualisation systems. Other examples are focused on teaching cultural heritage with serious games [16,17] and semi-immersive environments [18] due to fact that students are more eager to computer-based learning, although they may not be exhaustive enough.

With the smartphones evolution, AR apps have increased a lot in the cultural heritage field. Some researchers have implemented this kind of apps in museums [19], outdoor environments [20] or archaeological sites to understand the past [21]. Unlike virtual reality, where a world completely immersive is created by computer, AR allows the user to combine information from the real world with virtual information in real time; thus the user perceives both realities, virtual and real simultaneously [22]. This technology is really intuitive and is very useful for visualising reconstructions of lost sites *in situ* [23]. Last trends in AR applications integrate information on the ground and underground combining terrestrial laser scanning 3D models and ground penetrating radar (GPR) to identify buried structures on-site [24].

AR technology offers many advantages in cultural heritage dissemination, helping specialists to preserve history, improving visitor satisfaction as well as attracting new visitors [25], and it has also a positive impact on the students' motivation to learn [26]. For all these reasons, our proposal is to disseminate the rock art paintings through this visualisation technology.

Levantine rock art is found in the Mediterranean side of the Iberian Peninsula and is usually located in open-air sites exposed to external agents (both natural and human) that are damaging the paintings. Over the years, rock art paintings are fainting and in some cases, part or the whole motifs have disappeared; hence its interpretation is actually very difficult. Therefore, a swift action in terms of documentation, preservation and dissemination is crucial. Furthermore, Levantine rock art was declared World Heritage by UNESCO in 1998; this fact meant an increase in responsibilities and obligations towards the preservation and dissemination of this cultural heritage [27]. Much progress has been made in the rock art documentation [28–33], but dissemination must be part of the whole process as well [34] to achieve attracting more visitors and make them more aware of the historical background. In this regard, AR apps can help to promote the Levantine art in an innovative way. Moreover, due to the poor conservation of the paintings, AR can help to identify better the archaeological motifs, showing on the smartphone display the real location of the paintings on site. The e-ART project arose in 2015 [35] in Spain with the same objective, although at present it is not available for downloading, as well as the MARCH project [36], whose AR app based on marker tracking that allowed users to superimpose the expert's drawings on the prehistoric cave images. Despite the limited examples of AR apps applied to this field, the number of AR apps in cultural heritage has grown significantly in recent years, as pointed out by [37]

The present study uses the case study of the Cova dels Cavalls that houses many motifs heavily deteriorated or, as a consequence of the calcite that covers them, are difficult to see. Due to these facts, the identification of the motifs is very difficult thus, visitors can neither fully enjoy the visit to this archaeological site nor understand the motifs represented. Therefore, the AR app development aims to improve the rock art visualization on site through different information layers overlapping the real scene. Finally, in order to evaluate the AR app as dissemination method, a mixed group of people tested the AR app on site and answered a complete questionnaire.

2. Mobile augmented reality technology

AR is a visualisation technology that supplements reality with virtual information superimposed on the real world [22]. Thus, the real world is enhanced with all kinds of virtual content such as 3D models, 2D images or text information, which are placed in their real position in real-time and are displayed through the device display. The whole AR visualisation process can be divided into different steps: image acquisition, calibration, tracking, registration and display as is described in [7].

The main strength of an AR app is the ability to visualise the virtual content aligned with the real object. This is achieved through tracking methods, which determine the position and orientation of the camera relative to the real-world coordinate system [38]. Whenever the user moves the camera, the tracking method recalculates the new pose in real time to adapt the projected 2D image to the new camera view.

Nowadays, vision-based tracking is a method widely used to calculate camera pose from the data received by the camera view. There are different solutions to solve the camera pose estimation [39–41], depending on the available data, vision-based tracking can be classified in marker-based tracking and markerless tracking [42].

Marker-based tracking relies on markers; images or patterns easily detectable in a scene. Through image processing, pattern recognition and computer vision techniques, the marker is detected and the camera pose is calculated [43]. The use of markers is not always possible because there are places that cannot be altered with any image or marker, thus several markerless approaches emerged. These approaches can be divided into two groups: feature-based tracking, which only uses natural features easily detectable in the scene such as edges or corners; and model-based tracking, which uses a 3D model.

The AR application developed in this study implements the feature-based tracking approach. This method requires a database of previously extracted features of an image and then, with the set of correspondences between database features and their homologous features obtained by the camera and process in run-time, the camera pose is obtained and the virtual content is projected.

3. Cova dels Cavalls

This study uses the Cova dels Cavalls as a case study because it is in an accessible location, close to the Valltorta museum, and is one of the most important Levantine rock art sites [44].

The Cova dels Cavalls rock-shelter is located on the Valltorta Ravine, in Tirig, Castellón Province (Spain) (Figure 1a). Since its discovery in 1917, the Cova dels Cavalls has become one of the best known depictions of universal rock art. Moreover it was one of the rock art sets where the Levantine Art knowledge began [44]. This shelter highlights due to the quantity and variety of its rock art depictions with some Schematic art and more abundant Levantine figures (http://www.prehistour.eu/carp-guide/valtorta--gasulla).

a **b**

Figure 1: Cova dels Cavalls: (a) Geographic location in Tirig (Castellón, Valencian Community, Spain), (b) View of the environment in a cliff on the east bank of the Valltorta Ravine.

In 1994, the Valltorta museum was created to improve the conservation and dissemination of this and other rock art sites of Valencian Community, recognised by UNESCO as World Heritage. The museum was located in the Cultural Park of Valltorta-Gasulla (Tirig, Castellón) and it offers regular guided tours to the protected Cova dels Cavalls (Figure 1b) as well as other rock art paintings in the area.

The research presented herein is focused on the famous hunting scene of Cova dels Cavalls where an archers group faces a herd of deer (Figure 2a); in 1998 this rock-shelter was conserved by art restorers. This scene is one of the graphic references used most in Prehistory hunting illustrations [44], but its interpretation is difficult for inexperienced public (Figure 2b).

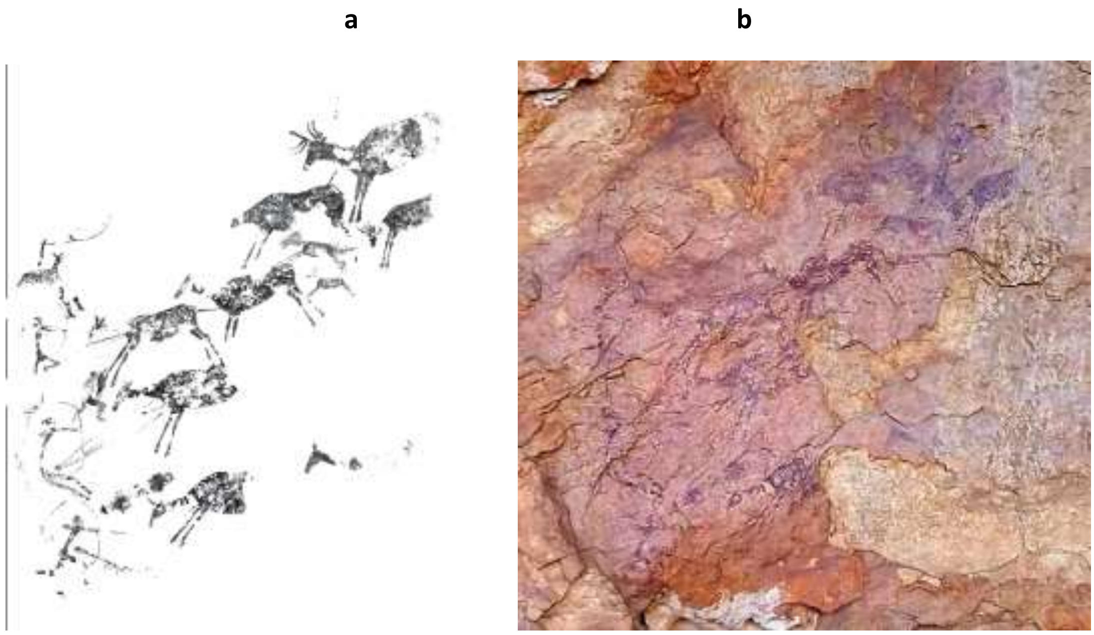

Figure 2: (a) Hunting scene according to [44]; (b) Photographic scene at present.

4. Design and implementation

The app structure is very simple seeking a user-friendly interface that allows a quick understanding. Visitors should only point their phone camera at the scene and the current state of the paintings should be displayed on the camera view over its real position. In addition, there are three buttons located on the right-hand side of the camera view (Figure 3) to interchange the virtual content between current state, possible original state and descriptive archaeological information about the paintings. This virtual content manifests clearly the damage that paintings have suffered over time and is enriched including not only a recreation of the motifs but also historical information about them.

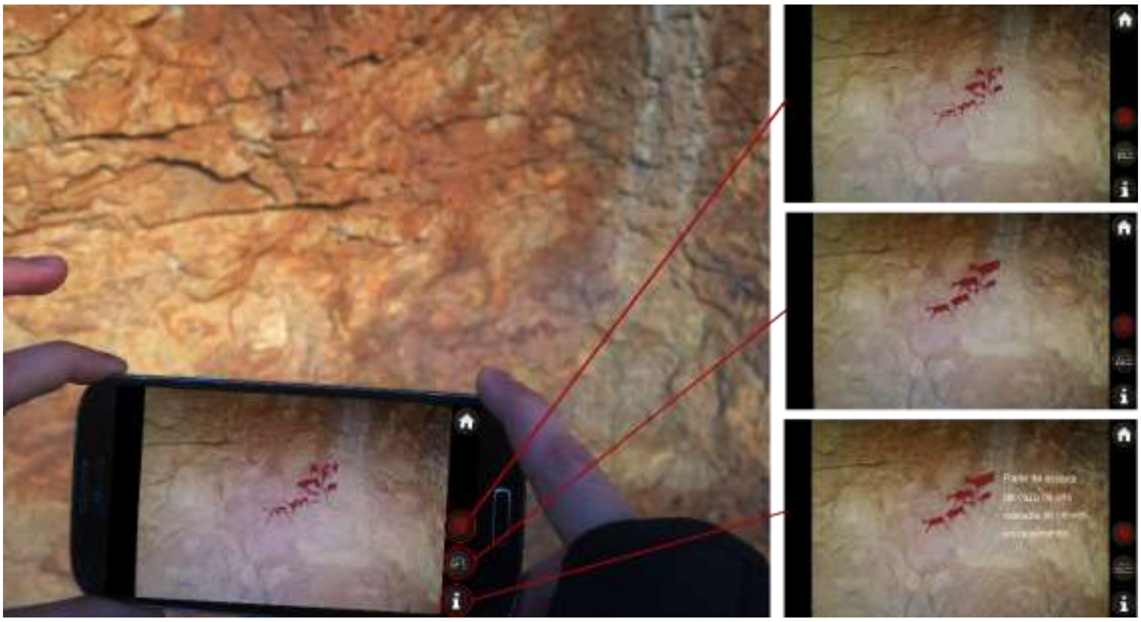

Figure 3: AR app interface and screenshots taken on site.

The app was developed using ARToolKit's AR for Unity game engine. Unity is a cross-platform game engine that supports 2D and 3D graphics, physics engine, graphics rendering and scripting, thus the creation of interactive 3D content is easier than with other platforms. Moreover, the app development through Unity software is faster and required far less programming [45]. For these reasons, nowadays it is used for almost all sorts of 3D projects (game or not) such as virtual reconstructions [15,46,47] and AR projects [48,49].

Thanks to AR libraries, the development of apps is greatly simplified. AR library provides developers functions and data structures implemented in a specific language. There are a large number of AR libraries such as ARTag [50], ArUco [51] and DroidAR [52] marker-based libraries or ARToolKit [53], Vuforia [54], Wikitude [55] and ARmedia [56], which do not just recognise markers but also real scenes [57].

ARToolKit 5 is an open source library that supports markers recognition, multimarker tracking and feature-based tracking, called as natural feature tracking (NFT), for image recognition. In addition, this library provides a plugin for Unity and an extensive documentation. However, its major limitation is that it currently does not support the model-based tracking.

In order to decide which library was best for this project, some preliminary tests were conducted. Libraries based on markers recognition were discarded because the rock art sites must not be altered with any object or marker, since they are protected places. Therefore, for this kind of project, the app must be based on image recognition. Despite the fact that the recognition scene is not flat, the motifs are split in small units (panels) that can usually be assumed as flat, hence feature-based tracking was tested. Vuforia failed on creating the database of known features whereas ARToolKit extracted many features of the training image and the recognition and tracking worked successfully.

The app implementation is greatly simplified thanks to the ARToolKit library. The process of recognition and tracking required the database generation of the known features, later the app is designed in Unity, where the virtual contents and different functionalities are added. These steps are described below.

4.1 ARToolKit feature-based tracking

The goal of the feature tracking system is to determine the camera pose in real time from the features of the real scene, in order to project the virtual content correctly. The process is based on matching keypoints from training images (images known in advance) with keypoints obtained in run-time [58]. Thus, the first thing is the creation of the features database extracted from the training image through *genTexData* program included in ARToolkit.

This program allows users to select the level of feature extraction for tracking and initialisation, being 0 the minimum level and 4 the maximum. This step determines the amount of extracted features; too many features usually slow down the recognition process. The features are extracted from a set of images with different resolutions and are stored in three different files: *.iset* file with the image set resolutions, *.fset* file with the features used in continuous tracking and *.fset3* file with the features used for identifying the pages and initialising the tracking [59]. These files contain the keypoints required at run-time to calculate the camera pose.

In order to achieve proper results in the recognition and tracking process, the intrinsic and extrinsic camera parameters are required as well. These parameters are obtained in the calibration process. To do this, ARToolKit provides an app called *ARToolKit Camera Calibrator* on Google Play which guides the user to take a set of photos of a calibration pattern.

4.2 ARToolKit dataset generation

The training image is the scene that launches the app, therefore this image was taken perpendicular to the hunting scene of Cova dels Cavalls (Figure 4a) from where the visitors will launch the AR app. This image was processed with the ARToolKit *genTexData* program to generate the features data files.

Level 2 was chosen for tracking, obtaining 3182 features and level 1 was chosen for initialisation, obtaining 688 features (Figure 4b). Selecting these levels, the program default values, a large number of features distributed throughout the image was obtained. These features are stored in different files into the app and are used in run-time to calculate the camera pose.

a b

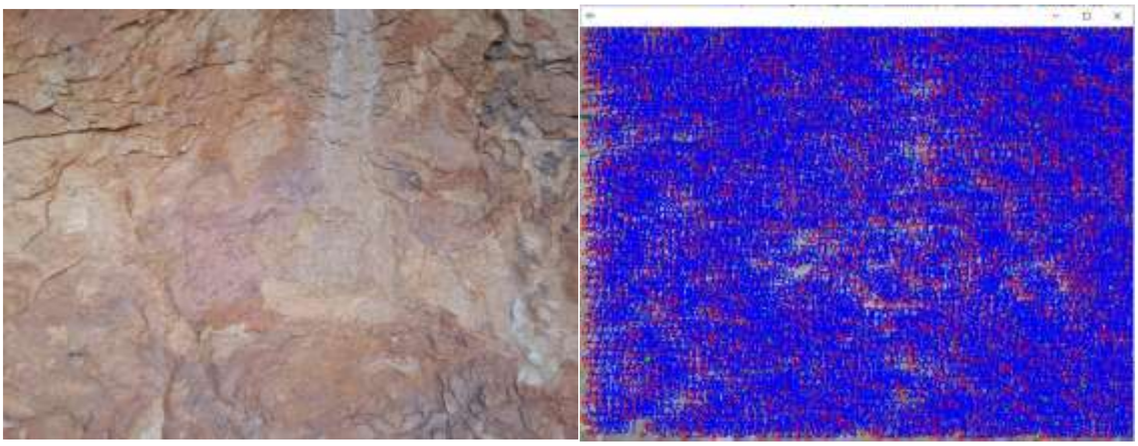

Figure 4: (a) Example of a training image taken on site; (b) Features extracted from the training image (a).

4.3 Virtual content

An AR app adds information to reality displaying any kind of virtual information such as 2D images, 3D models, texts, audios, or/and videos. The app developed in this study shows two different images of the hunting scene of the Cova dels Cavalls, one with the remaining pigments and another with its possible original state (Figure 3); the idealised scene obtained by Obermaier and Wernert in 1919 (Figure 5) might also be displayed, as well as others such as a final idealised scene taken from Martínez and Villaverde (2002). In addition, the app shows a descriptive text about the scene: "Part of hunting scene of a herd of moving deer".

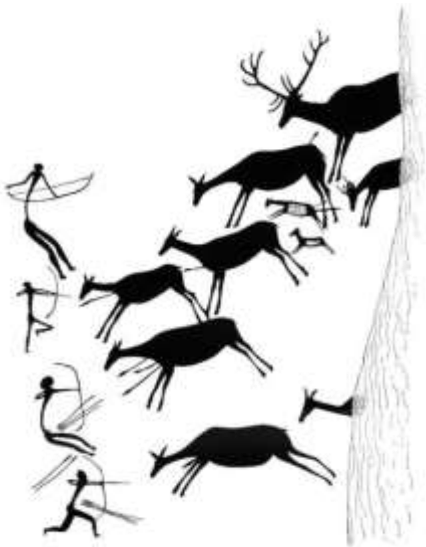

Figure 5: Idealised hunting scene according to Obermaier and Wernert (1919)

4.4 Scripting

Finally, the design and functionalities were developed in Unity. The features dataset and the virtual content was added to the Unity project as well as two scripts written in C# that were associated to three buttons to control the virtual content, switching on or switching off when the user press the buttons. An image with the text "LOADING…" is displayed while the AR app is initialising.

5. Usability evaluation

Mobile apps as a tool for dissemination and learning are experiencing extraordinary growth. Martinez et al. [59] evaluate mobile apps for heritage and conclude that most apps need to improve the user experience (UX) design; similarly, the historical content as well as archaeological context must be more precise. Other studies point to the lack of on-site evaluation by real users who do not know in advance the implementation or operation of the app [60,61]. In addition, only a small part of the visitors of archaeological sites or museums are specialists in the scientific contents presented [61]. The usability evaluation presented herein is focused on knowing if the AR app developed can help visitors (without previous rock art knowledge) to better understand the painted rock art scenes. In addition, the evaluation will allow us to know (as developers) whether the design and functionality are adequate. A group of 11 volunteers tested the AR app at Cova dels Cavalls shelter, 63.6% male and 36.4% female; the majority were over 41(63.7%) or between 31 and 40 (27.3%) and almost all participants had university degrees (90.9%). The survey was divided in two parts: first) a pre-questionnaire with questions related to the participants' information; and second) a questionnaire to evaluate the AR app, that included 15 questions. The answers were rated using a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

The pre-questionnaire was realised in order to gather participants' background information. In this evaluation, only issues related to rock art knowledge as well as the use of mobile devices was analysed. Regarding rock art knowledge, all participants claimed to be interested in rock art (100%) as well as to know this art (90.9%), but only 18.2% were experts in this field. These results indicate that it is important to invest in apps development related to this field. According to the mobile operating system, 90.9% were using Android phones and 45.5% were using both phone and tablet. Therefore, apps developed must be compatible with this operating system. Regarding the questions related to AR, 63.6% of the participants know the meaning of AR, and only 36.4% had previously used an AR app.

In the last decade, the use of mobile phones has increased greatly and thanks to the number of apps that are developed daily, a mobile phone can have all kinds of uses. Thus the mobile phone has been incorporated into our daily life and has become in an indispensable element. This fact is reflected in the questions related to the usage of the mobile where 90.9% answered that they are using mobile apps daily. The percentage of apps used by the participants is shown in Figure 6; the most used apps are related to social media (17.3%), messaging (17.3%) and photography (15.4%).

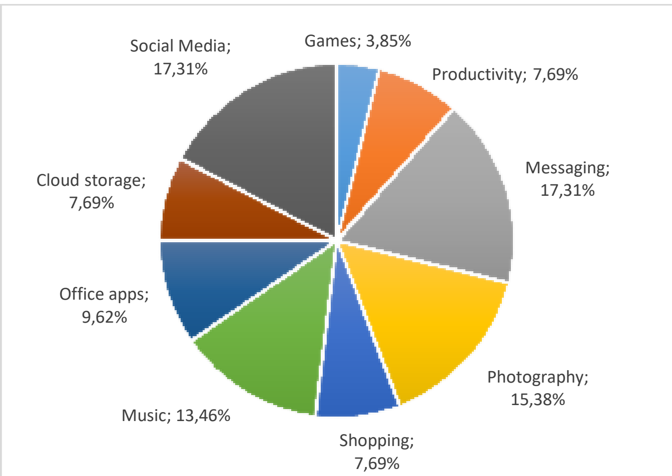

Figure 6: Percentage of apps used by participants

The last part of the survey measured participants' perceptions on AR usability as well as interest and motivation to visit rock art sites after using this app. Table 1 presents the 11 questions related to the usage of the AR app in the Cova dels Cavalls; Figure 7 shows the mean results. The mean answer value to questions Q1-Q4 was higher than 4.5, indicating a high approval degree, thus for most respondents AR improves visualization, understanding and recognition of rock art paintings. In addition, examining Table 2, the highest percentage of strongly agree answers (value 5) was for questions Q2 (82%) and Q4 (91%), indicating that this app improved a lot the painting identification.

The questions Q5-Q7 are related to the virtual content. The main problem in AR apps based on natural feature tracking is the need to recognise enough points in the scene to calculate the position and orientation of the virtual content correctly. In rock art scenes, it is more difficult to find highlighted features, thus the virtual content positioning can be less accurate or last long (around 3 s). In this case, participants are neutral to these issues.

Regarding the questions Q9 and Q10, the participants indicated a good agreement with these statements (mean higher than 3.5); AR added new information to the guided tours and was easy to use. Finally, most of the participants strongly agreed that AR is a very useful for rock art dissemination and they agreed with the AR app (Q8 and Q11 with a mean value of 4.5). As a whole, the responses indicated a great acceptance of AR as a tool to improve the visit to a rock art site.

Table 1: Augmented Reality questionnaire.

Q1	AR improves panel understanding	Q7	Virtual content is correctly placed
Q2	Rock art paintings are more easily recognised	Q8	AR app is very useful
Q3	AR improves rock art visit	Q9	AR app adds new information
Q4	AR improves paintings visualisation	Q10	AR app is easy to use
Q5	Virtual content takes a long time to appear	Q11	I like the AR app
Q6	Virtual content remains fixed, flicker-free		

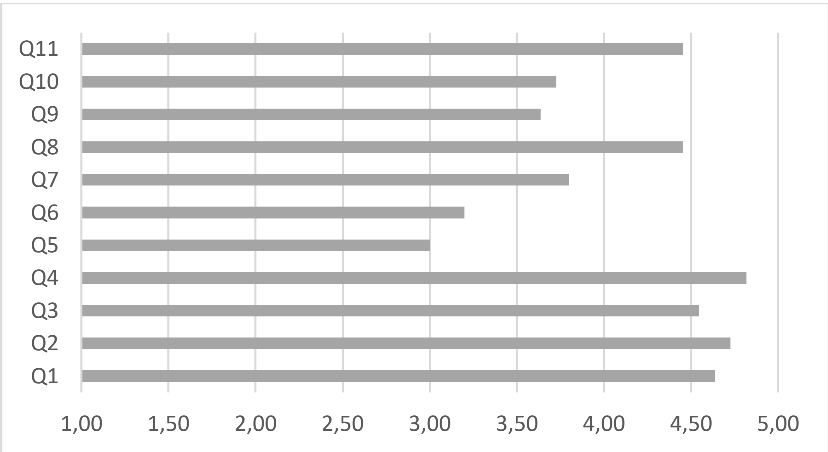

Figure 7: Overview of answers related to AR.

Table 2: Percentage of responses obtained.

	1	2	3	4	5
Q1	0%	0%	9%	18%	**73%**
Q2	0%	0%	9%	9%	**82%**
Q3	0%	0%	9%	27%	**64%**
Q4	0%	0%	9%	0%	**91%**
Q5	10%	10%	**60%**	10%	10%
Q6	10%	0%	**60%**	20%	10%
Q7	0%	0%	40%	40%	20%
Q8	0%	0%	9%	36%	55%
Q9	0%	9%	36%	36%	18%
Q10	0%	9%	36%	27%	27%
Q11	0%	0%	18%	18%	**64%**

The four last questions (Figure 8) assessed how this app influenced the participants' behaviour towards cultural heritage history and its conservation. These questions were based on [62], which aimed at raising the awareness of a students' group to the importance of cultural heritage preservation and documentation through building 3D virtual models. As Figure 8 illustrates, most participants agree with these statements. The app increased the interest in the site and its history, therefore, in addition to improving the visualisation of the paintings, this app helped to disseminate the cultural heritage and most of the participants found this means of dissemination interesting (Q15 with a mean value of 4.3).

Q15	I find interesting the rock art dissemination through AR apps
Q14	This app made me aware of the importance of the rock art conservation
Q13	This app increases my interest in the history of the site
Q12	This app motivate me to visit the site

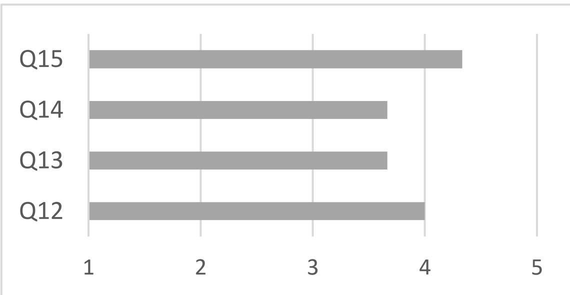

Figure 8: Answers related to questions about the cultural heritage site.

6. Discussion

First of all, not everyone is aware of the existence of Levantine rock art and the number of rock art shelters that can be visited in Spain. Investing in the development of new dissemination apps can help to attract more visitors, as pointed out by [25,63]. In addition, it can enrich whatever traditional guided tour, making it more intuitive and enjoyable. In this regard, the Cultural Park of Valltorta-Gasulla was created, aimed at protecting, disseminating and studying the Levantine art [64]. Findings of this case study showed that all participants were interested in rock art as a valuable heritage asset from our past societies. These results were expected owing to the fact that survey was conducted to a group of visitors of the Valltorta Museum devoted to rock art in the Valltorta-Gassulla area. On the other hand, most participants were not specialist in rock art, thus they were spending their spare time visiting the natural and archaeological environment. These findings suggest a clear interest of the participants in learning about our history, and more in particular, about prehistoric rock art sites. However, in order to know the society interest about this part of our legacy, this questionnaire should be asked to a larger group of people, especially to those who are not visiting the museum. The fact of running the AR app off-site at home or at primary/secondary school might attract their attention to visit more (and more often) rock art sites.

On the other hand, smartphones have become *de facto* a new dissemination tool. Smartphones are nowadays powerful computers equipped with a large number of sensors and that enabling the installation of all kinds of apps; therefore these devices have now become the new portable information and communication technology [65]. The usage of smartphone apps is increasing and, in some cases, is replacing laptops and desktops [66]. In this study, the usage of smartphones was evaluated and almost all participants claimed to be using smartphones apps every day, mainly for communication and social media (Figure 6). These findings support previous research by [66].

Regarding AR technology, future predictions suggest an exponential increase in the number of AR users [67]. This growth can already be seen in the number of AR apps available in the market. Despite of this, only 36% of respondents in this study had previously used an AR app although more than half claim to know this technology. These results show that today, the end user does not use AR technology. [68] suggest that this could be due to the fact that this technology has not reached the level of maturity yet.

Overall, the results points to the overriding importance of smartphone as a means of communication and information, and the potential of AR apps, and because of this, justify the relevance of implementing mobile AR apps in order to disseminate cultural heritage. However, AR apps have not been sufficiently evaluated to know the level of acceptance and understanding from a users' point of view [68]. Hence this study is focused on the evaluation of our developed AR app. Despite some participants were unaware of this technology, nearly all of them agreed with the great usefulness of this app to visit rock art sites.

The main goal of this app was to improve the current guided tour, making easier the recognition of faint archaeological paintings, since this task is very complicated due to the state of conservation. In this regard, practically all of the respondents claimed the AR app improved the rock art visit as well as the panel understanding, specifically 91% of respondents said they strongly agreed that the AR improves paintings visualisation and the understanding of the scene. Overall, the results showed great acceptance of this AR app, mostly because in addition to adding new information interactively, it helps to understand better the rock art motifs, making it very useful in guided tours. As other researchers pointed out [68,69], the perceived usefulness is a fundamental factor to determine the intention to using AR apps, thus it seems that AR apps constitute an essential tool for disseminating rock art.

Despite the advances in current markerless tracking techniques [39] and large number of AR libraries to develop easily AR apps [49,57], we have detected some problems in the AR app that can affect the user experience. These problems are related to the virtual content, which sometimes flicker or is not aligned correctly with the real paintings, causing misunderstanding. This is due to the pose estimation process, the main challenge in markerless tracking techniques [39,58]. ARToolkit calculates the pose estimation from a planar object, but other approaches exist to calculate the pose estimation in unknown environment, as presented in [40,70] which could improve the tracking results. In this regard, the respondents were neutral to the statement *virtual content remains fixed, flicker-free,* hence this is not a great problem for a user standpoint, although from the producer standpoint, it should be improved, testing other AR libraries or implementing other tracking methods. Another problem that might affect the user experience is the time that virtual content takes to appear (time response), since users have to wait around 3s until the virtual content appears on the smartphone screen. This is a technical problem due to the library used for AR tracking. The ARToolKit features dataset is large enough (3182 features), thus the time to process all these features to calculate the pose estimation is long. This technical problem related to time response was evaluated in [71] where Vuforia's tracking was much faster than ARToolKit, but Vuforia was not able to recognize all the paintings in rock art scenes, so Vuforia was discarded.

Some research analysed AR as a tool to improve the motivation for learning, specifically devoted to students [26,72]. The survey conducted in this study showed a common agreement that the AR app increased the motivation and the interest for the history of the archaeological site. These findings support previous research by [25] who pointed that AR enhanced cultural and historical value as well as attracted different groups of visitors. In addition, according to [62], digital technologies, such as the generation of 3D models, increased the awareness of university students about the importance of preserving cultural heritage. Similar results were obtained in this study, in which most participants agreed that the AR app made them more aware of the paintings degradation and the importance of the rock art conservation. This was possible because the AR app allows the visitor to visualise the current state and the original state of the paintings. Thus, the visitor was aware of the painting deterioration suffered over time.

7. Conclusion

This paper has presented an AR app developed to ease understanding and visualisation of faint rock art painted scenes on site through smartphones, using feature-based tracking. The AR app has been implemented in Unity with the ARToolKit library. A usability evaluation has been carried out through a questionnaire to a group of visitors in order to validate the app, as well as the method to identify the performance and user's satisfaction with the developed AR app.

Overall, the respondents showed strong interest in this AR app, highlighting mainly the usefulness of visualising paintings recreation, which helped the inexperienced visitors to understand the rock art paintings much better. Furthermore, respondents reported that these kinds of apps are particularly suitable for young's visits to the rock art site because they are attracted by these technologies, which are highly intuitive and enjoyable. In conclusion, after assessing the outcome of the survey, it can be stated that AR is an ideal means of dissemination that adapts perfectly to the rock art field, improving the visualisation and understanding of paintings. Therefore, it can be claimed that AR apps development in this field is more than justified.

New development will be carried out by the authors in the future, testing new libraries in order to improve users' satisfaction on highly depending scenarios such as open rock art sites in mountainous reliefs where non-contact solution are requested.

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