AUGMENTED VIRTUAL ACCESSIBILITY OF CH: THE WEB NAVIGATION MODEL OF INQUISITION PRISONS.

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ABSTRACT:

The latest advances in the architectural survey and 3D reconstruction have produced new technologies and methodologies to enhance cultural assets and improve their accessibility. The possibility of virtually visiting a place of historical and cultural interest is often the only way to have access to it. This can happen for various reasons: users' disabilities, temporary site closure, assets located in remote and inaccessible places, and assets destined to disappear over time. Fortunately, new Geomatics and Computer Science technologies allow the virtual reconstruction of entire archaeological and monumental sites with high levels of accuracy. Considering the technologies related to VR, online virtual fruition techniques were recently adopted, using the open source WebGL JavaScript libraries. These libraries allow users to virtually explore the virtual model employing web browsers without installing any client-side applications. The work presented adopts these technologies. It falls within the VASARI project, whose goal is to create a single digital platform for the enhancement, use, and management of the Italian artistic heritage. In particular, the described work concerns the survey, 3D reconstruction, and web visualization of the archaeological site of the Inquisition Prisons located within the monumental complex of Palazzo Chiaramonte in Palermo, known as the "Steri" and today the headquarters of the Rectorate of the University of Palermo. The adopted workflow and encountered issues during implementation will be described.

1. INTRODUCTION

The past lack of attention to the accessibility to Cultural Heritage (CH) has led to numerous difficulties in this field today. There is broad agreement in the literature that many factors limit accessibility to CH. Due to these factors, a large part of the public does not have the opportunity to enjoy heritage existing in r their own or other countries. This is a frequent problem in different parts of the world due to poor management of the heritage, the presence of architectural barriers, or the onset of physical or mental illness in people (Kosmas et al., 2020). Fortunately, modern information technologies offer several solutions, including the user-friendly realisation of virtual tours through Virtual Reality (VR). Nowadays, Virtual navigation is, among the many possible solutions, one of the most effective and one in which a lot is being invested. This research has two aims. The first is to demonstrate the value and efficacy of this technology in a scenario such as the Inquisition Prisons in Palermo, which is often closed to the public. The second purpose is to show an operational workflow for implementing this type of application to avoid the occurrence of operational issues.
Instruments such as laser scanners and cameras are increasingly sophisticated and efficient in collecting high-quality data. Similarly, software for processing the obtained data from survey instruments returns surprising results in a short time. There are many other sophisticated and accessible tools that, if correctly used, can achieve excellent results in a relatively short time. The problem lies precisely in how to use them. Data management, optimisation and processing can be complex and require special skills in geomatics.
Even the finished product, the VR application, must be accessible. This results in how to distribute it to the public. The use of personal devices is the safest, quickest and most effective solution as proven by several studies. Furthermore, due to the recent pandemic situation during which the work described here was carried out, the use of personal devices has become essential for obvious sanitary safety reasons. This has challenged the use of non-personal equipment such as VR helmets and AR glasses. There are also solutions to prevent these devices from running out of memory due to the countless downloaded apps. A VR or AR application, apart from being created as a downloadable app, can also be distributed as a web app. Using Javascript and the WebGL libraries, it is possible to bring virtuality to people's devices only through an Internet connection (Scianna et al., 2020).
This paper illustrates the work carried out within the Vasari Project, whose goal is the realization of a single digital platform for the enhancement, use, and management of the Italian artistic heritage. In particular, the work of the team of the GisLab laboratory of the CNR-ICAR institute has led to the realization of a virtual tour inside the Inquisition Prisons, belonging to the monumental complex of Palazzo Chiaramonte-Steri, today the headquarters of the Rectorate of the University of Palermo. The paper is organized as follows. Section 2 outlines the state of the art on the topic of Cultural Heritage accessibility, VR solutions, and Web-based accessibility. It also covers the history and current status of the Palermo Inquisition Prisons complex described in the same section. Then Section 3 focuses on the description of the entire operative process, starting from survey operations, leading to the realisation and web sharing of the interactive 3D VR navigation model. Finally, problems encountered with related

solutions and hints to future work will be discussed respectively in Sections 4 and 5.

2. STATE OF THE ART

2.1 General Instructions

Accessibility represents one of the key aspects of the dissemination of CH knowledge, as recently affirmed by the Council of Europe in one of the Social components of the Strategy 21 (Council of Europe, 2023). There are a lot of monuments and archaeological sites that present limited accessibility for tourists but also for specialized personnel (Pehlivanides et al., 2020; Scianna and La Guardia, 2019). Limited or no accessibility depends on various reasons that are not always related to the presence of architectural barriers. Psychological pathologies, lack of qualified staff, poor management of the cultural asset, etc. all contribute to limiting the enjoyment of CH. It is sometimes inappropriate to grant access to a cultural site when its preservation may be endangered due to its fragility (Lo Presti and Carli, 2021). This represents a limitation for the valorization of the site but also could be a limitation for the social and economic development of the entire area of interest. In Italy, there are a lot of historical stratifications that many civilizations left over the centuries. For this reason, in this territory, we can find underground archaeological discoveries, ancient underwater towns, and archaeological sites hidden inside historical buildings. This CH wealth fascinates historian specialists and tourists but at the same time leads to strong limitations on the valorization of this not-ever-accessible heritage.
In the case of the cultural object under study, the Inquisition Prisons, not only had the doors been closed to the public for a long time but also time partially compromised the accessibility to this site. Many drawings and depictions in the cells have been completely lost and will never be recovered. Hence the importance of a virtual tour is to preserve the cultural asset and store a digital copy of the monument.

2.2 VR Solutions

According to the policies of the European Commission, the democratization of goods that have value for all mankind should be ensured through digitization, accessibility, and interoperability. Although the impulse to exploit different forms of digitization in CH refers to decades ago, it is since the 2000s that immersive technologies (virtual, augmented, and mixed reality) have taken their place in the field of CH by providing sensorial experiences through various combinations of real and digital content. CH considerably benefits from using these technologies as users can enjoy cultural artefacts in a completely new way (Bekele et al., 2018). Probably this delay in the diffusion of such technologies in the cultural system was caused by the fact that many of the VR, AR, or MR applications aim more at spectacle than at solving specific problems (Pierdicca et al., 2015). Besides, technologies, offering entertainment and immersive experiences, can help in the exploration of CH from different perspectives. Interactively viewing reconstructions of lost elements or virtually accessing a remote and physically inaccessible site has renewed interest in the CH fruition. In particular, VR and AR offer different solutions for different types of accessibility (Cecotti, 2022). The 3D virtual reconstruction of a site ensures that it can be explored even if physical access is prohibited due to its fragility, as in the case of the Buddhist temple in Bagan, Myanmar (Paladini et al., 2019). Similarly, these technologies make possible the fruition of submerged archaeological finds that are inaccessible to anyone without diving experience (Bruno et al., 2017; Scianna et al., 2021).

2.3 Web fruition

The opportunity to participate in cultural life is part of the right to CH. This is a fundamental aspect as it allows to contribute to the very growth of the CH, preserving its authenticity and memory. It is therefore essential to make information easily accessible, especially in the case of digital information. This is why it is appropriate to choose the best way, or the best platform, to share it (Tommasi et al., 2019). Different types of fruition can be identified depending on their purpose. Indeed, it is possible to speak of maintenance, restoration, marketing for tourism, etc. The final goal of this study was fruition aimed at valorisation through free sharing with the public. The choice to share digital content via the web is strategic. Indeed, there exist many advantages, starting with avoiding overloading the internal memory of personal mobile devices. In fact, an app with 3D content can be very weighty and even the most memory-equipped smartphones often are found overloaded, forcing the user to delete something before being able to install anything else. Today Wi-Fi connections are very fast and allow large amounts of data to be uploaded in a short time. An entire 3D model can then be visualised via the browser, allowing easier and more immediate access to content. Furthermore, any changes to the files on the server do not involve updating an application, only refreshing the page.
HTML 5, Javascript and the WebGL libraries are therefore excellent allies in this field. There are also several tools, both commercial, free and open source, that facilitate the process of networking digital models. The famous Unity and Unreal game engines, for instance, allow projects to be exported in WebGL format for web browser navigation. However, it is currently not possible to access such content via smartphones, but only via desktops. PlayCanvas is a completely WebGL-based game engine that enables the creation of even very heavy and complex models. Available for a fee, it also offers a free version with some limitations. The solution adopted in this study was Verge3D from Soft8soft, for reasons discussed below. This is a WebGL-based game engine that also acts as a viewer for Blender files. It offers both a commercial and a free version but with negligible limitations.

2.4 The Inquisition Prisons

The monumental complex of Palazzo Steri is a perfect blend of Gothic and Sicilian architecture typical of stately palaces (White, 1976). The construction of the palace was completed in 1307 as the residence of Manfredi I Chiaramonte, Count of the Feud of Modica. Over the centuries, it was the residence of many important personalities in the Sicilian medieval and renaissance panorama until it became the seat of the Spanish Inquisition Tribunal between 1600 and 1782, with the annexed Penitential Prison. It was here that the cells now filled with graffiti were created at the behest of King Philip III.
The complex was restored in the 1950s by architect Carlo Scarpa, becoming the seat of the Rectorate of the University of Palermo. During the restoration, many of the testimonies related to the Inquisition period were lost. Only the cells on the ground floor and a few on the upper floor still contain drawings made by prisoners. The other cells were plastered over and only through the work of the Sicilian ethnologist

Giuseppe Pitrè in 1940, completed by Leonardo Sciascia (Pitrè and Sciascia, 1999), that descriptions of present and lost graffiti are known.

3. METHOD AND MATERIALS

This section will describe the workflow that led to the realization of the virtual tour of the Inquisition Prisons. This will start with describing the surveying operations carried out to obtain good-quality three-dimensional data. This is followed by a technical illustration of the 3D modelling techniques used and the realization of the web app through the Verge3D tool.
The problems and difficulties encountered, and the solutions adopted will be discussed in subsequent sections.

3.1 Survey and data processing

Figure 1. TLS survey with a Topcon GLS 2000 in polygonal mode.

The realisation of the web app dedicated to the virtual exploration of the Inquisition Prisons started with the survey operation of the monument. The operations included the survey of the exteriors of the buildings contained in the monumental complex of Palazzo Chiaramonte-Steri as it was initially planned to include these areas in the virtual tour. As mentioned above, laser scanning and digital photogrammetry were employed.

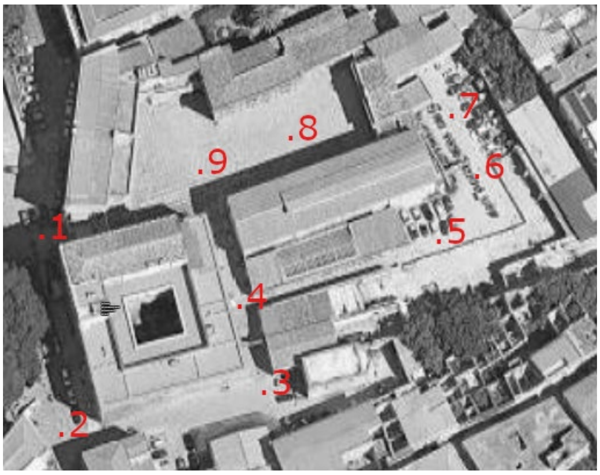

Figure 2. External monograph of laser scanner survey positions.

As can be seen in Figure 2 for the laser scanner survey 9 positions were chosen, the first two dedicated to the main elevation of Palazzo Steri facing Piazza Marina. A complete tour of the prison buildings and the archaeological area was carried out from the third position. The interiors of the latter two were then surveyed from 16 positions for the ground floor and 10 for the first floor. The data obtained were processed to merge point clouds using Topcon's Magnet Collage software.
The photogrammetric reconstruction, necessary to obtain high-quality textures to be applied to the 3D model, was mainly dedicated to the exteriors and interiors of the prison building and the archaeological area. Particular attention was paid to the interior walls of the cells, rich in prisoners' graffiti. The mosaic method was chosen for the reconstruction of one wall at a time. The images were then processed using Agisoft Metashape software for the reconstruction of photomosaics. A similar procedure was used for the excavation of the archaeological area. In this case, however, the photogrammetric reconstruction, in addition to texture generation, was entrusted with the processing of the point cloud of the entire excavation volume.

3.2 3D Reconstruction

Once the point clouds were processed, the data were used for subsequent 3D modelling. As will be described in later sections of this paper, automatic mesh generation did not yield satisfactory results. Therefore, a manual reconstruction of the 3D model was chosen. In this case, the free and open-source software Blender was used. This software offers many very useful tools to make the process faster. Through some add-ons, it was possible to import portions of the point clouds, such as individual cells or facades. These were used as a trace to be manually recalculated, resulting in a cleaner and simplified reconstruction. Through the Edit mode, in fact, the software allows very accurate manipulation of 3D elements, leading to complex shapes. Despite this, the process was very long. For example, it was not possible to duplicate multiple cells of the prisons to get more of them since they all had different shapes and sizes while looking very similar.

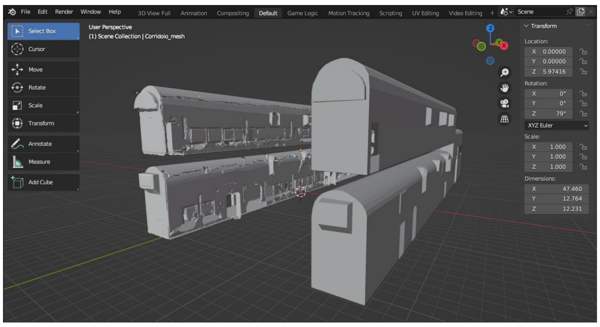

Figure 3. Modelling of the corridor of the Inquisition Prisons. On the left the mesh obtained from the point cloud and on the right the result of manual modelling.

The archaeological area has received special attention. Given the geometrical complexity of the parts of the Archeological Aria (excavations), it was not possible to opt for manual modelling. As mentioned earlier also, the point cloud from the laser scanner data had not produced sufficient results due to different elevations between the laser scanner and the excavations. Photogrammetric reconstruction, on the other hand, was more effective but required advanced-level processing to provide a good result. Considering the mesh generation, correction of shortcomings and imperfections was necessary to adapt the mesh to the reconstruction of the entire protective superstructure. This, on the other hand, was totally by manually done since the presence of large glass surfaces had made automatic reconstruction impossible. The realism component was achieved, both for the exteriors and interiors as well as for the archaeological area, through the projection of textures generated by digital photogrammetric reconstruction. The textures for the exterior facades needed no special attention, as well as those for the excavations of the archaeological area. A mixed approach between texture projection and virtual materials made in Blender was used for the protective superstructure. Textures intended for the interior of the cells required to be edited in Adobe Photoshop software in order to achieve a realistic appearance and to give more prominence to the graffiti. It was also necessary to reduce the resolution of all images maintaining at the same time the quality of visualization. The final results were more than satisfactory.

3.3 Web Publishing

Given the large size of the 3D file, the Verge 3D tool was chosen. The software act as a Blender viewer and allows the direct loading of .blend files. A visual programming interface is then provided via a puzzle. This allows user interaction to be programmed, as would be done with a common game engine. However, to avoid performance slowdowns, we chose to split the model into several parts to be reconnected later via links. Then three virtual tours were created: the outside of the prisons, the inside of the cells, and the archaeological area. For each model, therefore, a user interface was made to indicate possible actions, including forward and backward movement, camera rotation, and zooming. At doors in the 3D model, clickable icons were inserted with embedded links to access other sections of the model. This is the case for the transition between the interior and exterior of the prisons, between floors, or to access the archaeological area. On the graffiti that could be identified, icons depicting loudspeakers have been placed. If clicked a description can be heard in Italian or English. This was accomplished through the software puzzle system. Blocks, corresponding to blocks of javascript code, are provided to simulate object physics, link insertion, event handling, etc.

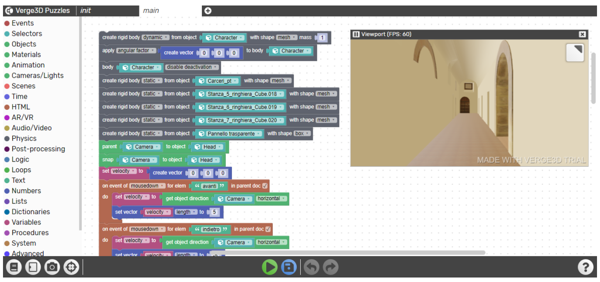

Figure 4. Puzzle programming interface in Verge3D

Verge is installed both as software and as a Blender plug-in. When it is started, it creates a local server to real-time display the changes that are being made. Once the project folder is chosen, both the .blender file and the 3D model export in glTF 2.0 format must be placed in it. Verge will create all the other auxiliary files. Working on the Verge3D interface generates a folder system with .html, .js and .json files that can be grouped and uploaded to a server for sharing.

4. DISCUSSION

The creation of the web app dedicated to Inquisition Prisons turned out to be a very long and complex process since its very early stages. Indeed, the study area is very large, alternating between exteriors and interiors with substantial differences in lighting conditions. Laser-scanner imaging for the exteriors did not present any particular difficulties. Obviously, the reconstruction of textures to be applied to the facades provided rather poor results, useful only to be used as a reference. For this reason, texture generation has been entrusted to digital photogrammetric reconstruction, including drone-assisted reconstruction. As for the interior of the cells, poor lighting conditions complicated both laser scanning and photogrammetry acquisition. For this reason, a white polystyrene panel was used to better diffuse the light of an LED spotlight.

Figure 5. Use of a polystyrene panel and a spotlight for better diffusion of illumination.

Indeed, the point clouds obtained by laser scanner processing were full of noise, yet sufficient to convey a general shape of the interior geometry. Considering the poor results of the automatic mesh reconstruction the point cloud data has been used as a geometric reference for the 3D modelling phase. Digital photogrammetric reconstruction was also not initially successful due to lightning conditions. For this reason, every internal wall was reconstructed one at a time, after illuminating it with the light of the LED spotlight reflected by the white panel. The resulting graffiti images, which were already of high quality, were then further processed through Photoshop software for optimal colour rendition and sharpness. Despite the good quality of the external acquisition by laser scanner, some difficulties were encountered in mesh reconstruction for this part as well, and again manual modelling was opted for. The use of the point cloud as a reference resulted in a double benefit: a cleaner 3D model and significantly less weight. The use of high-quality images as textures then contributed the right degree of realism offering a more immersive 3D navigation experience. In general, once again, the effectiveness of a mixed survey approach was demonstrated, combining the accuracy of TLS survey with the high resolution granted by digital photogrammetry.

5. CONCLUSIONS

The realisation of the Virtual Reality application involved only a part of the monumental complex of Palazzo Chiaramonte-Steri, focusing in particular on the Inquisition Prisons and the Archaeological Excavation Area. The result of this work can be found at the following web address: https://geomatica.icar.cnr.it/Steri/index.html.

As mentioned above, data were also collected on other parts of the monumental complex and are expected to be used to complete the 3D reconstruction at a later date.

This paper aimed to highlight the numerous advantages for accessibility issues related to CH offered by this kind of solution. The detailed description of the workflow from the survey of the architecture to the implementation of the virtual tour also provides ideas for overcoming difficulties that can be encountered in approaching specific technologies. Obviously, this type of fruition cannot replace a live visit today, but it certainly offers new ways and new points of view for the exploration of CH. Ways and points of view that for some, or often for many, may be the only ones.

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