



Immersive Virtual Reality for Cultural Heritage Exploration

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Abstract. Virtual Reality can provide an immersive experience that allows cultural heritage to be experienced in a more realistic and immersive way than traditional showcasing techniques. The objective of this paper is to provide a software pipeline that can be adopted for the realization of immersive experiences in cultural heritage sites. This work has been realized within the 3DLab-Sicilia project, which includes the realization of immersive virtual tours of UNESCO World Heritage sites located in the Sicily area (Italy).

Key words. Virtual Reality, Cultural Heritage, 3D scanning

1. Introduction

The use of Virtual Reality (VR) to enhance cultural heritage is increasing. Furthermore, through the use of this technology, geographical and temporal barriers can be overcome, allowing the user to virtually access the asset from anywhere in the world. In addition to being used to create virtual tours of historical sites and museums, it is a tool for preserving cultural assets, allowing digital copies of works of art and historical sites to be created for their long-term preservation. In the literature, there are several examples of the use of virtual reality in cultural heritage. For instance, Google Arts & Culture (Verde & Valero (2021)) makes it possible to virtually visit some of the world's most important museums and galleries, such as the Vatican Museum or the Uffizi Gallery.

The non-profit organization CyArk (Underhill (2018)) creates digital copies of historical sites and monuments through the use of 3D scanners. In Trunfio et al. (2022), it is investigated how innovative services offered by museums, including the use of VR, can improve visitor experience and satisfaction. One of the most used techniques for reconstructing virtual environments is 3D scanning, which captures objects of interest in an accurate way. Through these technologies, including photogrammetry, it is possible to create photo realistic 3D models in order to create a VR system that allows exploration and fruition, whether they are small objects or a complete cultural heritage area. It is also possible to combine the various techniques, using different types of 3D scanners, for example, to recreate large envi-

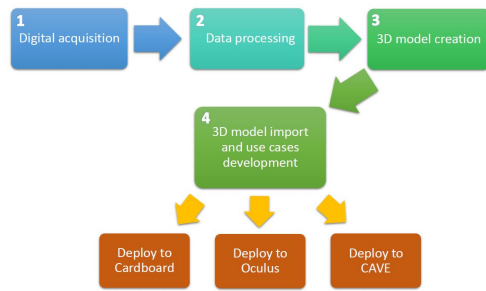


Fig. 1. The proposed Pipeline

ronments and buildings such as a castle while maintaining a high-quality graphic definition.

2. Methodology

Figure 1 shows the sequence of steps that have led to the creation of the immersive scenarios. The pipeline focuses on the development of multi-platform applications. After the digital acquisition of a cultural site through specific 3D scanners, 3D modelling software is used to process the output from a point cloud into a 3D model. Once the model complete with textures has been optimised, it is used for the realisation of immersive tours for VR devices - i.e. smartphones in combination with cardboard and Head Mounted Display (HMD) - and CAVE through the use of the VR development software Unity3D. Data acquisition was achieved with different tools such as laser scanners, drones, or 360-degree cameras such as Matterport. For the cultural asset to be scanned, surveys were carried out both outside and inside using white reflective spheres to improve orientation and alignment later in the merging and recording phase. The spheres were positioned to be clearly visible from each station point. Once the cultural asset was scanned, it was processed to obtain the mesh and texture through the use of dedicated algorithms within the 3D modelling software used, such as Meshlab (Cignoni et al. (2008)), Faro Scene¹, and Blender².

¹ <https://www.faro.com/en/Products/Software/SCENE-Software>

² Community, B. O. (2018). Blender - a 3D modelling and rendering package. Stichting Blender

3. Instruments

After the creation of the 3D model, the Unity[®] 3D engine was used both for the development of the HMD and for the development of the case studies on the CAVE system, using suitable libraries for each device. For the development of applications for VR devices, the open and royalty-free library OpenXR³ was used, which is designed to standardize the development of XR applications on all VR wearable devices. Instead, the Cardboard XR plugin was used for development on smartphones. Using the Carboard application, the user will be able to move within the environment using trigger points, i.e., points that, when activated by fixing them for a predefined time interval, allow the user to teleport to the area of interest. He will use controllers to move around the environment if he is using HDM instead. For the development of the CAVE system application, a template based on the UniCave⁴ plug-in was used, which was adapted to be compatible with the specific hardware of the CAVE used, i.e. a 3-wall CAVE with one front and two side walls. The template was integrated with the Mirror Networking library to configure and synchronise the projections on the walls. With regard to the configuration of the ART tracking system, the VRPN plug-in for Unity (Virtual-Reality Peripheral Network) was used.

4. Cultural Heritage sites

As part of the 3DLab Sicilia project⁵, several immersive virtual tours of UNESCO heritage sites located in the area of Sicily (Italy)

Foundation, Amsterdam. Retrieved from <http://www.blender.org>

³ <https://www.khronos.org/openxr/>

⁴ <https://widve.github.io/UniCAVE/>

⁵ 3DLAB-SICILIA. Progetto n. 08CT4669990220, finanziato dal Programma Operativo 2014- 2020, Azione 1.1.5 – Sostegno all'avanzamento tecnologico delle imprese attraverso il finanziamento di linee pilota e azioni di validazione precoce dei prodotti e di dimostrazione su larga scala, Ambito: SmartCities e Communities, Sub Ambito: Smart Economy (www.euroinfocilia.it) <https://www.3dlab-sicilia.it/>

were realized: the Church of Santa Maria la Vetere, the Church of the SS. Crocifisso al Calvario, the Castle of Mussomeli, and others are going to be processed during these days. For example, in the scanning of the church SS. Crocifisso al Calvario, a camera and drone were used for the reconstruction of the structure from movement and the Faro Focus 350S laser scanner for point clouds (Figure 2). Data processing was carried out with Scene software for the point clouds and with Zephyr software for the SFM reconstruction. The 3D scans of the church took quite a long processing time to merge and register the clouds into a resulting 3D model with very dense points. The reconstruction of the 3D model of the SFM was done by aligning about 500 photos. A single model was created by choosing the best parts of the different point clouds, such as the porch, the interior (with a view of the vaults), and the exterior walls from the laser scanner survey. After the mesh processing was completed, a 3D model with about 494,000 vertices and about 989,000 faces was obtained. Very similar was the approach used to scan the Church of Santa Maria La Vetere (Figure 3) in which data acquisition was achieved with different tools such as laser scanners, drones, or 360-degree cameras such as Matterport. Moving from the cloud to the mesh created considerable problems due to both the very high number of points and the size of the files (around 100 GB). At the end of the mesh processing and optimisation process, a 3D model with about 498,000 vertices and about 998,000 faces was obtained. The acquired and processed 3D models of the site were used to develop exploitable virtual tours on cardboard, VR devices such as Quest2 and Valve Index, and in the CAVE.

5. Conclusions

The software pipeline presented in this work represents a guideline for the realization of immersive experiences in cultural heritage sites by using several kinds of Virtual Reality Devices. Such devices are able to provide different performances in terms of immersion and the quality of the images. The VR headsets (Oculus, Valve Index) provide the best immer-



Fig. 2. View of the 3D reconstruction (photogrammetry and laser scanning) - SS. Crocifisso al Calvario Church

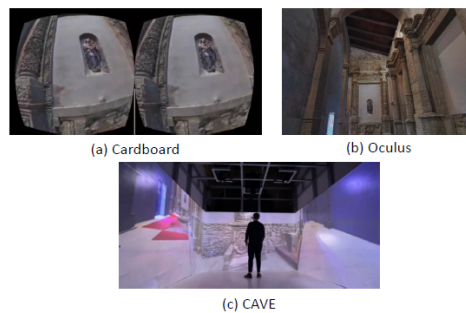


Fig. 3. Virtual exploration of the Santa Maria La Vetere Church

sive effect, and the CAVE offers the best resolution despite the immersion effect being quite low. Smartphones equipped with cardboard offer the worst experience in terms of both resolution and interaction capabilities. Some demos of our work are available for the Church of Calvario and for the Church of S. Maria La Vetere. More details about this work can be found in Barbera et al. (2022b) and Barbera et al. (2022a).

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