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IMMERSIVE VIRTUAL REALITY TO VISUALISE THE VISIBLE AND INFRARED LAYER OF A MEDIEVAL ALTARPIECE

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Abstract

This article describes the conception, development and implementation process of an interactive, immersive virtual reality experience for a museum environment, which allows viewers to virtually explore the 'Retablo de San Jorge del Centenar de la Ploma' in detail and in its entirety. This altarpiece is a pivotal work in the International Valencian Gothic style. It is also an example of Relocated Heritage, which has belonged to the Victoria & Albert Museum in London since 1864. Currently, it is exhibited there in the room housing the Raphael Cartoons. The fact that it is impossible to physically view this work in the Museo de Bellas Artes de Valencia along with other medieval Valencian Gothic altarpieces has motivated the creation of this virtual reality experience. This will enable researchers and visitors interested in this period to virtually examine the work. To produce this experience, different data-gathering technology has been used, such as visible and infrared radiation, photogrammetry and computer design programs like Blender and Unreal Engine. For the viewing, high-range computer equipment and virtual reality headsets have been implemented, which totally immerse the user in the created environment. In this experience, the viewer is taken on an aerial tour of virtually reconstructed 15th century Valencia and finally brought to the altarpiece, where a close examination can be made. This examination implements both the visible light spectrum and that of infrared radiation, enabling the contemplation of the iconography of each of its scenes and characters and the detailed study of the techniques used in the creative process of this emblematic altarpiece.

Keywords: environments, exhibition, interaction, images, Oculus Rift S

1. Introduction

The aim of this paper is to present the design, development and implementation of an immersive virtual reality experience in a museum

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environment. The subject of this experience is the altarpiece San Jorge del Centenar de la Ploma (Figure 1).

Figure 1. The altarpiece currently exhibited in the *Victoria & Albert Museum*, dimensions: 660 cm x 550 cm.

Since the altarpiece San Jorge del Centenar de la Ploma left Valencia in 1864, it has never returned from London, now, thanks to the Valencian Government (Generalitat Valenciana), effort is being made to bring this example of relocated Valencian heritage closer to the Valencian population, given its particular importance as an emblem of the history of Valencian culture [1]. Among the actions being taken, the following can be listed:

a) The establishing of a collaboration agreement with the *Victoria & Albert Museum* to carry out research on the altarpiece [2] (restored in 1970) and the preservation and restoration of the predella, the only part which has not been restored for centuries. It has been necessary to bring this part of the altarpiece to the Museo de Bellas Artes de Valencia in order to carry out the restoration.
b) The undertaking of a research project by the Generalitat Valenciana titled: *El Gótico Internacional Valenciano: El Retablo del Centenar de la Ploma y otras obras clave en torno a ésta, para su estudio, análisis científico y/o identificación de su autoría* (GV/2018/154).
c) The designing, development and implementation of an application for the immersive and interactive visualisation of the entire altarpiece, not only using visible light, but also infrared radiation, highlighting the importance of the collaboration between institutions in cases of relocated heritage.

The *Retablo de San Jorge del Centenar de la Ploma* is a pivotal example of Valencian International Gothic due to its combination of styles and artistic influences which draw from the Dutch, Saxon, Florentine, Sienese, Pisan and Cypriot styles. These currents, along with those already existing in the Kingdom of Aragon, converged in 15th century Valencia as a consequence of the economic and cultural splendour that the city enjoyed at that time [3, 4].

This altarpiece is an example of Valencian medieval art, which is of great interest for art historians since it is the first representation of an historical event. It is also intriguing due to doubts about its attribution. Various artists are known to have participated in its creation between 1400 and 1405, such as Marçal de Sax and Miquel Alcanyis, although the collaboration of others cannot be ruled out [5]. Furthermore, the original commissioning document has not been found [6]. The singularity of this altarpiece is evidenced by the fact that it influenced other works of its time, as can be seen in pieces preserved in the Museo de Bellas Artes de Valencia, Segorbe and in Valencian temples, and others from the Kingdom of Aragon.

The altarpiece was commissioned by the urban militia the Centenar de la Ploma, as is demonstrated by the crossbows and crosses of Saint George in the carved moulding of the altarpiece. This militia was a company of one hundred archers responsible for protecting the Aragon flag. It was established by Pedro II el Ceremonioso on 3rd June, 1365 under the name of Centenar del Gloriós Sant Jordi, as it was put under the patronage of this saint. The militia was popularly known, however, as the Centenar de la Ploma, for the egret feathers which the archers wore on their helmets. Their uniform was a dalmatic of white linen with a red cross of Saint George on the front and the back covered in chainmail. The main weapon they used was a crossbow.

The altarpiece was created for the now inexistent chapel used by the company in the Iglesia de San Jorge, located in the present day Rodrigo Botet square in Valencia. It is quite large (660 cm x 550 cm) and shows Saint George slaying the dragon in the bottom centre panel. Saint George is dressed in the same way as the archers. On the panel above this, we can see a battle in which Christian soldiers are defeating the Moors with the aid of Saint George, called the Battle of El Puig (Figure 2). In the panel over the battle scene a beautiful rendering of the Virgin of Victory surrounded by angels can be observed. The top panel of this central part shows a majestic Christ flanked by Elijah and Moses. To each side of the centre, we find sixteen narrative scenes of the life and martyrdom of Saint George, taken from Jacobus of Voragine's Golden Legend, with the four evangelists accompanied by angels in the panels at the top. The figures of twenty-six major and minor prophets divide the central and side panels. In the mouldings bordering the entire altarpiece, we find the twelve Apostles and the dove of the Holy Spirit, alternatively separated by a cross and a crossbow. On the bottom part of the altarpiece, the predella depicts ten scenes from the passion and resurrection of Christ.

Figure 2. Scene of the Battle of Puig.

The disappearance of the company of the Centenar de la Ploma in 1707 as a consequence of the Nueva Planta Decree resulted in the abandonment and eventual disappearance of this temple and the dispersal of its artistic property, including the altarpiece. A French antique dealer put it up for sale in Paris in 1864, when it was acquired by the South Kensington Museum in London, which was under construction at that time. This later became the Victoria & Albert Museum, where the altarpiece is currently exhibited in the room housing the Raphael Cartoons.

In order to be able to show and analyse this valuable piece of Valencian Cultural Heritage with the highest fidelity, a digitalization project for this relocated heritage was proposed. Through the use of photogrammetry and immersive virtual reality, a valuable tool is made available to museums [7] that not only displaces the user in time and space, but permits a chromatic and volumetric display in detail.

2. Materials and methods

A Hasselblad ixpress 96 sensor was used to take the infrared images. The altarpiece was divided by height, and the registers were taken from scaffolding, which made it possible to record images of the entire surface from a distance of 1.5 m.

A Canon EOS 5D Mark III camera was used for the photogrammetry, with a focal length of 50mm. Flash was not used. The same methodology employed for the infrared images was used. The total number of images taken for the complete registration of the altarpiece was 276 photos. They were recorded in a raw format (5760 x 3840 px) to be able to continue working on future files and images. The light used was ambient light, the museum's own light, and the shots were made

perpendicularly. The software used to obtain the cloud of points and 3D mesh was Autodesk ReCap.

Blender® was used for the re-topology of the 3D archives obtained from the processing of the cloud of data. This process permitted the preparation of the mesh for visualisation in real time and the processing with other programs to allow user interaction.

Unreal Engine was the rendering engine used to program the interactivity in the file, making it possible to generate the final applications for the museum exhibition.

Oculus Rift S® is the virtual reality headsets which allowed full immersion in the virtual experience, giving users the possibility to interact thanks to the Oculus Touch controllers. These headsets permitted viewers to isolate themselves from background noise and, at the same time, they were submerged in ambient music, which removed them even more from reality, strengthening the immersion experience.

Leap Motion® is an added device for advanced users to give them the possibility to achieve more natural movement, and consequently, greater immersion thanks to hand scanning and their subsequent visualisation as virtual hands inside the scene.

3. Results

The results obtained from the registers taken on the scaffolding (Figure 3), placed *ex professo* to take images, permitted us to work with the comfort and tranquillity necessary for studying such an important work of art. At the same time, having the possibility to visualise the entire altarpiece from a distance of 1.5 meters without needing to dismantle the artwork, it has been possible to evaluate *de visu* the general state of preservation of the altarpiece. But it has been the close range photogrammetry [8, 9] which provided the high-resolution digitalization of the entire altarpiece, with excellent accuracy in terms of volumes and chromaticity (Figure 4), improving previous experiences [10]. The development of the process to achieve this faithful digital reproduction was made possible by the collection of a cloud of points through the software Autodesk Recap which, using images from different points of view, calculated the 3D coordinates, and after a laborious process of preparation, resulted in a high-poly mesh, which can be seen in Figure 5. Blender was then used to retouch and reduce the polygon in the mesh, converting the initially obtained mesh to low-poly [11].

In Figure 6 we can see an image processing sequence of the low-poly mesh whose fusion results in the high quality digitalization (Figure 4) used in the virtual reality application. These images have been obtained using xNormal, after processing the files obtained in Recap. The first image from left to right in Figure 6 serves to give colour to the mesh; the normal one helps to give an effect of depth to the altarpiece, optimising the number of polygons used; in the metallic layer, roughness and occlusion helps to adjust the properties of the material.

Figure 3. Scaffolding used to take infrared photographs and for the photogrammetry.

Figure 4. 3D rendering for immersive visualisation with the Oculus Rift S headset.

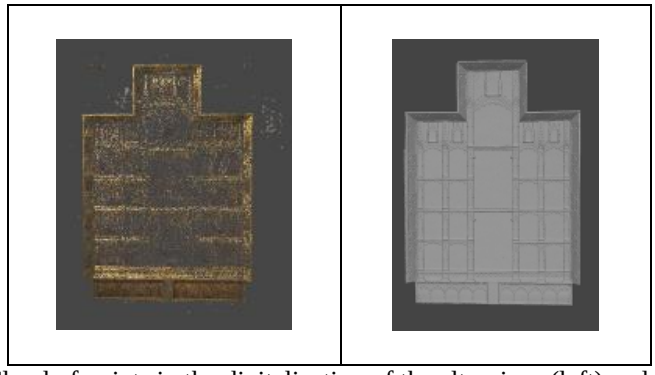

Figure 5. Cloud of points in the digitalization of the altarpiece (left) and result of the mesh after image processing (right) obtained by the ReCap programme.

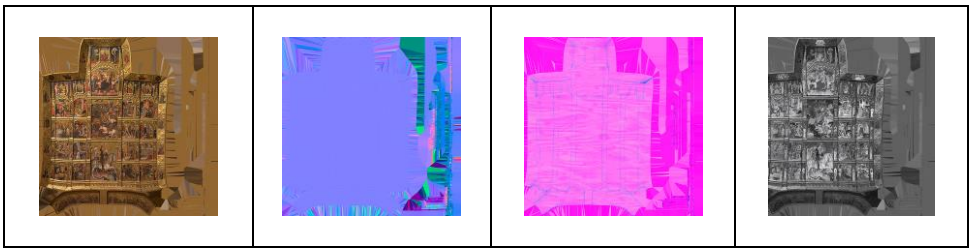

Figure 6. Processing of images with diffuse texture, normal texture, metallic, roughness and occlusion and infrared diffuse.

Figure 7. Photograph of a detail of the Coronation of the Virgin taken with visible light (left) and the same detail taken with infrared radiation (right) in which the lines of the preparatory drawing can be clearly observed.

Figure 8. Screenshot of the language selection option at the beginning of the application, with the choice of listening to the audio in Castellano, Valenciano or English.

Figure 9. Screenshot of the immersive visualisation of the modeling of Valencia according to the map made by Padre Tosca in 1704.

Finally, the infrared layer allows us to see the inscriptions that were initially in the altarpiece. Then, Unreal Engine was used to set up the scene and schedule user interactions with the application [11, 12]. The infrared images allow the visualisation of the lines of the preparatory drawing hidden under the paint to be captured thanks to the use of electromagnetic radiation, which is invisible to the human eye. The results can be seen in Figure 7.

The virtual reality application is available in the two official languages of the Comunidad Valenciana; Castellano and Valenciano, as well as in English (Figure 8). It was considered appropriate to contextualize the history of the altarpiece from its origin in 15th century Valencia to its present in the *Victoria & Albert Museum*. For this reason, the city of Valencia was modelled in Blender according to the map made by Padre Tosca and the map of Valencia by Anton van den Wyngaerde. In this way, the viewer can move through medieval Valencia with a bird's eye view, taking emblematic buildings that are currently standing as references (Figure 9) to aid them in the location of the now non-existent Iglesia de San Jorge, the original home of the altarpiece.

Figure 10. Immersive visualisation of the part of the room that contains the altarpiece in the V&A Museum.

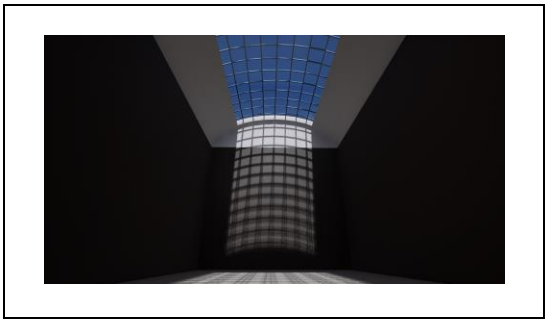

Figure 11. Immersive visualisation of the part of the room in the V&A Museum facing the altarpiece, paying special attention to the lighting in order to recreate the serenity achieved in the real space in VR.

After this spatial and historical-graphic contextualization accompanied by audio, we come to the virtual scene of the altarpiece (Figure 10), with the reference to the collaborating institutions in the space where the altarpiece is currently located. The lighting has been reproduced as faithfully as possible to

recreate the light cast from the skylight in the V&A museum room where the altarpiece is on display. In the real space, this light generates a feeling of great tranquillity. The modelled space has been designed to maintain this magical atmosphere (Figure 11).

4. Implementation

In connection with the celebrations of 9 October, 2019, the Generalitat Valenciana organised two exhibitions, both open for ten days, in the city of Valencia. With the aim of solidifying this research and being able to evaluate the communicative capacity of the technique, its usability and the dissemination of cultural knowledge, immersive virtual reality was installed in both exhibitions. In this way, an informative and scientific exhibition which could be understood and enjoyed by all was made available to the public.

On 2 October, 2019, the exhibition 'El retablo del Centenar de la Ploma. Joya del arte valenciano' was inaugurated in the hall of the Escribanía del Palau of the Generalitat Valenciana. It included 7 VR systems, computers (GTX 1070), VR headsets and sensors available to the public [13], with a reduced, 4-minute version of the tour, accompanied by a complete vinyl reproduction of the altarpiece at a scale of 1:2 stuck to the floor, over which it was possible to walk. Various explicative panels were placed on the walls which contained brief information about the history, artistic importance and scientific research carried out on the predella of the altarpiece.

Also on 2 October, 1 km away, another exhibition with the same name, 'El retablo del Centenar de la Ploma. Joya del arte valenciano' was inaugurated in the Choir Room of the Museo de Bellas Artes de Valencia. This is an open area that leads off the main room housing the museum's altarpieces. Here, there were two complete sets of VR systems, computers (GTX 1070), Oculus Rift S headsets and sensors available to the public [13], with the full 10-minute version of the tour. As part of the installation, there was a complete vinyl reproduction of the altarpiece at a scale of 1:2 attached to the wall. To complete the exhibition, the original predella, which was undergoing restoration, was exhibited on easels. Next to it, the restorers from IVCR+i who were carrying out the work explained the restoration process (Figures 12-14).

The implementation of this Project has allowed us to test VR technically, identifying, resolving or minimising concerns and questions raised by the public. It has also given us the opportunity to interview users about their sensations during the experience, which provided us with information about viewers' perceptions of a work of art using this technology, both in visible light and infrared radiation. We also learned how visitors to the exhibitions received the information given in the oral content, which narrates the history, iconography and making of the work. The public has been able to compare this experience with that of the direct observation of the altarpiece in the vinyl reproductions placed on the floor (Palau de la Generalitat) and on the wall (Museo de Bellas Artes) and in

respect to the original works present in the adjoining Gothic Altarpiece room of the Museo de Bellas Artes de Valencia (Figure 15).

Figure 12. Exhibition 'El retablo del Centenar de la Ploma. Joya del arte valenciano' Museo de Bellas Artes de Valencia. Students from the Universitat de València attending a technical explanation given by a restorer from IVCR+i.

Figure 13. The public interacting with the virtual video.

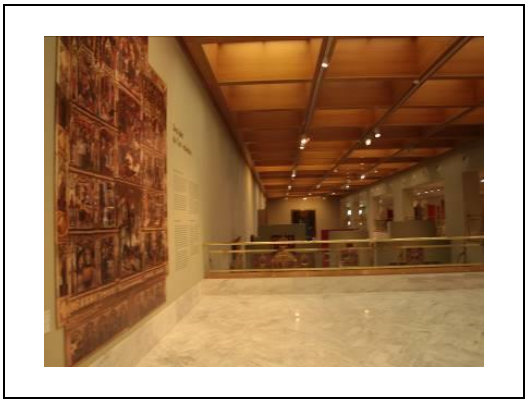

Figure 14. Vinyl reproduction of the altarpiece on the walls of the Choir Room of the Museo de Bellas Artes de Valencia.

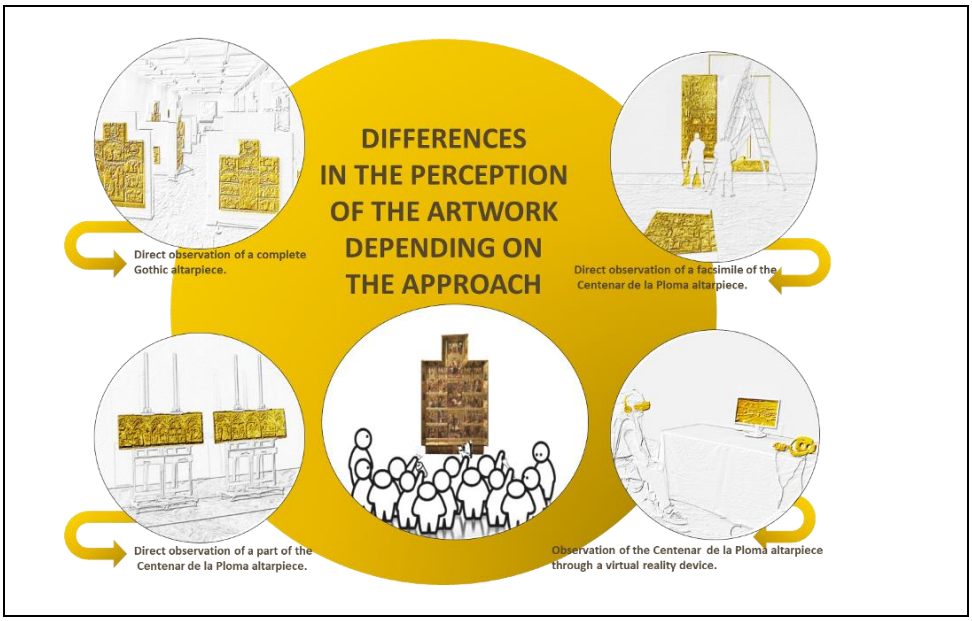

Figure 15. Diagram of the differences of flow in the perception of the artwork, depending on the approach.

It should be noted that the experience using controllers and leap motion has been reserved for viewings with fewer attendees, where there could be a qualified technician to explain the different handling and interaction options to each user.

5. Discussion

It is important to mention an issue which has been observed in both exhibitions and which will be the basis of future study. It is noticeable that older users and even many middle-aged users prefer to experience immersive visualisation guided only by a video as they listen to the technical content being narrated. However, children manage the controls with ease and have little trouble acquiring skill in leap motion, even when they had never used the system before. What has been surprising for us is the number of middle-aged viewers who do not even attempt to use the controls. These are what really allow autonomy in the visualisation and analysis of the work's details, inspiring one of the aims of this project, which is for the viewer to understand the technical work carried out by restorers and the important role that science plays in our field. A possible reason for the lack of engagement with the controls could be the great amount of artistic, historical, iconographic and technical information provided, both visually and aurally, which for a non-digitally native public, discourages the use of more interactive tools. Although a large part of this information appears on the walls and floor of the exhibitions in large-scale photographs of the altarpiece and with explanatory text, viewers do not normally read it. They go directly to the VR equipment without having previously acquired any introductory knowledge.

Users' behaviour has been carefully observed, and based on this observation, a survey is being developed which will permit us to gather indicators in this area in order to improve future implementations. From our observation, different circumstances could explain this lack of interaction. Among these could be the large turnout at the two exhibitions, which caused the waiting period to be quite long at times, and resulted in the viewer being "tired", and preferring a more comfortable visualisation through the video, or that the user had little experience managing the controls. Apart from the spectators' comfort enjoying the experience in a more passive way through the immersive video, we also consider certain disorders which make virtual reality unadvisable due to projection speed, such as slight dizziness occurring to some people who are extremely sensitive to the number of frames per second, or people using virtual reality for the first time and to whom this will disappear with the use of the technique.

The support staff in the exhibitions was trained to guide viewers in the use of the installation. They were prepared to deal with possible instances of dizziness, blurriness and to indicate, for example, that the headsets allowed viewers to wear their own glasses. However, when faced with technical problems, they did not have the necessary knowledge about the equipment to be able to solve them, even when the problems were basic. It is important to consider the need for a technician trained in this type of installation who would be present at all times, and would have the capacity to solve any technical problem that arises, as well as helping to bridge the digital gap and making it possible for this cultural project to be experienced by all types of users.

6. Conclusions

A tool of immersive virtual visualisation which makes possible the visualisation and 'virtual' approach of a relocated piece of our cultural heritage has been placed at the service of the public, eliminating the need to travel to experience it. This work has returned virtually to the city for which it was created. The exhibition in the Museo de Bellas Artes de Valencia permits its enjoyment alongside the few International Valencian Gothic altarpieces still preserved, and the exhibition at the Paláu de la Generalitat Valenciana allows it to be admired contextualised in the place which provides its historical significance.

This instrument of cultural access is positive, as it permits people with functional diversity or those of older ages to gain knowledge about the artwork.

The possibility of visualising what the eye can see in visible light and what can be seen under infrared radiation, with explanations which are detailed and easy to understand by non-technically oriented viewers, increases the quality of a project offered to the general public, since it delves into the technical aspects which restorers use in their work. This also aids in the knowledge about and appreciation of this profession.

Interactivity permits viewers maximum control over what they wish to visualise, how they wish to do it (visible or infrared radiation), and when; pausing on the details that are of interest to each one without time limits. The immersive

visualisation of the altarpiece improves the real visualisation as well, due to the proximity it allows viewers to have of every part. This is a very valuable tool for historians, scientists, restorers and disseminators and users of cultural heritage in general [14].

The digitalization of the altarpiece has meant, in addition to everything mentioned above, its historical and documented registry. This is extremely important to the entire scientific restoration community, since if faced with any misfortune, a piece of cultural heritage can never be lost.

Nevertheless, the option of immersive visualisation accessible to the user is making it evident that a larger digital gap than expected exists among the middle-aged public. We believe this can be easily addressed with the patient intervention of a technician who could explain how to interact with the controls and leap motion. This will also encourage older people to venture into a visualisation experience previously unimaginable.

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