Chapter 1

Enhancing the Visitor Experience with Immersive Technologies and Gaming: the Monserrate Use Case

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Abstract

Immersive technologies, such as augmented reality (AR) and virtual reality (VR), are effective technologies being implemented across diverse fields. We propose an AR/VR-based web app to be applied in the cultural tourism field with the objective of enhancing the visitors' experience of the Monserrate Palace, part of a UNESCO cultural landscape located in Sintra, Portugal, managed by Parques de Sintra – Monte da Lua SA.

This chapter overviews the state of the art on immersive technologies in cultural heritage sites and the visitor experience at these sites. Then, it exposes the palace's historical and cultural significance and some of the challenges it faces in engaging its visitors. The potential applications of immersive technologies in the palace are explored, including interactive storytelling and immersive experiences that allow for a higher level of visitor engagement. Next, it addresses potential challenges and limitations of deploying the proposed solution in the palace, such as technical constraints and preservation concerns. It then concludes with a reflection on the significant potential of AR and VR in enriching the immersive experience of Monserrate Palace, offering new possibilities for engaging with cultural heritages and creating a memorable and enjoyable visit for modern audiences.

Key words: Augmented Reality, Virtual Reality, Gaming, 360º Imaging, Tracking, Cultural Heritage Site, Monserrate Palace, RESETTING

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1.1 Introduction

Cultural heritage sites are an important part of the identity and history of each nation, making their preservation and sharing crucial to uphold the traditions and their customs. In recent years, new technologies have been introduced to these sites to enhance the visitor's experience. In this chapter we will focus on immersive technologies that can enrich the visiting experience of its visitors, them being Virtual Reality (VR) and Augmented Reality (AR). Their objective in this context is providing a high degree of interactivity, allowing users to engage with their content in a meaningful and memorable way, and in more specific cases, VR provides an elevated sense of presence in virtual worlds and allows its users to interact with virtual objects, mimicking real-life situations more accurately than other media, while AR enhances the user's perception of reality by overlaying virtual elements onto the real world. Thanks to these features, immersive technologies offer a more immersive and engaging user experience, while also enhancing the learning experience of its users. With all these benefits, these technologies can bring innovation in various fields, such as healthcare, entertainment, education, training, tourism, etc.

Given its broad implementation and adoption in various fields, it is often no surprise that immersive technologies have also been extended to tourism, and in the case of this chapter, into cultural heritage sites. One way these have manifested are through virtual tours where users experience the real-world location in an immersive simulated world. Another way is the reconstruction of physical heritage artifacts/rooms into virtual ones, allowing the visitor to interact with them while also preserving them. Furthermore, augmented virtual guides and information overlays have been widely used to provide visitors with greater amounts and quality of information about the sites they visit.

While these technologies have already begun to be implemented in cultural heritage sites, there are still challenges to be addressed. Which brings us to our research question: *"how to create on-site immersive experiences that are both engaging and rewarding for visitors in order to improve tourism experiences"*.

To answer our research question we propose the design of immersive technologies in Monserrate Palace, part of a UNESCO cultural landscape located in Sintra, Portugal, aiming at enhancing the visitor experience. This initiative is being carried out under the framework of the COSME RESETTING project[1].

This chapter is structured as follows. In section 1.2, we present the findings of our literature review, which highlights factors affecting cultural heritage site experiences and the role of immersive technology in enhancing visitor engagement. In section 1.3, we provide an historical background of the Monserrate Palace, with a rich history dating back to before Sintra's reconquest. In section 1.4, we detail the design of the "Monserrate in the Cook family era" gaming app, highlighting the game design, the user-centered prototyping approach and the preliminary results of our proposed

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[1] Relaunching European smart and SustainablE Tourism models Through digitalization and INnovative technoloGies

techniques that enable the immersive visitor experience. In section 1.5, we draw conclusions and describe our plans for further research.

1.2 Literature Review

1.2.1 Visitor Experience at Cultural Heritage Sites

Several studies have shed light on the various factors that contribute to a positive visitor experience at cultural heritage sites. One of the key factors identified is the quality of the visitor experience, perceived value, satisfaction, and sustainable behavior. For instance, one paper found that the quality of experience directly influences the perception of value and satisfaction, ultimately impacting behavioral intentions [5], while another discovered that perceived quality and emotions play direct roles in determining visitor satisfaction, with the individual's mood state serving as a moderator along the cognitive path to satisfaction [20].

In addition to these findings, [4] proposed a conceptual framework that integrates visitors' heritage experiences, their attachment to heritage sites, and their engagement in sustainable behavior. This framework highlights the interconnections between visitors' experiences, emotional connections to the site, and their inclination towards sustainable practices, ultimately shaping their overall experience.

Moreover, [1] conducted a study focusing on the factors influencing tourists' willingness to travel to cultural heritage sites. They discovered that aspects such as education, variety of sites, multiple destinations, cost, and the reasons for visiting significantly impact tourists' decision-making process. These findings underscore the importance of considering diverse elements when designing and promoting cultural heritage sites to attract visitors.

Furthermore, [2] explored the role of tour guide performance in enhancing visitor sustainable behavior and, consequently, contributing to a positive visitor experience. The study revealed that tour guides have both a direct and indirect effect on visitors' sustainable behavior, thereby shaping their overall experience.

By considering these research findings, cultural heritage sites' managers can better understand and address the key factors that influence visitor experiences. Focusing on factors such as quality, perceived value, satisfaction, emotional engagement, sustainability, and the role of tour guides can lead to a more holistic and enriching experience for visitors, ensuring their lasting enjoyment and appreciation of the cultural heritage site.

1.2.2 Immersive Technologies in Cultural Heritage Sites

Immersive technologies, such as VR and AR, have the potential to enhance visitors' engagement with cultural heritage sites and improve learning outcomes. Additionally,

VR and AR can aid in the preservation and conservation of heritage sites by digitally documenting and safeguarding fragile structures or artifacts.

A systematic review conducted by [22] found that the most common use of these technologies was in marketing and in tourism education, as well as highlighting some gaps and challenges on the adoption of such technologies, these being the awareness of the technology, usability and time commitment to become proficient.

Another paper identified AR related factors that influence the user's satisfaction and with those factors, presented a user experience model with product features for a user-centered interface design for AR applications [10].

Some other studies focused on the examination of the learning outcomes of the use of these technologies. One of them compared a control group whose tour was conducted through traditional approaches while the experimental group conducted its tour with the aid of an AR system using image-based recognition. The experimental group exhibited significant differences and improvement in the learning outcomes [8]. Another study found that by just providing instructions to the visitors with a mobile application made their experience more valuable and recommends the use of new approaches to visitor engagement and experience enhancement [6].

An interesting use case found was a web portal with integration of high-resolution spherical panoramas and information representing the cultural heritage in Bulgaria [13] that concluded that the visual and metric qualities of those panoramas are sufficient for many applications, namely, tourism, documentation and demonstration of cultural objects.

The effectiveness of a VR/AR application named JejuView was evaluated to advertise the cultural heritages of Jeju Island to tourists. The authors found that when using immersive media, consumers are more focused on the hedonic value than on the usefulness of the medium [12].

These technologies can be used to recreate life inside historical sites, as [3] and [9] discuss the use of VR in cultural heritage, including the creation of immersive virtual environments and interactive virtual archaeology projects. Additionally, [18] provides an overview of AR in virtual heritage systems, which can be used to reconstruct historical buildings and monuments. Similarly, [21] contributes to the discourse by presenting a case study on the construction of a computerized model of the Roman Theater of Byblos, which includes both VR and AR applications.

Overall, these studies suggest that immersive technologies can be effective tools for enhancing visitors' engagement with cultural heritage sites and improving learning outcomes. However, there is still a need to be cautious about certain aspects of the application to ensure the success of its implementation.

1.3 Monserrate Palace Brief Historical Background

The Monserrate Estate is believed to have had a chapel on its grounds before D. Afonso Henriques' reconquest of Sintra back in 1147. In 1540, Gaspar Preto, a cleric, commissioned the construction of a chapel dedicated to Nossa Senhora de

Monserrate, which at that time belonged to the Hospital of Todos-os-Santos in Lisbon. The property was leased to the Melo e Castro family in 1601 and purchased by D. Caetano de Melo e Castro in 1718. The property was kept by caretakers until 1755, when the great Lisbon earthquake left the houses uninhabitable. In 1790, the property was leased to Gerad De Visme, a wealthy English merchant, who built the first neo-Gothic palace and demolished the 16th-century chapel. William Beckford leased the property from De Visme in 1793 and invested heavily in the palace and gardens. The property remained in the hands of the Melo e Castro family until 1856 when it was sold to Francis Cook, a wealthy English textile millionaire. Cook made Monserrate the family's summer residence and employed a considerable amount of people to care for the house, park, and family. He also bought neighboring properties and the Convento dos Capuchos, becoming a major employer in the surrounding area. In 1947, the Cook family sold the property due to financial difficulties, and it was purchased by Saúl Fradesso da Silveira de Salazar Moscoso Saragga, a Lisbon antiques dealer, who sold it to the Portuguese state in 1949 along with 143 hectares of the Tapada de Monserrate. In this sale, the valuable contents of the palace were scattered during an auction [16, 17].

This palace has also hosted another project to enhance the visiting experience which was *"FalaComigo"*. This project involved the creation of interactive virtual characters, namely Sir Francis Cook and a fictional butler named Edgar Smith. The visitors could interact with these characters and other audiovisual content through touch and speech, using a touch table, an interactive kiosk, located in some palace rooms, and a smartphone app, which would help to capture the visitor's attention. The project provided the visitors with a new attractive and interactive way to acquire the history of the palace [15].

Fig. 1.1: Monserrate Palace main entrance [14]

The Monserrate palace is rectangular in plan and mostly symmetrical on its two axes (see Figure 1.1). The two ends of the building are circular towers whose interiors are appropriately circular rooms. One of these towers can be understood as the face of the palace, since it is the first face we see when arriving at the palace (assuming we come from somewhere other than the garden). Inside this first tower we find the main atrium that functioned as the main entrance for those arriving at the palace for the first time and gave access to the main bedroom. In the opposite tower is the music room. This tower has no access to the outside, effectively being understood as the end of the palace. The large corridor that connects these two towers serves as the main axis of circulation, also giving access to the various rooms located between the two ends of the palace towers. These rooms all have the same morphology, rectangular plan whose larger sides have windows (on one side) and a door to the central corridor (on the other side). These four rooms are arranged in pairs, symmetrically facing the corridor: the dining room and library, the living room and billiard room. Between these four rooms we have the palace's central point, the midpoint of the corridor that connects the circulation space to the two side entrances. This point is an octagonal plan space, and, in the center, we find a fountain (whose plan is an offset from the larger octagon). The palace is oriented with its major sides perpendicular to the northwest and minor ones to the southeast.

1.4 Designing an Immersive Game for the Monserrate Palace

The Monserrate palace faces some challenges in appealing the visitors with an on-site experience that could recreate the indoor spaces at the time of the Cook Family, since such spaces are now essentially empty, ever since the 1949 auction. In this context and to properly answer our research question, we designed a solution based on an immersive gaming user experience (UX), named *"Monserrate in the Cook family era app"*. This gaming app was designed specifically for use on the smartphones of visitors inside the Palace of Monserrate, to complement and enrich the visit. The focus of the game will be to convey what it would be like to live in the palace in the era of the Cook family, at the beginning of the 20th century.

When visiting the palace, a visitor is confronted with a lack of furniture. Analyzing historical photographs[2], taken inside and outside the palace around 1902 [7], made available to the authors by the Monserrate palace, we can see the fully furnished first floor rooms, and the Cook family in an outdoor enclosure of the palace. From these photos, we get a more faithful view of the Cook era, something that has been lost today, in part due precisely to the lack of furniture (and obviously the residents themselves, the Cooks). Although these photos portray a more faithful perspective of the palace, they are just photos. There is always a discrepancy between seeing the world from two-dimensional photos and experiencing the world in three dimensions, i.e., physically. For this, the introduction of immersive environments (VR and AR)

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[2] These photographs are part of the Monserrate Palace private collection and were taken by David Knights-Whittome, at the Palácio de Monserrate, in the early XX century (circa 1902).

with a mobile (smartphone) based user experience, within a gaming framework, is suggested.

1.4.1 Gaming Experience Proposal

After some discussions and brainstorming with tour guides, specialists of the romantic period of the mid XIX century, and palace curator and bibliographic review, we came up with some ideas that could be explored in the game.

One of the ideas that stood out as we reflected on the world illustrated in the 1902 photos, compared to the real world of today, is the day-to-day experience of the Cook family, when they were visiting the Palace of Monserrate during vacation, in the dawn of the 20th century. We can thus focus the basic theme of the game on an event that occurred daily such as "the Cook family mealtime".

The Cook family's way of life inside the palace was quite particular, with customs that no longer exist today and in accordance with the upper-class British lifestyle of the time. Some of the spaces were segregated in gender. For example: the "Billiard Room" was dedicated to men, as a smoking room too, and the "Living Room" ("Indian Room") to family women. The life of this family was thus much more "ritualized" than the family life of today.

Our gaming experience explores the following scenario. At noon, the Cook family returns from an early morning walk through the Monserrate gardens, enjoying the exotic nature and the panoramic views of the surrounding landscape, and enters the palace through the "Garden Entrance", where some members of the family meet others coming down from the upper floor by the monumental staircase. Together and in a single line, they make their way through the "South Gallery" and into the "Dining Room", passing by the "Library", a room set aside for study and reading, where Sir Cook was busy dispatching business matters. Sir Cook joins the group, and together they enter the "Dining Room". After a pleasant light lunch, the family leaves the room and walks through the "South Gallery" towards the "Octagon", then through the "North Gallery", and divides into two groups: the female group goes to the "Indian Room" left, where they socialize and discuss social topics, and the male group goes to the "Billiard Room" right, where they discuss contemporary political and business topics, in a relaxed atmosphere, and where they also play billiards and smoke cigarettes and cigars. Later, both family groups gather again in the "Music Room" to enjoy the rest of the day while appreciating the music of that era[3].

For a game that addresses this theme, the visitor may be invited to walk through the rooms, starting from the south wing, going into the "Library" first, followed by the "Dining Room", "Indian Room", "Billiard Room" and finishing in the "Music Room", according to the ritualized order already mentioned. In each of these rooms, the visitor must finish some challenges.

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[3] An example could well be Antonín Dvořák's "Serenade in G major, Op. 95" on piano and violin, very popular at the time, played by the palace's resident pianist.

1.4.1.1 1st Challenge: Match 1902 photos that correspond to the visited room

In this challenge, when entering one of the rooms of the palace, the visitor is invited to use the app to browse through the gallery of historical photos of the palace. The player will have to choose the photo that corresponds to the room he or she is in, from auditory and visual clues of the room today. For example, when entering the "Billiard Room", the visitor would have access to a sound ambience (either in egocentric mode - only for a given visitor, or exocentric - for all the visitors present in the room), reflecting what is going on in the room. As an example, in the billiard/smoking room there could be the sound of men talking to each other and the billiard balls hitting the corners of the table. As far as visual clues are concerned, to be able to identify the correct picture, the player will have to pay some attention to the room in front of him, noticing the details of the ceiling, the floor, and the walls, since there is no furniture. There are some rooms where the choice is easier. For example, the library is the only room with bookshelves lining the walls, and the music room is the only one that has a different shape from the other rooms. Other examples are not so clear to identify, such as the living room, which will have to be identified based on the ornamentation of the walls. Each time the player chooses the correct picture, he or she receives a reward that corresponds to a brief overview of the historical and cultural significance of the room, enabling the visitor to assimilate information that may have been neglected otherwise.

1.4.1.2 2nd Challenge: Discover the photographer's position

In this challenge, after choosing the photo that corresponds to the respective room, the game focuses on getting the visitor to understand what the pose (position and orientation) of the photographer was, when he took the photo. The visitor moves around the room and uses his/her cell phone as a "sonar": as he/she approaches the correct position and orientation, the smartphone will vibrate more intensely until success is achieved. To accomplish this feedback interaction, there will be indicators situated inside each room to get the initial position of the visitor, which combined with the sensors of the visitor's device enables the tracking of the user throughout the room. When arriving at the required pose and position, the visitor will receive a reward which is a VR experience based on 360º images on the smartphone, where he/she will observe a panoramic image of the current room merged with the image(s) of the room collected in 1902. The visitor is then invited to participate in the next challenge.

1.4.1.3 3rd Challenge: Discover room curiosities

In this 3rd challenge, the visitor must discover a set of curiosities and associated information, which can be found in the room of the previous challenge. Thus, the app would invite the visitor to discover "Where are the curiosities in this room?". As an

example, the music room has some wall busts that belong to muses and goddesses. By pointing the phone at different parts of the room, the player would observe points of interest and could click on the screen to reveal information about what he or she sees. For example, if the visitor points the phone at one of the busts previously mentioned and clicks on the screen to find out who they are, the app will display the pertinent information. After finding these curiosities, the player is rewarded with an AR experience, where a virtual 3D scene will augment the physical space. The challenge in realizing this idea has to do with the fact that we select curiosities and objects that have an important connection to the Cook family's past and the era we are portraying.

1.4.2 User Interface Design

We adopted a user-centered design approach. In fact, to demonstrate the feasibility of our solution and to get feedback on the proposed design and functionalities, we start by designing a user interface prototype. The prototype serves as a visual representation of our ideas and allows us to validate our assumptions and gather feedback from experts and end-users (visitors), and make informed decisions towards the development of a minimum viable product of our gaming app. All this before the beginning of the software development of the solution, so mistakes or wrong assumptions do not become costly to modify, since it is much cheaper in terms of resources to modify the user interface prototype than to modify the end product.

A low fidelity paper prototype was first designed to get a broad idea of how the interface would look like, which can be seen in figure 1.2 and it was shown to 2 experts that had the chance to interact with it, via a "human-computer" interaction paradigm [19].

After collecting some feedback, we improved the prototype and developed a high-fidelity prototype version with the help of Figma[4], a user interface design tool that also allows for the creation of interactive prototypes, that can be seen in figure 1.3. The high-fidelity prototype allows us some degree of interaction such as navigating the existing pages and some limited animations, this will be quite helpful when performing tests with the end-users, since it will be much closer to the end-product.

The prototype has been designed with the user in mind and it aims to provide a simple and natural user experience. Some design choices made were for example the color pallet that is illustrated in figure 1.4, which derived from colors present in the palace while maintaining a pleasing visual experience, keeping things simple and easy to use, minimizing the learning curve and the implementation of some feedback mechanisms.

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[4] Figma. https://www.figma.com. Accessed: 2023-04-20

(a) Photograph matching challenge

(b) Discover curiosities challenge

(c) Curiosity additional information overlay

(d) Augmented 3D object reward
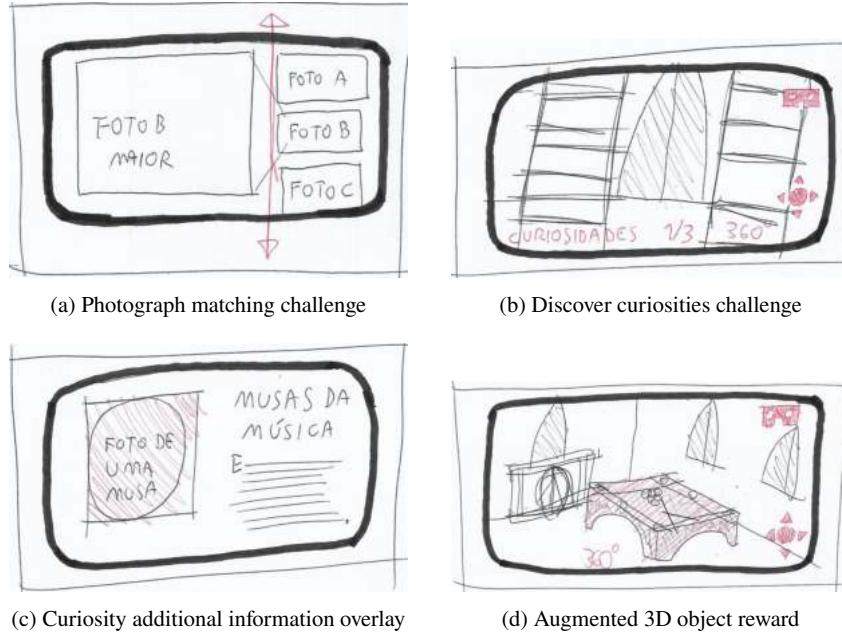
Fig. 1.2: Low fidelity user interface prototype

(a) Photograph matching challenge

(b) Discover curiosities challenge

(c) Curiosity additional information overlay

(d) Mimicked augmented 3D object reward

Fig. 1.3: High fidelity user interface prototype
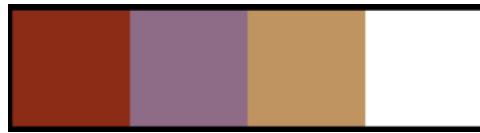
Fig. 1.4: Color Pallete

1.4.3 Proposed Software Architecture

Our solution's system architecture is illustrated in Figure 1.5. A server will host the web service as well as the database, which means that users can access the content of the app without downloading an application to their devices. The client (a web app) will need to provide data from its camera and from its inertial measurement unit, which uses a combination of accelerometers and gyroscopes to calculate changes in position and orientation, and will support a graphical user interface, also featuring user experience with AR and VR based in 360º imaging.
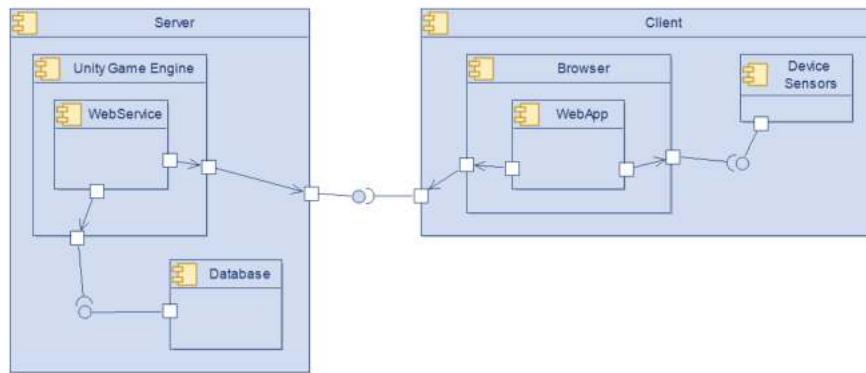
Fig. 1.5: Component diagram of proposed solution

To achieve this, we will use Unity[5] and WebXR[6]. Unity is a game engine that provides powerful tools for creating and rendering 3D and 360º imaging environments that can be explored in VR and AR user experiences, while WebXR is an API for web content and apps, that need to interface with VR and AR software and hardware. By combining these tools, our solution will only require end-users to access the envisaged immersive experience via a web browser.

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[5] Unity. https://www.unity.com. Accessed: 2023-04-05

[6] WebXR. https://immersiveweb.dev. Accessed: 2023-04-08

1.4.4 Feasibility Study

In preparation for the full software development of the proposed web app, several preliminary tests were conducted, some of them involving image-stitching and colorization of historical photographs. In more detail, using a high-quality camera and specialized software[7], a series of images of the interior of the palace were captured by the authors in arbitrary poses and then stitched together to create a seamless panorama which then was also merged with the historical photographs, made available to the authors. Another test, represented in Figure 1.6, entailed the use of Photoshop's[8] neural filter to automatically colorize the historical photograph.

In Figure 1.7, we depict results of applying both automatic colorization and image stitching in panorama images of the library room, comparing situations before and after applying the effect. Results are promising, but we can see some limitations of this approach. We do not have yet the knowledge of the original pose of the 1902 photograph nor the camera intrinsic parameters and today´s situation image panorama was captured in an ad-hoc manner. Therefore, image distortion is perceived. This will be corrected with better 360º imaging capture, and also an estimation of the 1902 photograph camera pose and its intrinsic parameters, which is under way.


(a) Historical photograph of the library [7]   (b) Colorized version of the library

Fig. 1.6: Results of colorization tests

1.5 Conclusions and Future Work

In this chapter we have addressed our research question, namely, *"how to create on-site immersive experiences that are both engaging and rewarding for local visitors*

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[7] PTGui. https://ptgui.com. Accessed: 2023-03-16

[8] Photoshop. https://www.adobe.com/products/photoshop.html. Accessed: 2023-03-14

(a) Present-day at the library without any stitching

(b) Present-day at the library, stitched with colorized historical photograph

(c) Present-day at the library, stitched with historical photograph

(d) Gray scaled present-day at the library, stitched with historical photograph
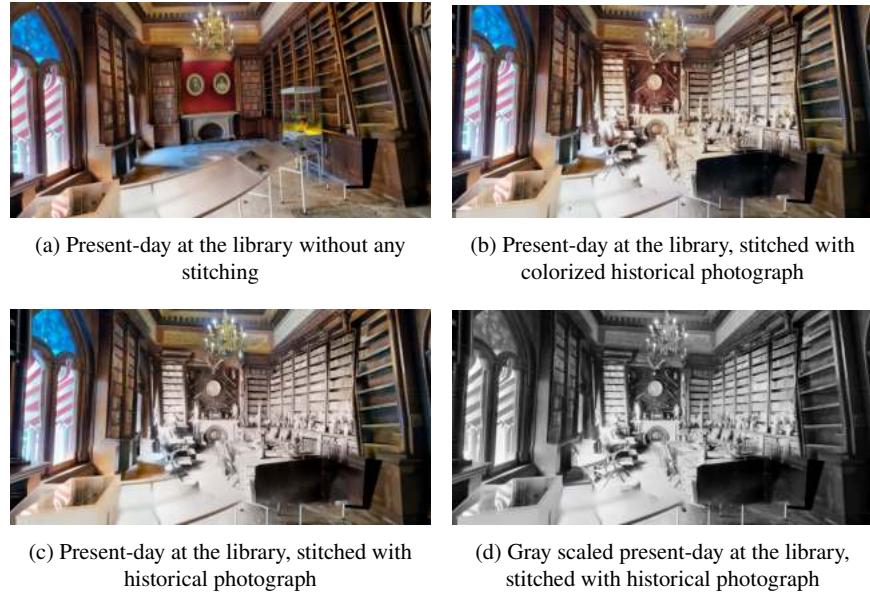
Fig. 1.7: Sections of resulting panorama from image stitching tests

in order to improve tourism experiences", with the design of a solution for the Monserrate Palace, part of a UNESCO cultural landscape located in Sintra, Portugal, more specifically, a web gaming app.

We performed a literature review that shows that immersive technologies, when properly implemented, can be very beneficial to the visitor experience at cultural sites, by providing tourists with a more engaging and interactive experience, where immersive technologies (VR and AR) can enhance their appreciation of the site's cultural and historical significance.

With this analysis at hand, we proceed to the design of an immersive gaming app to enhance visitor experience at the largely unfurnished Monserrate Palace. Referred to as the "Monserrate in the Cook family era", the gaming app uses historical photos and modern smartphone technology to recreate the daily life of the Cook family, in the early 20th century. Visitors will play the game onsite, navigating the palace's spaces and completing challenges that include matching photos to rooms, locating the photographer's pose, and discovering room curiosities. Successful completion of tasks rewards players with insights into the room's historical and cultural significance and AR experiences. User-centered design and expert feedback guided the app's development and prototype testing, and a feasibility study using image-stitching and colorization of historical photos yielded promising results. The game combines education and entertainment, offering a unique, engaging, and interactive tour of the palace.

Current work involves the collection of 360º imaging on-site with proper camera equipment, the estimation of the 1902 photograph camera poses, and its intrinsic

parameters of available photos taken in the palace rooms, to improve our image stitching process. In the context of our user-centered design approach, we are going to proceed in the near future, with expert review usability studies using popular approaches from the literature, that will drive the improvement of the user experience [11].

The beta version of the gaming app, including backend and frontend will also be subject to an end-user study, prior to the deployment of the proposed solution in the palace, to help us gauge the visitor's impressions of the palace. Additionally, the study helps to define end-users' levels of satisfaction and engagement with the current traditional visiting experience, as well as providing insights into the visitor's attitudes and opinions towards the use of immersive technologies and identifying the barriers to the adoption and use of the proposed solution. Final refinements in the app will then result in its deployment on-site to serve the end-users visiting the Monserrate Palace [11].

Continued efforts will be required to identify areas for improvement and optimization of the app, in order to better align with the needs and expectations of visitors. This will involve conducting visitor experience surveys and actively seeking feedback to gather valuable insights.

Overall, our work represents a step towards the development and implementation of immersive technologies in cultural heritage sites. By embracing these technologies and finding innovative ways to integrate them into the visitor experience, we can ensure that the younger generations are able to appreciate and learn from cultural heritages in new and exciting ways.

The app and supporting libraries will be mostly developed adopting open-source software, by means of a re-usable toolkit that can be leveraged by SMEs in the tourism sector to easily implement AR/VR-based experiences, as planned in the workplan of the RESETTING project.

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