Virtual Reality and Educational Tourism - Study Case

Alexandre Fernandes Jarosz Antunes - 43692

Dissertation presented to the School of Technology and Management of Bragança to obtain the Master Degree in Informatics. Under the double diploma course with the Federal Technological University of Paraná.

Work oriented by:

Prof. Ana Isabel Pereira

Prof. Rui Pedro Lopes

Prof. Mauren Louise Sguario Coelho de Andrade

Bragança

2022

Virtual Reality and Educational Tourism - Study Case

Alexandre Fernandes Jarosz Antunes - 43692

Dissertation presented to the School of Technology and Management of Bragança to obtain the Master Degree in Informatics. Under the double diploma course with the Federal Technological University of Paraná.

Work oriented by:

Prof. Ana Isabel Pereira

Prof. Rui Pedro Lopes

Prof. Mauren Louise Sguario Coelho de Andrade

Bragança

2022

Dedication

I dedicate this work to everyone who has supported me along the way throughout my academic and professional development, especially my parents Adriano Kaminski and Francine Charara Fernandes Rosa, who have always encouraged me and worked hard for my personal, intellectual and professional development, and my professors, who have assisted me in my professional career.

Acknowledgement

This work would not have been possible without the valuable participation and contribution of the following people, institutions, and governments, to whom I am deeply grateful and wish to express my gratitude.

Firstly, I thank God Who has given me strength and meaning to overcome all the difficulties encountered. I am grateful to my parents Adriano Kaminski and Francine Charara Fernandes Rosa for understanding, encouraging, and financed my studies, as well as being my emotional supports and making everything possible.

I thank professors Ana Isabel Pereira, Leonel Domingues Deusdado and Rui Pedro Lopes who have encouraged me, oriented me and made my research possible. I thank professors Gleifer Vaz Alves, Mauren Louise Sguario Coelho de Andrade and Simone de Almeida who have encouraged and oriented me throughout the double degree process. I also thank my other professors and colleagues for motivating me during the entire graduation and master's process.

I thank my friends Felipe Gimenez da Silva, who has assisted me in the recording of the videos for this work and provided me with emotional and strategic support to conduct the dissertation, as well as Lucas Cavalcanti Viveiros, who was in charge of the beginning of this work and helped me in many parts of the process, introducing me various things about virtual, augmented, and mixed reality,

I thank all the people who have participated in the tests of this dissertation and have given their feedback for the real understanding of the significance and effectiveness of the project. Also to the people who have participated in the staging of the videos and the project partners located in Italy, Lithuania and Spain. I am grateful to the governments

of Brazil and Portugal for the opportunity to study and, with their partnership, they enabled me to receive an excellent professional education.

I am grateful to Instituto Politécnico de Bragança (IPB) and Universidade Tecnológica Federal do Paraná (UTFPR), especially the Ponta Grossa campus, for providing excellent education in several areas of the computer science degree and enabling a life-changing experience. I to thank The Research Centre in Digitalization and Intelligent Robotics (CeDRI) and Escola Superior de Tecnologia e Gestão (ESTiG) for making environments, equipment, and assistance for the project available. Likewise, I am grateful to Casa de Ciência Viva de Bragança and the Virtual Reality Science Tour (VRSciT) project for making this wonderful study field feasible and possible.

Abstract

Virtual reality is a growing technology that offers a variety of immersive experiences, due to increased investment and scientific research over the years. By wearing virtual reality glasses, the viewer disconnects from the real world and begins to have immersive experiences, allowing for intense and enjoyable entertainment. The tourism industry is one of the most profitable, providing the country with economic power, great visibility, and diverse new investments. Despite going through difficult times, tourism has not been shaken and has grown significantly in recent years, demonstrating the human desire to visit new places or revisit those they already know.

By combining both areas, a new range of possibilities emerges, allowing for the development of content that enables educational tourism, as well as the creation of 360-degree videos, which allow people to share their culture to the world in a new format for most people, making it interesting to be studied and applied. In addition, the incorporation of 3D objects is one of the most widely considered applications for virtual reality, because the possibilities for interaction are limitless. This means highlighting a people's history by displaying and allowing interaction with cultural objects and scenarios for educational tourism and cultural heritage.

The current project aims to use virtual reality in tourism to teach about the culture of Bragança, Portugal. Share traditions, events, locations, and the history of the lifestyles of people who live in this region. A 360-degree video was created to promote important representations of the region's fascinating culture, with the goal of reaching as many people as possible through digital media. Major video edits were required for such production, ranging from illumination and color corrections to object removal, scene reconstruction,

and stabilization, with the goal of characterizing the old moments without technological objects in the scene and preparing quality content for exposure.

Tests for the project with the video revealed that most people are very interested in all of the topics mentioned, owing to the fact that most of them are unfamiliar to this type of technology. Despite the fact that some of them were a little scared or nauseated by the new experience, the tests were mostly positive and demonstrated the developed product's high market appeal.

Keywords: Virtual reality; Educational tourism; Cultural heritage; Video editing; 360-degree video; Immersiveness.

Resumo

A realidade virtual é uma tecnologia em ascensão e proporciona diversas experiências imersivas, ao ser uma área que recebe crescente investimento e pesquisas científicas ao decorrer dos anos. Ao utilizar óculos de realidade virtual, o espectador desconecta-se do mundo real e começa a ter experiências imersivas, o que possibilita entretenimento intenso e divertido. O setor do turismo é um dos mais rentáveis, ao qual proporciona ao país um poder económico, grande visualização e novos investimentos diversos. Apesar de ter passado por tempos difíceis, o turismo não se abalou e cresceu fortemente nos últimos tempos, mostrando o desejo humano de conhecer novos lugares ou revisitar os que já conhece.

Ao unir ambas as áreas, uma nova gama de possibilidades abre-se, possibilitando desenvolver conteúdos que viabilizem um turismo educacional, assim como a criação de vídeos em 360 graus, algo que permite passar a cultura de povos para o mundo todo num formato novo para a maioria das pessoas, o que a torna interessante ser estudada e aplicada. Assim a integração de objetos 3D é uma das mais pensadas para se utilizar na realidade virtual, pois as possibilidades de interação são infinitas. Para o turismo educacional e herança cultural de um povo, isso significa evidenciar a sua história, mostrando e possibilitando interação com objetos e cenários culturais.

O presente trabalho visa aplicar a realidade virtual na área do turismo como ensino à cultura de Bragança, Portugal. Com isso, compartilhar tradições, eventos, locais e a história da vida de pessoas que fazem parte dessa região. Para isso, foi produzido um vídeo em 360 graus que exibe representações importantes para a cultura fascinante da região, transmitindo conhecimento via meios digitais ao máximo de pessoas possível. Para tal

produção, foi necessário grandes edições de vídeo que foram de correções de iluminação e cores à remoção de objetos, reconstrução de cena e estabilização, buscando caracterizar os momentos antigos sem objetos tecnológicos na cena, e preparar um conteúdo de qualidade para exposição.

Testes realizados mostraram que a maior parte das pessoas tem um grande interesse em todos esses aspectos mencionados, sendo novidade para a maioria deles, o que causa alta curiosidade. Apesar de muitas vezes sentirem medo ou enjoo pela nova experiência, os testes mostraram-se majoritariamente positivos e evidenciaram a alta potencialidade de atração de mercado com o produto desenvolvido.

Palavras-chave: Realidade virtual; Turismo educacional; Herança cultural; Edição de vídeo; Vídeo 360 graus; Imersividade.

Contents

List of Tables

List of Figures

Acronyms

2D Two-Dimensional.

3D Three-Dimensional.

AI Artificial Intelligence.

AR Augmented Reality.

CeDRI The Research Centre in Digitalization and Intelligent Robotics.

COVID-19 Coronavirus Disease.

DDR Double Data Rate.

DoF Degrees of freedom.

ESTiG Escola Superior de Tecnologia e Gestão.

EU European Union.

FOV Field Of View.

FPS Frames Per Second.

GPU Graphics Processing Unit.

HD High Definition.

HDMI High-Definition Multimedia Interface.

HMD Head-Mounted Display.

Hz Hertz.

IMU Inertial Measurement Unit.

IPB Instituto Politécnico de Bragança.

IPD Inter Pupillary Distance.

LCD Liquid-Crystal Display.

mAh Milliampere-hours.

RAM Random-Access Memory.

UNESCO United Nations Educational, Scientific and Cultural Organization.

UNWTO United Nations World Tourism Organization.

USA United States of America.

USB Universal Serial Bus.

UTFPR Universidade Tecnológica Federal do Paraná.

VR Virtual Reality.

VRSciT Virtual Reality Science Tour.

WoS Web of Science.

WTTC World Travel Tourism Council.

Chapter 1

Introduction

Tourism and Virtual Reality (Virtual Reality (VR)) are two major industries that are becoming increasingly interconnected due to the immersiveness that VR can provide and the importance of discovering lovable places that are appealing to humans. “If I have to explain VR in a simple way, I would describe it to be an interactive fantasy world where everything is possible” (Jarle Fink Kondrup). The Sections that follow will present the project’s motivation and goals, as well as the structure of this document.

1.1 Motivation

Many people are still unaware of the capabilities of virtual reality, despite the fact that there has been a surge in interest in the field in recent years. Big companies investing heavily, increasing scientific research, and the popularization and diversification of VR all indicate that it is becoming a promising area. The tourism industry is booming, with more people wanting to travel around the world and experience different cultures. The combination of the areas brings together two universes that are both highlighted and desired by many people. Creating a work in this area allowed to get to know and experience each universe more closely, recognizing the importance and breadth of possibilities to be explored.

1.2 Objectives

The current project aims to promote educational tourism through digital media, with a focus on the use of VR and its great immersiveness and variety of application possibilities. The following topics summarize the main objectives.

- Using a 360-degree camera to record 360-degree videos at important events in the Bragança district of Portugal;
- Produce and edit videos to tell stories while transmitting diverse cultural values to various locations around the world via digital media;
- To promote Bragança and Portugal as a destination of choice by valorizing and displaying cultural assets through the use of virtual reality and 3D modeling;
- Assisting the development of the tourism and virtual reality sectors, as well as their union, which has grown over time which requires more scientific investment.

This project aims to produce a 360-degree video for the city of Bragança in Portugal in order to promote tourism in VR, using 360-degree glasses, as well as three-dimensional (3D) models based on important objects from the country's culture, with the goal of sharing the country's culture and history.

This necessitated developing a script to analyze the best locations for recording, as well as recording several videos at these points, telling a story that depicted the district's culture, beginning in the past and progressing to the present, analyzing the videos and questioning different viewers to improve the editing to ensure immersion in the story and maintain cohesion with the respective periods of the video.

Thus, through a digital environment, tourist and historical knowledge can be transmitted globally, assisting in the preservation and sharing of memory of the origins and current customs of people and places. It also includes 3D objects to improve the experience and provide a better understanding of the monuments and objects associated with such history.

The work is part of the Virtual Reality Science Tour (VRSciT) project, funded by the European Commission, which aims to use VR and 3D modeling for virtual educational tours. The project's locations are of interest to the participating countries, Italy, Lithuania, Spain, and Portugal. The project's goal is to expand informal education through digital means. Each country has two partners for this, a museum and a higher education institution. Portugal has the Instituto Politécnico de Bragança (IPB) and the Casa da Seda (Silk House), a museum at the Associação Centro Ciência Viva (Association Live Science Network) in Bragança where the project will be exposed to the public.

The project began in January 2021, with the goal of understanding points of literature from both scenarios mentioned, bringing research and development to each partner country, and culminating in the production and editing of the videos in December 2021. Since then, it has been produced and edited in order to further develop the project. It went through tests and validations in July 2022, and the physical module will be inaugurated in February 2023.

1.3 Documents Structure

The current document contains six Chapters, the first of which is the current one that presents the introduction, motivation, and intended goals, while the others explain the work into different Sections and are discussed below.

- Chapter 2 discusses the state of the art in the fields of tourism and virtual reality, as well as their integration, resulting in the creation of virtual reality focused on tourism, bringing data and scientific papers from these fields;
- Chapter 3 informs the technologies and methodologies used to develop the work, defining how and why each tool was used, as well as the approach chosen to complete the tasks;
- Chapter 4 describes the development of the work's final product, a 360-degree virtual reality video focusing on educational tourism in Bragança, Portugal;

- Chapter 5 explores the usability test of the developed product, going over all of the tests performed and improvements implemented in the production of the video;
- Chapter 6 presents the conclusions and projections for future work.

Following that, the study of the art and important information for the fields of tourism and virtual reality, as well as their union, will be presented.

Chapter 2

State of the art

The wish to seek knowledge, the unknown, to go to faraway lands, to explore and appreciate varied habitats has been present in people since beginning of human history, as evidenced by what has been documented. As nomads, we tried to change location whenever we required new resources, especially food, becoming sedentary during the age of the agricultural revolution, and the development of collective work was fundamental to maintain the fruitful environment and assure the survival of these people. With a greater agglomeration of people, it became necessary to share resources and define tasks, resulting in more evolved societies [1]–[3]. As time passed, it was realized that it was possible to have commercial relations between peoples, because each region has different conditions and has easier or harder access to certain raw materials and productions, increasing temporary or permanent migration for economic, political, cultural, religious, or natural disaster reasons. With this new aspect, commercial routes were pushed [4], allowing for increased ease of movement and contact between these social groupings. Furthermore, the ambition for greater territory dominance has been present throughout history, transforming continents geographically and politically and frequently providing the catalyst for new revolutions such as the industrial and urban ones [5].

As noted previously, the ability to maintain a fertile environment, increase their population, share interests between regions, and improve commuting between such societies required the entire meaning and practice of migration to be improved and adapted by

taking steps to enable longer and safer journeys. Explorers, scholars, pilgrims, merchants, colonizers, warriors, soldiers, and plunderers, among other titles and positions who used migration for a purpose, started to stay briefly, sometimes for just one night or a few hours, in tents, hostels, or hotels along their route, allowing them to travel farther [4], [6]. Because of this desire for migration, humans developed more sophisticated strategies for traveling farther and faster while requiring less energy and carrying more cargo. Horses, camels, oxen, donkeys, mules, and even elephants in some communities were necessary for efficient movement until being replaced by technical advancements like boats, trains, cars, and other forms of transportation [7], [8]. Despite the fact that people previously traveled for their own interests and that economic goals were the primary focus, N. Jayapalan states [9] that "Travel in the distant part was not a thing of pleasure as is the case now", emphasizing the differences between the past and the present while also separating tourism into 17 different categories. The word "tourism" has evolved to mean leisure travel that is primarily done for the enjoyment of the traveler. The notions of tourism, cultural heritage, and technologies related to tourism will then be further explored in this paper.

2.1 Tourism and cultural heritage

According to United Nations World Tourism Organization (UNWTO), the primary international tourism agency, tourism "is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes" [10], [11]. It is evident that the role of tourism in people's life is increasing through economy, culture, politics, and other social spheres [12]. Thomas Cook [13], considered the father and pioneer of tourism, was the first to take a tourist excursion in 1855, travelling through Belgium, France, the Netherlands, and Germany. I in the future, a travel company with his name arose, initially with train travel and also providing discount coupons for road hotels, then expanding to include air travel and accommodation [14], among other companies in the same business that arose

later. In addition, he published travel guides for various locations across the world, such as Tourist's Handbook. His assistance was essential in the establishment and definition of tourism and the tourist, "A traveler enters the world into which he travels, but a tourist brings his own world with him and never sees the one he's in" [4], [12], [15].

Sustainability, which is intended for diverse industries and approaches, stresses the responsible use of resources while keeping the same that will be required for future generations. It is conceivable, and increasingly important, to combine such terms to establish sustainable tourism. The literature review of Purwaningsih et al. [16] divides the area into six more correlated sub-areas, which are Government, Local Community, Tourist (visitor), Management Agency, Tourism Destination (Location), and Tourism Supporting Facilities, emphasizing the need for the collaboration of various stakeholders and involved parties to achieve the sustainable goal in tourism. It is noticeable that preventative measures are more valuable than corrective ones, and their application is vital to maintaining the environment as well as the natural and cultural heritage. This includes taking care of biodiversity, climate, pollution, and other resources, which requires a social, environmental, and economic attitude. For such a sustainable goal, it also requires investment and the exchange of real effective information, in accordance with Bausch et al. and the UNWTO [17], [18]. When going deeper into this ideal, the term cultural heritage, along with cultural heritage and natural heritage, is described by United Nations Educational, Scientific and Cultural Organization (UNESCO) [19] as "Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural and natural heritage are both irreplaceable sources of life and inspiration", being of worldwide approach [20], [21]. This definition can be extended to the tourism sector by using the term heritage tourism, which refers to the use and preservation of historical environments, artifacts, and activities as a cultural, historical, and touristic form [22], [23]. Many sources consider such concepts to be phenomenon, which the Oxford dictionary defines as a person, fact, or circumstance that is remarkable, perceptible, and observable to a person, especially with explanations for the events referred to [24].

Bitušíková conducted a literature analysis to combine ideas and notions concerning

cultural heritage and heritage tourism, noting that in today's globalized world, these terms have varied definitions and perspectives. Positive opinions about it because of its importance in understanding what the world was and is, encouraging preservation and monetary and cultural investment in humanity's assets, but also negative because of the massive commercialization of these historical treasures, since the tourism industry is highly profitable and interesting, increasing its deterioration through misuse. It is concluded that the importance of the study is of great value and profitable, despite opposing ideologies to the concepts, does not mean that both are not right, reinforcing the idea of the need for partnership between all parties involved in tourism and teaching tourists, as mentioned above, and increasing realize a trend in a better development of local communities by communication, being an improvement to the development of tourism [16], [25].

2.1.1 World and Europe

Despite global social, health, and economic difficulties caused by the Coronavirus Disease (COVID-19) pandemic, which severely impacted tourism, one of the most affected economic sectors in general and globally, the UNWTO barometer recorded a significant recovery in the first five months of 2022, with approximately 250 million international trips registered [26], revealing that Europe and America had the best tourism results, emphasizing the growth in tourism spending in important industry areas such as France, Germany, Italy, and the United States at pre-pandemic levels. The World Travel Tourism Council (WTTC) [27] believes that the travel and tourism sector could reach $8.6 trillion this year, an increase from the approximately 9.2 trillion made in 2019 [28]. Statista [29] generated a graph, shown below in the Figure 2.1, based on data from the UNWTO, that demonstrates the significant increase in international visitor visits globally from 1990 to 2021, with an estimate for 2022. Although the SARS epidemic of 2003 and the global financial crisis of 2009 had little impact on this increase, the COVID-19 pandemic shocked this trend, making it the worst year in tourist history, with a decrease of more than one

billion worldwide arrivals [30]–[32].

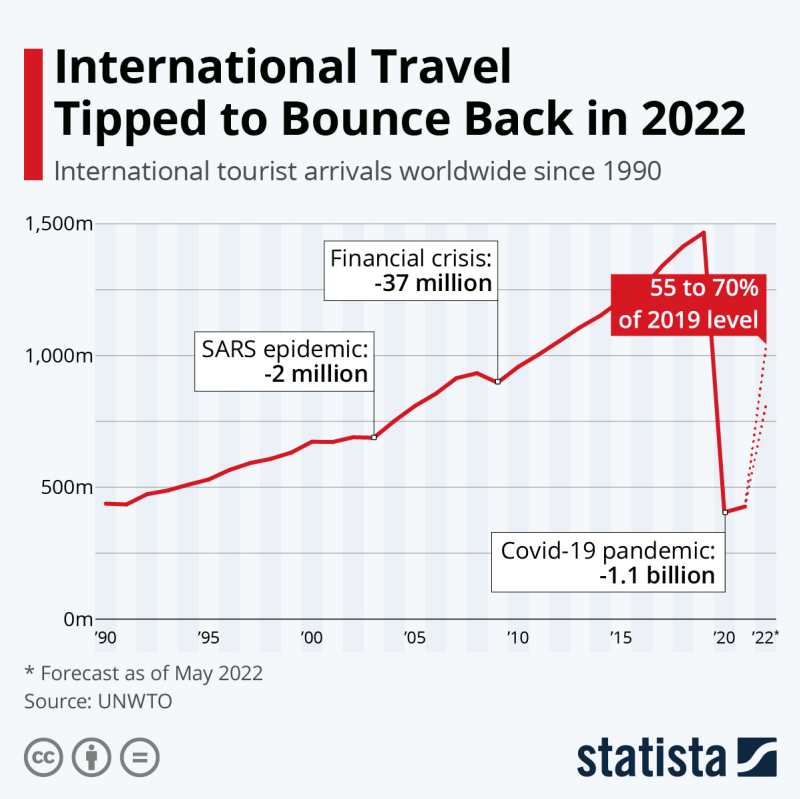

Figure 2.1: International Travel Tipped to Bounce Back in 2022.

Nevertheless, it already shows an encouraging rise in 2021 and an optimistic growth forecast for 2022 and subsequent years. The growing desire to visit or revisit destinations all over the world is noticeable, and the tourism industry appears to be becoming increasingly profitable and in demand by individuals and investors of all types. Such statistics can also be seen on the dashboards on UNWTO's website, as shown in the Figure 2.2 (A), which shows an overview of world travel in 2019 and 2021, with notable improvement over the previous year but still underperforming of the last pre-pandemic year [33], [34].

In addition to global data indicating a promising recovery, despite ongoing pandemic and economic difficulties, Europe is in a similar scenario. Despite ongoing challenges, Figure 2.2 (B) statistics indicate that travel on the continent has already begun extremely well for the current year and is quite near to what it was in a non-pandemic scenario [33].

It's no surprise that the sector is expected to strengthen and that increasing numbers

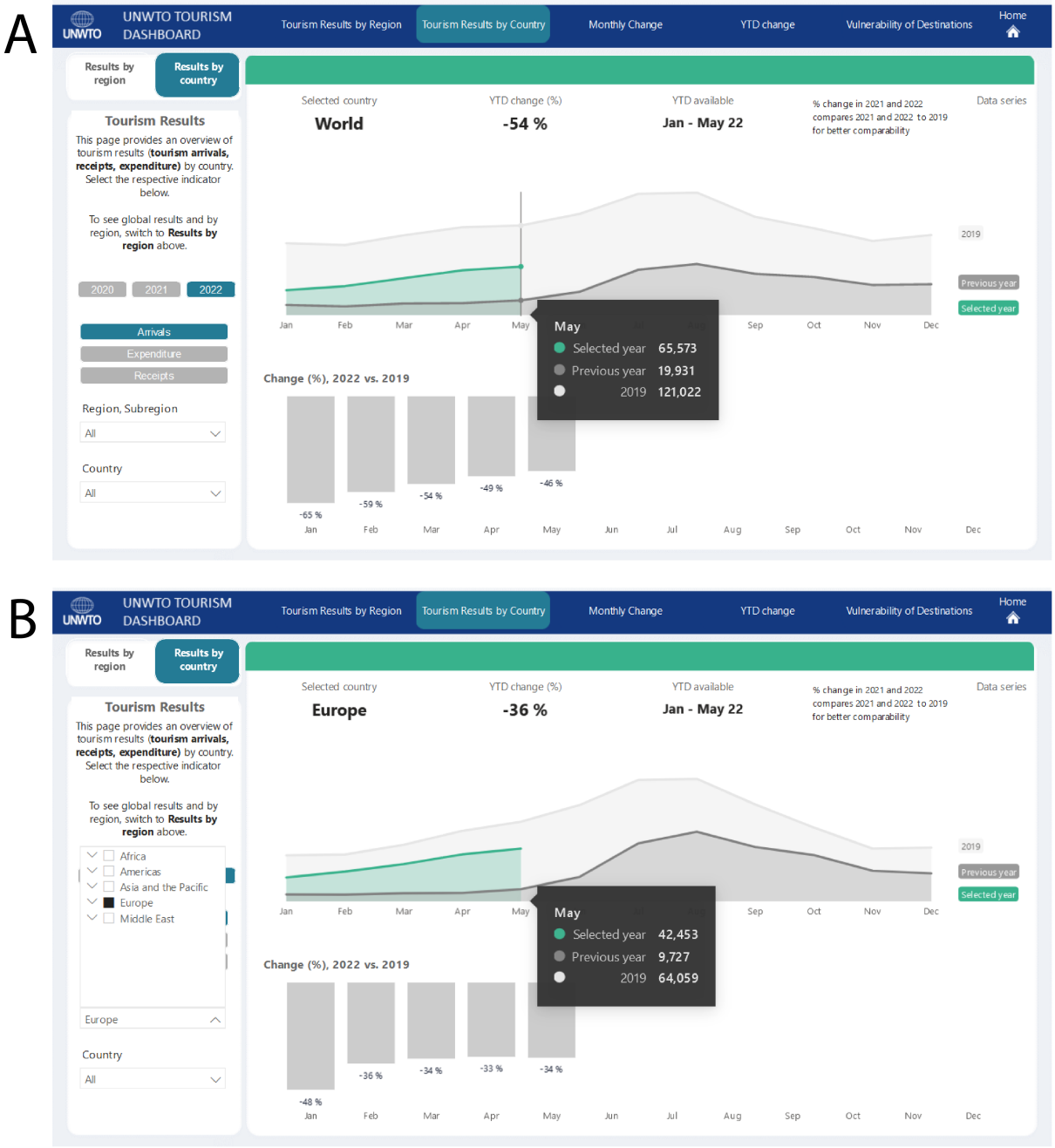

Figure 2.2: UNWTO Tourism Dashboard - 19-08-22 - (A)World (B)Europe.

of investments will be made to boost tourism growth and development. In addition to the data shown, there are many other interesting categories to evaluate on the UNWTO Tourism Data Dashboard website [34], however most need to be updated for the year 2022 as of the writing of this document, with many categories of data only in pre-pandemic

periods.

The analysis presented is consistent with what has been reported about tourism in Europe by Tourism Economics, a division of the Oxford Economics company, in collaboration with the ETC, exposing data from the increase in travel to a high probability of improvement, accompanied by the reduction of restrictions in relation to COVID-19, even though the population has faced a current scenario troubled by high and rising inflation, with great economic turbulence [35]–[37].

The European Union (EU) believes that the pandemic will have a long-term impact, but emphasizes that in order to encourage Europeans to travel, it is vital to support sustainable tourism, including ecological transportation, consumption of local products, and environmental protection. Furthermore, it claims that 82% of the population is already prepared for such a transformation and plans to become the first climate neutral continent by 2050, due to initiatives such as the NextGenerationEU project [38]–[40].

2.1.2 Portugal

Portugal has expressed optimism and encouragement in the tourism sector for the decline in COVID-19 cases. It is no longer necessary to show proof of immunization or a negative test in order to enter the nation, including the Azores Islands and Madeira. CNN Travel [41] reports that more than 87% of the population has been entirely vaccinated, and that, while COVID-19 instances peak in January, data and graphs show a reduction in the remaining months of 2022, according to information from the National Institute of Statistics of Portugal [42]–[44]. Portugal's tourism sector has improved significantly as a result of increased searches for the country and strong investment, as reported by the European Commission, WTTC, Organization for Economic Cooperation and Development, and Trading Economics, with an investment of more than €1.7 million, a value that is close to exceeding the largest investment of June 2021, with more than €1.8 million, which, if it occurs, will only be lower than the amounts invested in 2019. The national triumph against the crisis is demonstrated by Portugal Resident's announcement that Portugal is

the EU's "fastest expanding economy" [27], [45]–[53]. Such information accords with the UNWTO, as shown in the Figure 2.3, which shows a significant increase in travel compared to the previous year, approaching the last pre-pandemic year. This demonstrates a higher facilitation of tourism in the country, with a prediction of continuous improvement in the industry in an optimistic analysis before to COVID-19 [33].

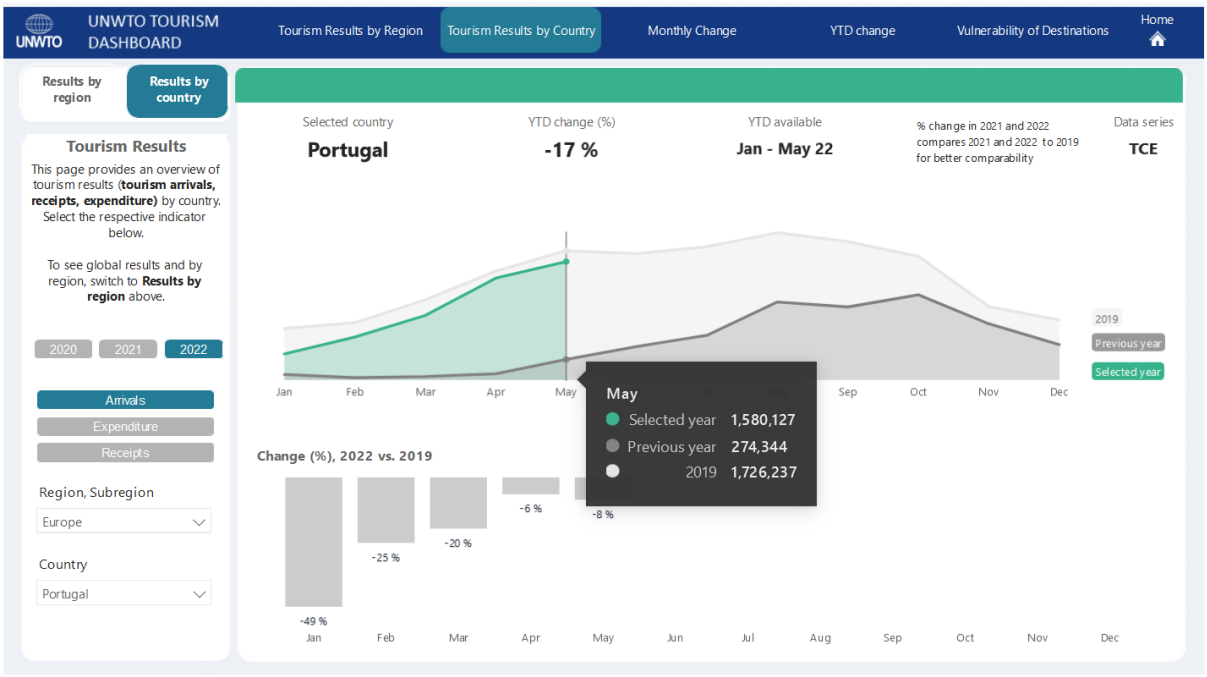

Figure 2.3: UNWTO Tourism Dashboard - Portugal - 19-08-22.

In Portugal, there are various attractions, commemorative events, and tourist locations to discover, in addition to a wonderful history and good preservation of old customs, but it is still renewing itself each time more, opening the doors to tourists and new residents from all over the world. Go To Portugal has compiled a list of 100 locations to visit in Portugal [54]. The country has 17 of the 1154 properties on the UNESCO World Heritage List, 16 cultural and one natural, scattered over the continental country and islands [21], [55].

2.1.3 District of Bragança

Bragança, a district in north-eastern Portugal with the same-named capital city, has more than 160 built patrimonies dispersed over its municipalities [56], [57]. It receives an increasing amount of investments through its development and has developing connections with the other districts around it, including Vila Real, Viseu, and Guarda, as well as with Spain, via its border cities of Ourense, Zamora, and Salamanca. Because of this information, it is gradually attracting visitors from all over the world, owing to its extensive history, cultural and tourist attractions, and for hosting students from several nations through the IPB [58]. As a result, the expanding contribution of research and initiatives for the city, district, and country is assisting in the preservation of the old and development of the new. Projects like as Bragança EcoCidade, which intends to create a strategic plan to become a class, are examples of this. A municipality, Bragança saudável, focuses on the promotion of healthy habits in society, "Bragança. Naturally!" promotes the city and its culture, "RURBAN Link" encourages urban-rural relations centered on sustainability and efficiency, and several more programs [59]–[62]. And research like Cultura para Todos Bragança, which aims to increase accessibility for people with hearing, intellectual, and visual impairments and disabilities, Pança's master's thesis, which focuses on the use of nature in industrial zones to mitigate the effects of negative human actions on the environment, Pinto's master's thesis, which focuses on public awareness of sustainability and ecology in waste reduction and the like, and various other types and focuses of research [63]–[65].

The focus of this effort will be on the city's tourism, cultural, and historical areas, with a concentration on two patrimonies, one physical and one cultural. The physical one is the Bragança Castle, which can be seen in Figure 2.4 (A) , located in the historic center of Bragança, is one of Portugal's best maintained castles. It was built by order of D. João I in 1409 and became a military museum in 1932 [66]–[69].

The Carnaval de Podence, seen in Figure 2.4 (B) takes place in the Trás-os-Montes region, more specifically in the municipality of Macedo de Cavaleiros and the parish of

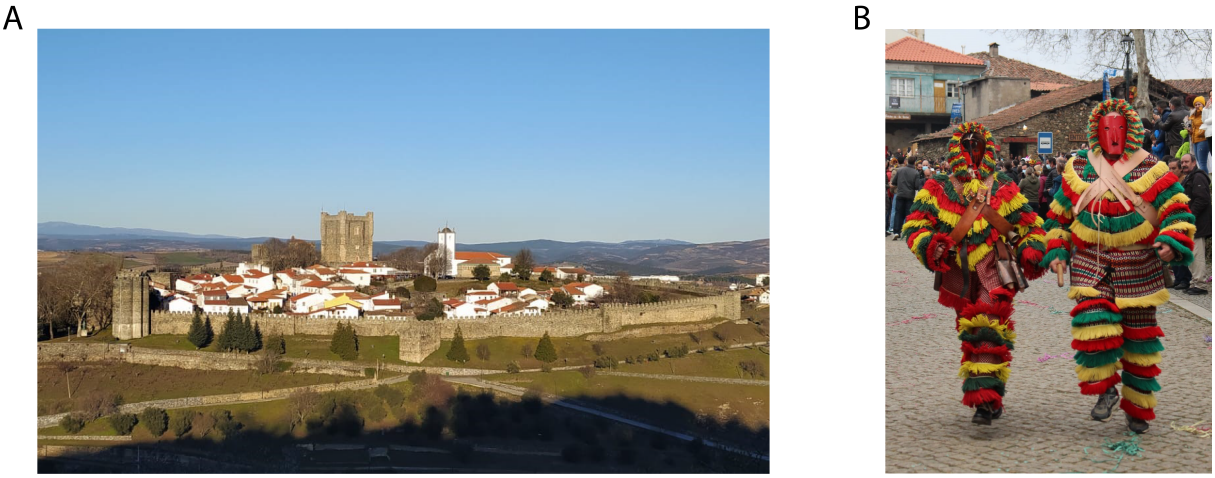

Figure 2.4: (A)Bragança castle (B)Podence carnival with Caretos.

Podence. This event, also known as Entrudo Chocalheiro, represents rejuvenation and the beginning of a new cycle, taking place at the end of February and beginning of March, near the end of winter and the beginning of spring, in which people dressed in colorful clothes made of wool quilts, with masks made of leather, brass, or wood, and bells around their waists, they go out on the streets jumping, dancing, and interacting with whoever is around. Known as Caretos, these characters are currently listed on the Representative List of the Intangible Cultural Heritage of Humanity maintained by UNESCO [70]–[72]. Both will be discussed in further details in Section 3 of this document, Methods and technologies.

2.2 Tourism and virtual reality

Tourism and VR are large fields with numerous distinct uses, as demonstrated in the preceding Sections, with research and investment increasing year after year. By combining them in one context, a new universe of possibilities opens up that strongly needs to be investigated, because, despite the fact that both phrases have existed for decades, their merger is new and little explored, something that is changing dramatically and merits attention and investment. Palmer Luckey, the founder of Oculus VR, once asked in an enterview to The Wall Street Journal [73], “Why shouldn’t people be able to teleport

wherever they want?" [74]. Furthermore, he emphasizes that the VR user must operate as if he is not constrained by physical laws. Adopting his statements to the world of tourism fits wonderfully with this topic, enhancing and empowering the arguments for employing VR in the tourism business.

2.2.1 Scientific database

With this in mind, it was vital to first understand how the scientific union of the two sectors has evolved through time. To that goal, a search for documents, articles, books, final papers, among others, was built in repositories of significant importance such as Scopus, an Elsevier's abstract and citation database, and the Web of Science (WoS), a platform that provides access to a database of scientific documents [75]–[77].

To filter the documents of interest, it was searched in both repositories using the terms Tourism and Virtual Reality or VR, with no time, language, or country limits, because the goal is to first verify how the current scenario is as a whole. Scopus returned 1101 documents, while WoS returned 1289 documents. To facilitate data analysis, all documents from both repositories were exported to the computer in full record BibTex format [78].

2.2.2 Bibliometrix

Bibliometrix [79] is an open-source tool package for the R statistical programming language [80] that evaluates research success using quantitative analysis and statistics of scientific documents (also known as scientometrics), with its community growing worldwide. Its commands are simple to use, which makes it easy to use, being linked to RStudio [81] that only need to install its package by a command [82]. One of its most intriguing features is the ability to analyze the references, allowing users to generate several detailed graphs that display the information much more clearly and can be used for practically any data in the files. Another useful feature is the capacity to connect references from Scupus and WoS repositories, removing all duplicate references by joining both papers in

BibTex format. Because of these characteristics, it has proven to be an excellent tool for use in the project.

To do this, the *bibliometrix* and *openxlsx* libraries were imported, the function `conver2df` was used to convert the BibTex files into a data frame, and the `mergeDbSources` command was used with the `remove.duplicated` option set to T (true). The xlsx file was then written into with the `write.xlsx` command, and the `biblioshiny()` command was used to access the bibliometrix site locally. *Load bibliometrix file(s)* was selected from the menu *Data*, submenu *Import or Load files*, and the xlsx file was loaded with the data already corrected.

2.3 Literature results

Following the process, 475 duplicate references were deleted, leaving a total of 1915, as shown in Table 2.1. As a result, it is clear that the Bibliometrix tool aids in data arrangement such that there is no repetition of information, which would invalidate the graphs.

	Scopus	**Web of Science**	**Scopus + WoS**	**After Bibliomatrix**	**Deleted repeated**
Amount of References	1101	1289	2390	**1915**	475

Table 2.1: Bibliometrix process.

With this, it is possible to begin analyzing the data in more depth and see how the world is collaborating with the tourism and VR segments together. Because we have all references from Scopus and WoS repositories, we can verify the number of authors, types of references, places of origin, and the time span since we released documents when linking the segments of interest, which is showed in Table 2.2.

Authors	**References**	**Reference types**	**Sources**	**Timespan**
4789	1915	18	1116	From 1985 to 2023

Table 2.2: Refereces' details.

An interesting analysis to consider is how the fields of VR and tourism have collaborated over time; this analysis reveals if scientific investigations are on the rise or decreasing. Figure 2.5 illustrates such information in graphical form, and it is clear that scientific study between the two areas has increased significantly over the years. This collection of references began in 1985 with one article, and there are some small and spaced peaks in 1991 with two documents and 1995 with four works. From this year forward, the perception is that there will never be another year without scientific investigation in the correlation of the sectors. Other high points were in 2001 with 14, 2007 with 29, 2011 with 52, and 2014 with 70 scientific papers.

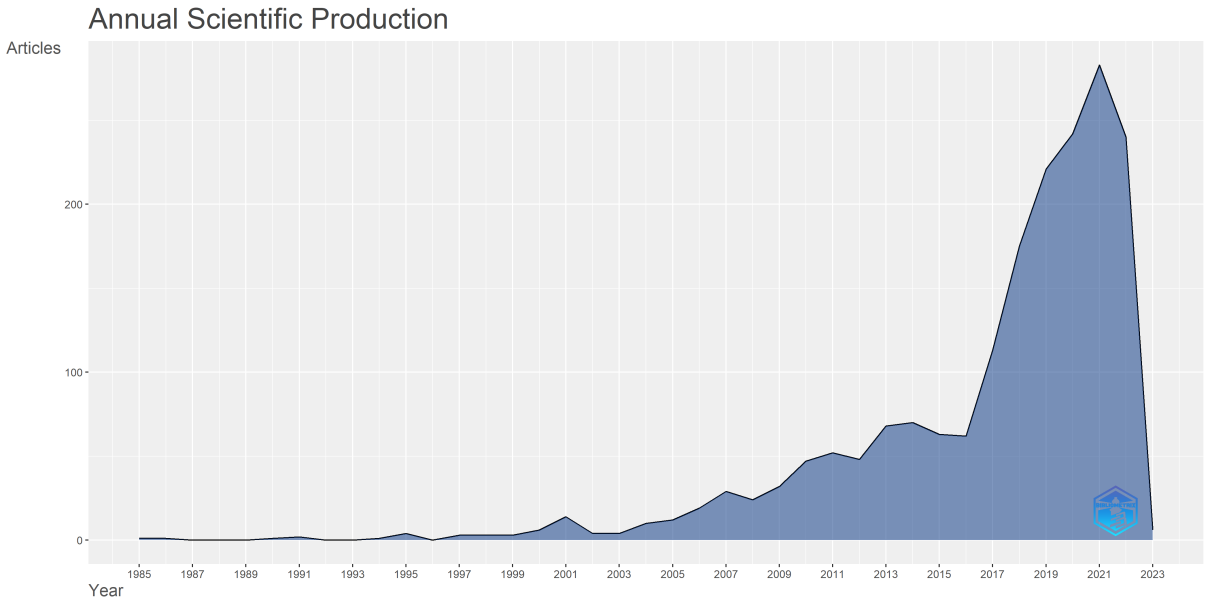

Figure 2.5: Annual Scientific Production.

The year with the most papers was 2021, with 283. However, the current year (2022) has so far produced 240 papers, and there are still some months till 2023, which has already listed 6 papers. Despite this, 2022 is yet to surpass the number of papers issued in 2020, which was 242. An admirable view is that even during the worst pandemic years (2020 and 2021), the amount of scientific products in the area increased, allowing the deduction that VR is a great technique for tourism to employ VR in cases of mobility challenges or for pure amusement.

Another significant year was 2017, when the rate of studies skyrocketed. Talafubieke et al. [83], who studied the economy in relation to the two areas and discovered that the virtual economic revenues of the VR tourism product increased from 50 million to 1 billion between 2017 and 2020. Furthermore, the data according Annual Scientific Production category, in Figure 2.5, reveal that scientific research in the last century produced in 19 publications. Between 2000 and 2010, 201 papers were published, 363 scientific documents produced between 2011 and 2016, and 1280 from 2017 to the present. When analyzing such data, another way to visualize the area's growth in recent years is to note that between 1985 and 2019, 1092 documents were published, while those between 2020 and 2023 are already 771, implying that 70.6% of the amount produced in the previous 34 years was produced in the last four years.

These works had some characteristics in common, and there were countries and educational institutions that worked the most to establish a correlation between the areas. Figure 2.6 exhibits the five most often used keywords (A), the five countries (B), and the five educational institutions (C) having the greatest influence in this database derived from Scopus and WoS repositories.

According to Figure 2.6, the most frequently used keywords (A) are virtual reality (695 times), augmented reality (248), tourism (116), cultural heritage (76) and mixed reality (62), the most relevant countries (B) were China (569 papers), United States of America (USA) (243), Spain (238), South Korea (201) and Italy (121), and the most influential institutions were China's Capital Normal University (494 papers), South Korea's Korea Advanced Institute of Science and Technology (113) and Kyung Hee University (102), China's The Hong Kong Polytechnic University (88), and Australia's Griffith University (2).

The keywords are significant because these are the terms highlighted in the documents. Although the works are related to virtual reality and tourism, as shown in Figure 2.7, they can also be related to cultural heritages, three-dimensional computer graphics, experience, and others.

It is also possible to list the references' thematic sources. Table 2.3 displays the 10

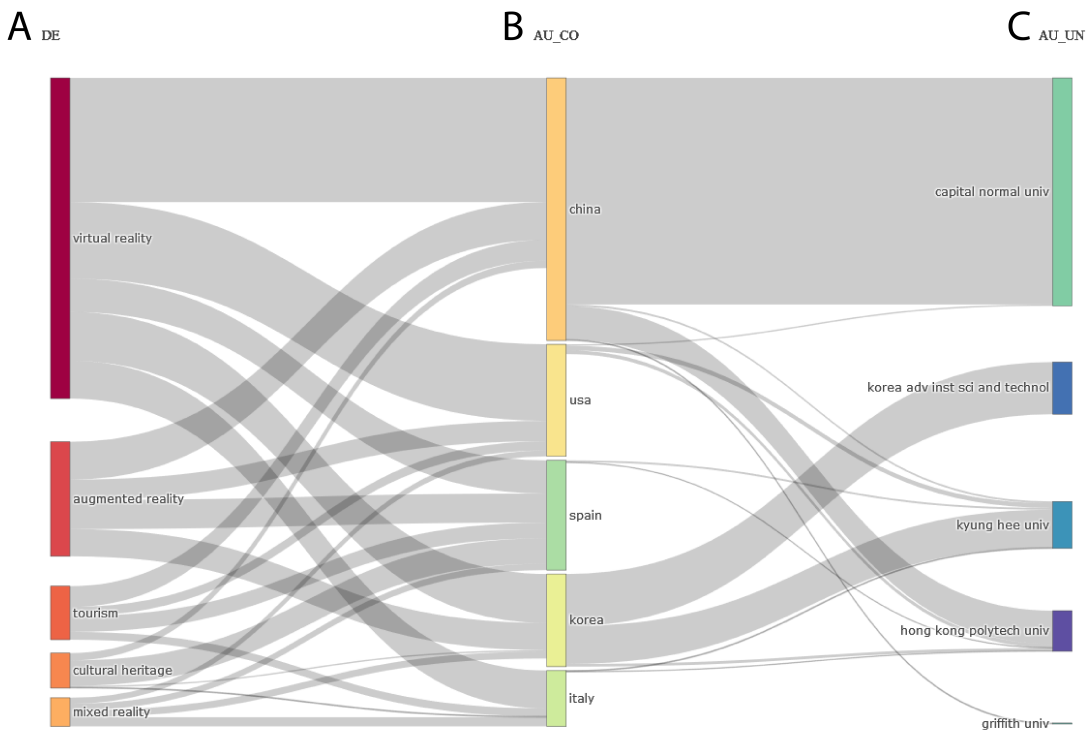

Figure 2.6: (A)Keywords (B)Countries (C)Affiliations.

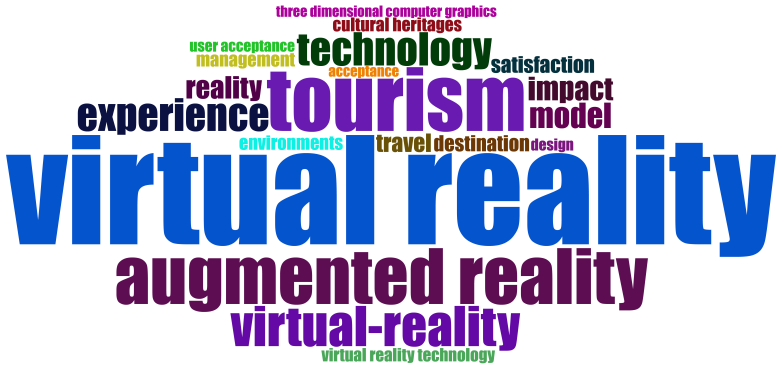

Figure 2.7: 20 Most Frequent Words.

most relevant origins as well as the amount of work done in each one. It is interesting the perception that sustainability is a topic on the rise, as most commented in Section 2.1, Tourism and cultural heritage, and has a very strong link with tourism, information that shows the main concern of academic studies.

Source	Amount
Sustainability	38
Lecture Notes in Computer Science	34
Tourism Management	29
Current Issues in Tourism	27
ACM International Conference Proceeding Series	17
Journal of Hospitality and Tourism Technology	15
Smart Innovation Systems and Technologies	13
Communication in Computer and Information Science	12
Frontiers in Psychology	11
Information Technology and Tourism	11

Table 2.3: Most Relevant Sources.

The general analysis of academic papers allows one to understand how the field is evolving, serving as a great filter for understanding what else is produced in the correlation of VR and tourism. Many students create literature reviews in order to group papers for the purpose of analyzing something specific. Lee et al. [84] noticed a lack of literature reviews in the correlation of VR and festivals, so he gathered 19 articles on the subject, because many events that could not take place in person during the pandemic were implemented in virtual environments. Verma et al. [85] gathered 1652 articles on virtual tourism, including VR, to reach the conclusion of the growing evolution of this correlation, in accordance with the researches in Section 2.3, among other works [86]–[95].

Chapter 3

Methods and technologies

The current Chapter intends to provide the methods and technologies utilized in the dissertation project's development process, informing the significance, general usage, and peculiarities of the reported aspects.

3.1 Technologies

The subtopics that follow detail several ascending technologies and influential software programs in the current market and in its field of expertise that have provided great benefit for the composition of the current work's final product.

3.1.1 360-degree video

The primary goal of this project was to create a 360-degree video, an innovative technology for audiovisual productions, also known as surround, immersive, or spherical videos. They are recorded with an omnidirectional camera, a device with a cluster of cameras positioned to record in all directions simultaneously, and are later merged in a process known as "stitch", which is the stitching of distinct videos at points of similarity, resulting in an overlap [96]–[98].

The application of this technology is broad, and it is being increasingly invested in by

market leaders such as Google, Youtube, Vmeo, and, most notably, Meta (Facebook)[99]–[102]. Today, such videos can be viewed using VR glasses, mobile devices such as a cell phone, and computers, and it is also becoming more popular to have 360-degree material on social networks, as in the aforementioned companies.

Despite the vast amount of data gathered, it is not possible to observe the entire video extension because, like the human eye in the real world, it is constrained to focusing on a certain fixation point and having a limited perspective of the complete environment in which we are inserted. This knowledge gave rise to the term Field Of View (FOV), which specifies the viewable portion of a scene, having a value for horizontal and other for vertical views, and is illustrated in the Figure 3.1 (A). A mathematical equation was established for this, as given in Equation 3.1, where s (subtends) is the quantity of perceived visualization, determined by multiplying the values r, the radius of visualization distance, and θ, the angle between the extremes of information acquisition by the eye [103].

$$s = r\theta \tag{3.1}$$

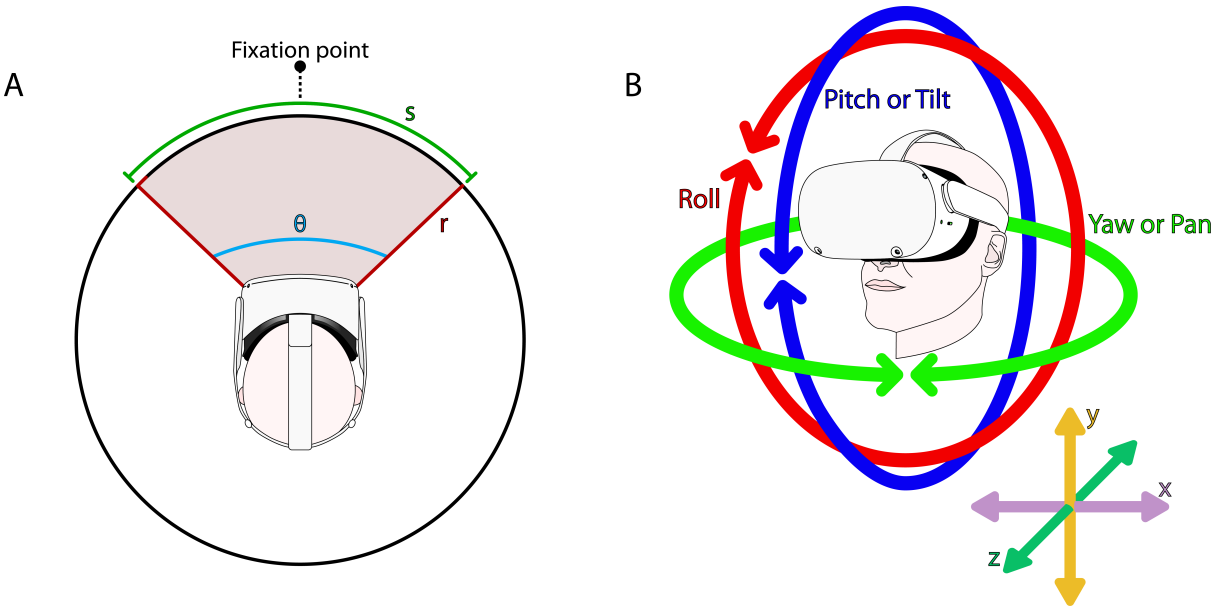

Figure 3.1: (A)Field of view (B)360-degree view head movement.

This requires the viewer of the video to turn their head (or utilize the device's particular

interaction) to be able to assess all points of the 360-degree video. Being in the most recent VR glasses, it is possible to rotate the head, neck, or entire body to change the video fixation point, known as rotational tracking, or 3Degrees of freedom (DoF), which uses electromechanical gyroscopes, as shown in Figure 3.1 (B), with pitch on the x-axis, yaw on the y-axis, and roll on the z-axis (or tilt, pan and roll, on the respective axes, in Euler angle). Some devices additionally include positional tracking, or 6DoF, which captures body movement in the x, y, and z axes and moves the user within the virtual situation they are experiencing in VR [104].

3.1.2 Virtual reality

Virtual reality, abbreviated VR, is an interface technology that simulates an artificial virtual environment, linking a user to a computer system in a visual and auditory manner, as well as allowing various interactions with the virtual universe. Because of the increasing investment in the area, it is gaining more fans and enthusiasts who seek out games and various applications in order to be transported to another scenario, disconnecting from the real world, by diving into the great immersiveness it provides, which is made possible by the possibility of simple navigation and the great potential for various involvements resulting from sensory feedback. There are three sorts of virtual experiences: non-immersive, semi-immersive, and fully-immersive [105]–[107].

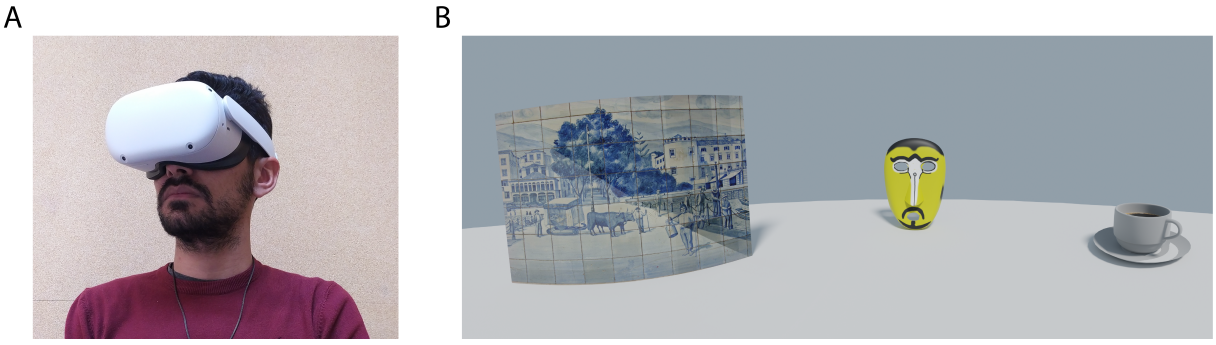

Figure 3.2: (A)VR usage (B)3D models in a 3D cenario.

The virtual environment can be a 3D scenario (composed of 3D models, seen in Figure

3.2 (B) which is being displayed in the user's view of VR with a limited FOV, as previously described), a 360-degree image or video that is played back in real-time through VR glasses, as it can be seen in Figure 3.2 (A), which are a combination of Head-Mounted Display (HMD) and Inertial Measurement Unit (IMU) and it uses head tracking to determine the user's head movement. Such technology has a wide range of applications and is primarily associated with the computer graphics field. The glasses utilized in the project will be discussed in greater detail in the subsection 3.2.3.

3.1.3 Insta360 Stitcher

Insta360 Stitcher [108], developed by Insta360 [109], is a free software program used for stitching images and videos captured by the Insta360 Pro, Pro 2, and Titan 360 degree cameras. This is accomplished by overlapping the common points of the image or video, so that at the end of the process, the content from each of the cameras is joined as one, resulting in the creation of a new 360-degree material. It has three stitching modes: the new optical flow, which aims for a good result of blending the contents while taking time and speed into consideration, the optical Flow, which seeks to get the most out of the software and delivers a better stitching of the images but takes longer to process, and the scene-specific template, which focuses on reduced speed but does a simpler stitching.

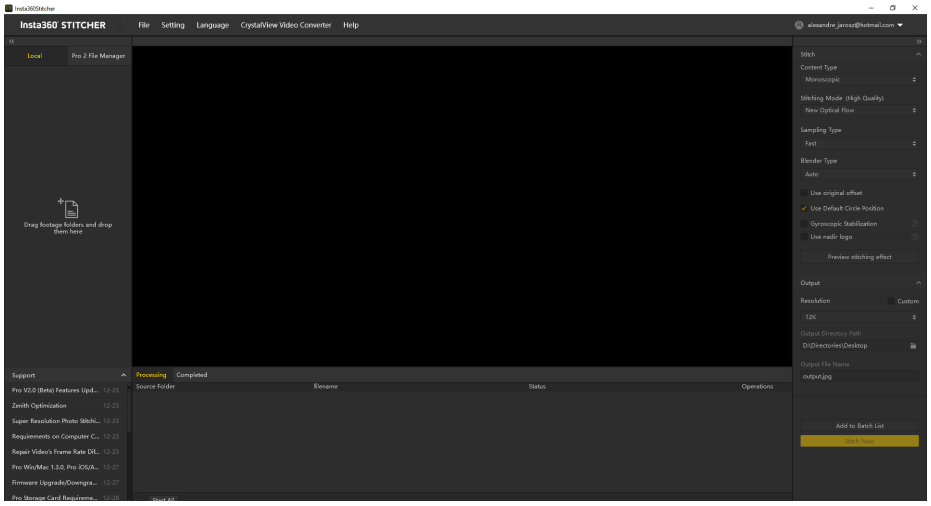

Figure 3.3: Insta360 Stitcher.

Furthermore, you can select between rapid, medium, and slow sampling, which alters your working time. Such modes can be selected based on the complexity of the files and the desired level of quality. Another option is to encode in H.264 or H.265, as well as to set the encoding speed. It also enables the creation of 360-degree films at resolutions of up to 8K (7680 by 4320 pixels). The main page of the software can be seen in the Figure 3.3. The developer includes various tutorials that teach you how to use the product step by step, as well as a plug-in for interacting with Adobe Premiere [110], which will be covered in the subtopic 3.1.6.

3.1.4 Adobe After Effects

After Effects [111], developed by Adobe Inc. [112], is a computer application software mainly used in post-production filmmaking, among other things, for numerous types of digital purposes, such as visual effects and animation in general, due to its enormous amount of tools and its adaptability in covering most needs of audiovisual production [113]. It is highly compatible with the company's other products and receives considerable changes with each new version published each year. Its internal capabilities are quite accurate, and it uses modern processing technology to give high-level tools rapidly, something it could not accomplish a few years ago. Despite this, it works remarkably well on computers that do not have the most up-to-date components, even if it takes a long time, being adaptable to a wide range of people and its level of professionalism does not frustrate users in their needs.

Despite its concentrate on effects for audiovisual productions, it expands into offering tools beyond this area and enables the community to produce plug-ins, scripts, and extensions that are quite useful in projects. The main page of the software can be seen in the Figure 3.4. The software has various tutorials scattered over the Internet that aid in the creation of new effects and has become a market reference.

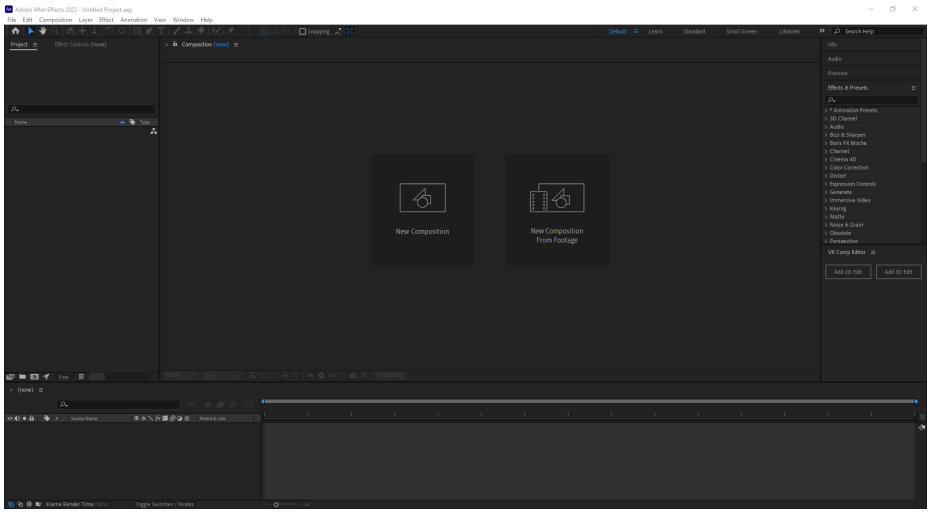

Figure 3.4: Adobe After Effects 2022.

3.1.5 Adobe Photoshop

Adobe Photoshop [114], developed by Adobe Inc. [112], which also has a mobile version known as Adobe Photoshop Express [115], is a computer application software mainly used for manipulating digital images. As a raster graphics editor, it allows the user to create and edit images with great freedom and ease in detail editing [116]. Its interaction with other Adobe products is solid, and the evolution at each annual edition is innovative, with advanced technology for its many tools being highlighted. It increasingly incorporates Artificial Intelligence (AI) for image composition, reconstruction, colouring, and effects, and it employs today's powerful computation to produce surprising outcomes.

The program's professionalism allows it to reach a wide range of audiences with a broad variety of objectives. The main page of the software can be seen in the Figure 3.5. Its popularity has created a vast global community, and there are several tutorials on how to use the software for various purposes, making it one of the most developed and preferred image editing programs for most editors.

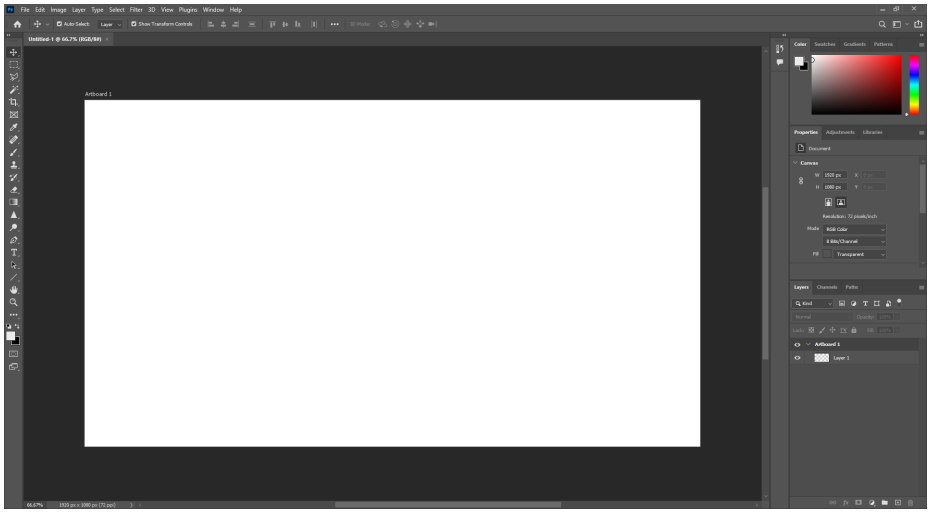

Figure 3.5: Adobe Photoshop 2022.

3.1.6 Adobe Premiere Pro

Adobe Premiere Pro [117], developed by Adobe Inc. [112], is a computer application software mainly used for video editing. It offers various tools dedicated to audiovisual editing and can provide the user with simple post-production [118]. Because it offers creative settings and effects, handling numerous video formats and qualities, the tool is extensively used by editors to generate professional content.

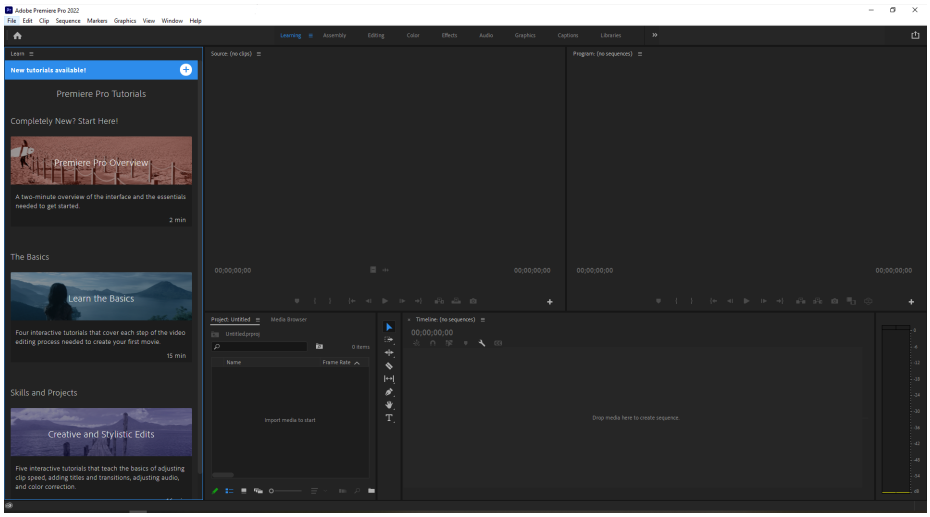

Figure 3.6: Adobe Premiere Pro 2022.

It has a wide range of applications and users, making it a market standard despite

intense competition. The main page of the software can be seen in the Figure 3.6. It is updated on an annual basis and is strongly integrated with other Adobe products, which boosts its visibility. Its community extends over the world, making tutorials, plug-ins, and new effects each time more.

3.1.7 Media Encoder

Adobe Media Encoder [119], developed by Adobe Inc. [112], is a computer application software mainly used for video and audio compression and conversion in a variety of formats. Its technology enables the rendering of audiovisual productions in an optimal and agile manner, far superior to the renderers of other Adobe products that require similar processing. As a result, it is useful for connecting with such applications and can work as an encoder on its own, making it an appealing tool. Furthermore, it can manage several videos through the use of queuing concepts, allowing users to request multiple videos for processing [120].

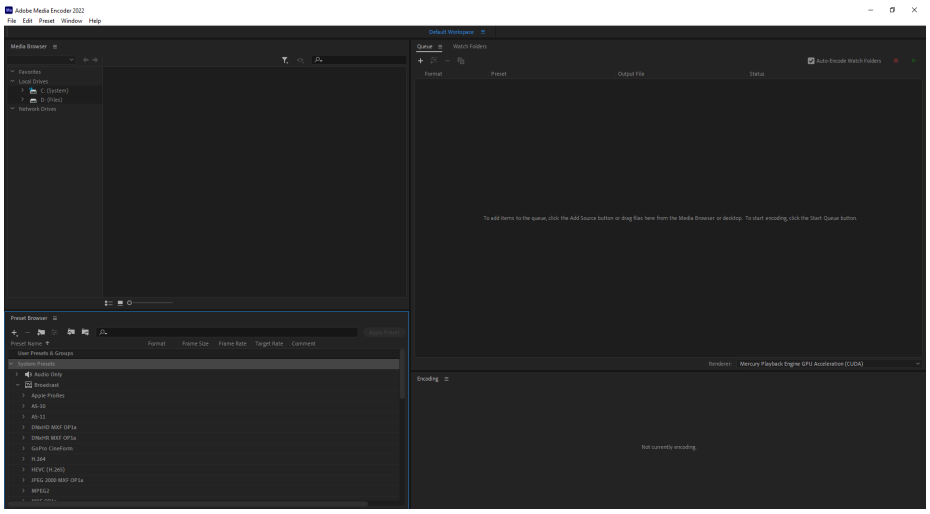

Figure 3.7: Adobe Media Encoder 2022.

In addition to these benefits, it allows the user to work in the background without interfering with editing programs, allowing the user to continue with other tasks while the software processes the content. The main page of the software can be seen in the Figure

3.7. The program is updated on an annual basis, adapting to and utilizing the benefits of modern technology to speed up processing.

3.1.8 Blender

Blender [121], developed by the nonprofit organization Blender Foundation [122], is a free and open-source computer application software used for a variety of tasks such as 3D modeling, rigging, and animation. It is a program that has been updated and highlighted over the years by the number of features, lightweight, and professionalism, becoming a reference among applications in the world of computer graphics, with support for C, C++ and Python programming languages [123].

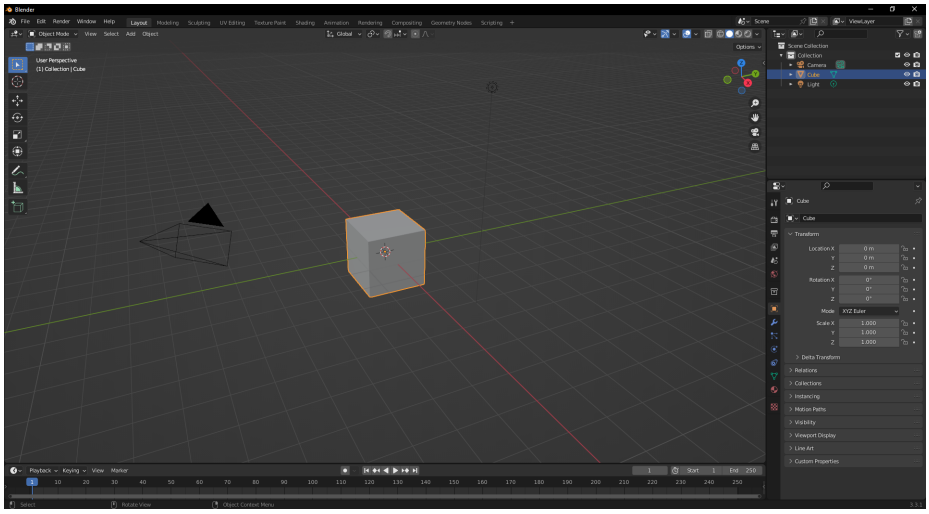

Figure 3.8: Blender 3.3.1.

Its several workspaces, each with tools dedicated to a certain goal, facilitate a simple and concise workflow, and allow for greater creative freedom. The main page of the software can be seen in the Figure 3.8. Because it is free and open-source, the software has a wide global community that develops tutorials, plug-ins, scripts, assets, and is able to achieve more complicated objectives through extensive knowledge exchange.

3.2 Hardware

Aside from the aforementioned technologies, an important aspect of the project is the employment of specialized equipment that allows for the recording, editing and watching of 360-degree videos, as described in the following subtopics.

3.2.1 Insta360 Pro Camera

Insta360 Pro [124], developed by Insta360 (also known as Arashi Vision Inc.)[109], is a professional camera that can take 360-degree photos at 60 megapixels and records 360-degree videos in 3D (stereoscopic), with quality up to 8K (7680 by 4320 pixels) and rate up to 30 Frames Per Second (FPS). It also records slow motion videos at rate up to 100 FPS, using a 5000 Milliampere-hours (mAh) battery. It has six 200-degree 2.4 Fish Eye lenses that can simultaneously capture photographs or videos. It can be connected via Wi-Fi, High-Definition Multimedia Interface (HDMI), Ethernet, or Universal Serial Bus (USB)-C.

Figure 3.9: Insta360 Pro.

The camera can be controlled by the buttons contained in the device itself or via a cell phone or computer app, called Insta360 Pro Camera Control App. Figure 3.9 [124] shows the design and positioning of the cameras on the Insta360 Pro. On their website, the developer also offers the Insta360 Pro Stitcher, which stitches the videos as mentioned in

Subsection 3.1.1, the Insta360 Pro Firmware, which ensures that the camera is updated and operational, and the Insta360 Moment CrystalView Player, which allows the user to play the videos from the camera in Crystal View format [125]. Furthermore, there is a page on the developers' website dedicated to comprehending the camera's operation [126].

3.2.2 Desktop computer

One of the most important working tools was a desktop computer with high technical specifications provided by CeDRI, which greatly aided project development. The graphics card is an NVidia Quadro RTX-4000, which has 8 gigabite of Graphics Double Data Rate (DDR) 6 Graphics Processing Unit (GPU) memory, 6 giga rays cast per second, 36 cores, and 2.304 parallel-processing cuda cores. The processor is an AMD Ryzen 7 3700X with 8 cores, 16 threads and a clock speed of 3.60 giga Hertz (Hz) without overclocking. These cards are powered by a 650 Watts bronze Urano VX power supply. It had 16 gigabite of HyperX Fury DDR4 Random-Access Memory (RAM) that ran at 3200 mega Hz. The operating system was a 64-bit version of Windows 10 Pro [127]–[131].

3.2.3 Meta Quest 2

Meta Quest 2 [132], from Meta Quest series and formerly Oculus Quest 2, developed by Meta Platforms Inc. [133], is the best-selling VR headset in history to this day and has established a market reference, as seen in Figure 3.10 (A)[132]. It has an Android-based operating system and uses an Liquid-Crystal Display (LCD) panel with Full High Definition (HD) resolution (1920 x 1832 pixels) on both lenses, with some rendering rates set by the user ranging from 60 Hz to 120 Hz, as well as the option of choosing between three Inter Pupillary Distance (IPD) levels, being a lightweight, standalone product, and having 3D sound [134], [135].

Another important characteristic is the FOV of the glasses, which is the amount of visible area inside the device, as mentioned briefly in Subsection 3.1.1. Each type of glasses has a different FOV, which also varies depending on the IPD setting and from

person to person, so this measure is defined by tests with applications within VR itself, such as the TestHMD application [136], but it always has a possible correction rate up or down, with one value for horizontal vision and another for vertical vision. For Meta Quest 2, this value is 89-degree (±4-degree) in horizontal and 93-degree (±5.1-degree) in vertical, while other sources report greater values such as 97-degree in horizontal and 93-degree in vertical [137], [138].

Quest 2 included several technologies in an innovative way, such as its four attached cameras that can analyze position and rotation (6DoF), as well as the interactive recognition of the user's hands (removing the need to utilize controllers for simple activities), which is in constantly improving. Other components include two touch controllers and two AA batteries to interact with the glasses' system, as seen in picture 3.10 (B)[132], a glasses spacer that moves a little the user's face away from the glasses, which can be useful when the user wears normal glasses, as seen in picture 3.10 (C)[132], and a charging cable and power adapter to charge the VR headset, as seen in picture 3.10 (D)[132]. Its connectivity works via Wi-Fi, bluetooth and USB-C.

Connecting the glasses to mobile devices, via the Meta Quest program (old Oculus Quest), or computers, via the still-named Oculus, is needed for additional configurations, and each of them brings distinct key configurations for the use of Quest 2 and other products from the company [139]. Aside from these connection and external configuration options, the glasses itself has a few interesting features, such as the possibility to create guardians, as shown in Figure 3.10 (E)[132], which are environment limitation markings designed by the user to avoid colliding with walls or objects in the real world while interacting with the VR world.

Another interesting feature is the possibility to cast what the user sees inside the glasses to another device, as shown in Figure 3.10 (F)[132] that transmits the content to a television, allowing other people around to understand what the Quest 2 user is experiencing, because the VR glasses can be used for much more than just games, something that entertain everyone in the environment.

Figure 3.10: (A)VR headset (B)Controllers (C)Glasses spacer (D)Charger (E)Guardian (F)Casting.

3.3 Methods

A methodology for the operation of the final 360-degree video production process was defined for the development of this work. This decision was made since it allows for a better and easier understanding of the tasks to be completed, as well as better time management until new versions of the video are ready.

The first stage of this process was the choice of the venue where the Insta360 Pro camera would be positioned, which was essential for capturing points of interest by selecting strategic positions and allowing easy viewing of the main objective. This was followed by recording at opportune moments that could be appealing to be revealed in the final video, using the Insta360 Pro Camera Control App for remote control of the Insta360 Pro, which aided in the recording of moments that occurred quickly at the moment of the events. Figure 3.11 illustrates the procedure of selecting the location (A) and recording (B) with arrows between the blocks in a way that could be done as many times as necessary until

all points of interest were recorded.

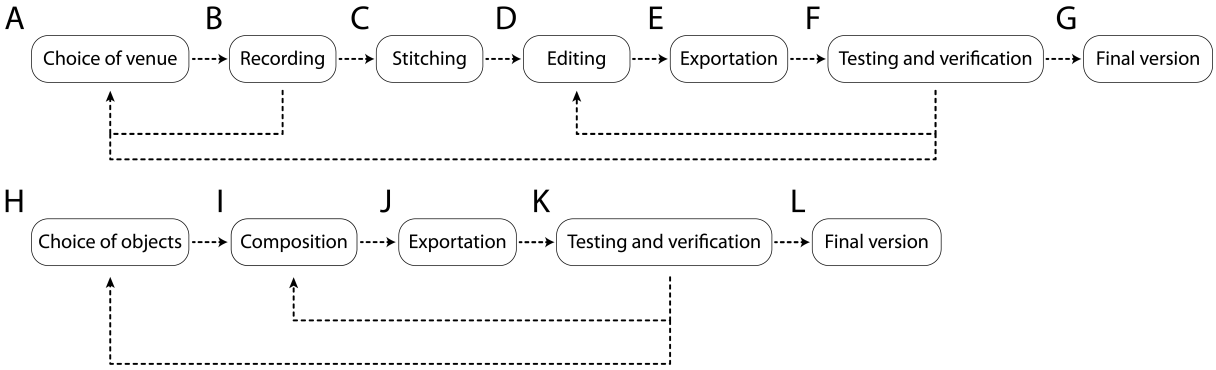

Figure 3.11: Methods.

Following the capture of these videos, it was possible to proceed to the next phase, stitching, as shown in Figure 3.11 (C). This stage joins the video recorded by the Insta360 Pro's six cameras into a single video, needing computer processing to achieve such stitching, which was done using the Insta360 Pro Stitcher application from the camera's developer. The processing time varies depending on the settings used and the weight of the recorded content, as it will be explained in more detail in the next Section.

The fourth stage, called as editing, was the most important and usually took the longest to complete, as indicated in Figure 3.11 (D). At this point, the editing software packages mentioned in the previous Chapter were employed to correct many issues that could spoil or improve the scenes. After Effects was utilized first for color adjustments, center adjustment of the 360-degree movie, lighting, cuts, and stabilization, among other elements. Many times during this procedure, Photoshop was used as an aid for more specific adjustments, such as the removal of complex items and the reconstruction of parts of the scene for some plausible purpose. The following Section will go over all of the specifics of this stage.

For each video that was edited, it was made in sequence an export procedure that was orchestrated by the Media Encoder, shown in Figure 3.11 (E). Everything that was edited is converted and encoded into video again in this step, allowing to proceed to the next step, testing and verification, as shown in Figure 3.11 (F), which is based on viewing the

entire video in search of missing details or something that went wrong during the editing process. In addition to being checked on the computer screen, the videos were sent to the glasses to see how they would appear on the device's display, mostly for lighting and coloring concerns.

Several aspects were identified in this analysis that were either overlooked or needed to be improved during the editing process, leading the 360-degree video to be returned to the editing stage several times (D). When the video was accepted and no more details needed to be altered, or more time was needed for detail, a preview of the completed video was created using the Premiere Pro software, which received all of the video and audio files. As a result, compositions that gave a direction to how the final video would proceed were produced, always analyzing if the storytelling was flowing and passed an educational tourism, which also meets the aspects (D), (E), and (F) of Figure 3.11.

Because it was sometimes necessary to record more locations or other events, there is a transition from the testing and verification process (F) to choosing the venue (A), going through the entire process again. Finally, after testing and verification of all the separate videos and version compositions of the final video, the final version of the 360-degree video was reached, illustrated in Figure 3.11 (G).

Another component of the project defined certain virtual 3D models that would be used to show real objects from Portuguese culture, going through a similar process to the video. Figure 3.11 also shows this sequence, beginning with the choice of more emblematic objects (H), progressing to scene composition (I), exporting it in the same qualities as the video (J), performing tests and verifications with the glasses to ensure a good arrangement of elements and visualization (K), and finally the final version of the 360-degree image (L). This methodology also required a return from tests to composition due to unexpected details or image enhancements, as well as the selection of items, which was modified several times throughout the process. All of the procedures in Figure 3.11 will be discussed in further detail in the following Section.

Chapter 4

Product development

For this Chapter, the product developed in the project will be detailed, being a 360-degree video that will be exhibited through VR glasses, with a focus on educational tourism in Bragança, Portugal. Along with the elaboration process of the idea from the VRSciT project, the creative process, editorial and validation testing for the elaboration of the 360-degree video, the usage of 3D models as a cultural highlight of Portugal, and the real exhibition of the produced product.

4.1 Virtual reality science tour

The VRSciT [140] project, funded by the European Education and Culture Executive Agency [141] through the Portuguese National Agency for the Erasmus+ Programme [142], focuses on developing unique virtual educational approaches by combining 3D modeling with 360-degree immersive VR environments. It aims to provide educational experiences in a variety of fields through digital media, including VR, open-source 360-degree videos and virtual materials based on real-world objects.

The project has several partners from four countries, namely the IPB and Centro Ciência Viva de Bragança representing Portugal, the educational institution Pixel and the University of Teramo from Italy, the Institution eMundus and the Museum Lithuanian Education History from Lithuania, and the University of Leon and onganization Scayle

from Spain [58], [143]–[149].

4.2 Video 360-degree

Several steps were necessary for the 360-degree video conceptualization, recording, editing, and testing, which resulted in the final video. These steps will be discussed in further detail in the Sections that follow.

4.2.1 Cultural heritage

Because the video's focus is educational tourism from Portugal's Bragança district, the first step was to identify places and events important to the region's culture that would be interesting to record in a 360-degree video, which is a new format for most people and requires care with the content (which will be better explained in Subsection 4.2.4), enabling the understanding of its history, customs, and what remains to this day as historic landmarks.

With this in mind, it was realized the fundamental relevance of the cultural past being present in modern times, leading the project to change course. It was intended to emphasize this perspective by presenting old actions and events being performed in the present. The video was then divided into two parts past and present.

For the past, the castle of Bragança, one of the most interesting places in the region, was evidenced, with people dressed in various costumes and with historical attitudes. A very important annual event for Bragança, the Caretos parade in Podence, was chosen for the portrait of the present, demonstrating and evidencing the local population's nostalgia and cultural zeal.

Bragança castle

Without a doubt, the castle of Bragança is one of the most prominent tourist destinations in the district. As a historic national monument built in the 13th century, it is one of

the most important and well-preserved castles in Portugal, as previously indicated in Subsection 2.1.2.

Nowadays, it contains a museum inside the tower and receives visitors from all around the world. Within the castle's walls are some old residences, the church of Santa Maria and the *Domus Municipalis*, as well as some stores and leisure facilities. Various cultural events are still held near to the castle tower today, therefore its current purpose perfectly reflects the ideal old zeal cultural intended to exhibit on the video.

Caretos parade in Podence

The Caretos parade, which began in the 20th century and is now held annually in Podence, is one of the most important traditional events in northern Portugal, serving as a source of local pride for being an Intangible Cultural Heritage of Humanity, as well as being well known by other people with similar cultures, and receiving a large number of admirers each year, as previously mentioned in more detail in Subsection 2.1.2.

Because of the demonstration of cultural richness by the presentation of the Caretos, it became the highlight event for the part that portrays the present, bringing a lot of color and excitement to the video, something that contrasted positively with the older tone of the first part shown in the castle.

4.2.2 Recording

The recordings were made with an Insta360 Pro camera, which was mentioned earlier in Subsection 3.2.1, and was set to record in 360-degree, 8K (7680 by 4320 pixels), and 30 FPS. As with reference [150], all videos are accessible via the YouTube playlist link.

In the Section of the video that portrays the past, which was captured in Bragança's castle, 21 videos were recorded and 8 videos remained in the final version, which can be seen in Table 4.1, along with their durations (in minutes and seconds) and direct YouTube links to the original and edited video (edited videos have a different duration than the respective original ones, as revealed in the Section 4.2.4). Furthermore, the total amount

and duration of the recorded videos, as well as the amount and duration of the videos that remained until the final video, are provided at the end of the Table.

Video name	Duration	Used in final video		Direct link	
Around the camera	1:03	Yes	0:06	Original	Edited
Going to the castle	0:56	Yes	0:06	Original	Edited
Going up the stairs[1]	1:19	Yes	0:06	Original	Edited
Rampart with birds	1:12	Yes	0:10	Original	Edited
Santa Maria Church	1:12	Yes	0:14	Original	Edited
Spitting fire at the castle[2]	0:06	Yes	0:04	Original	Edited
Time lapse[1]	0:27	Yes	0:27	Original	Edited
Top of the castle tower	1:03	Yes	0:15	Original	Edited
Among the trees	1:07	No	0:00	Original	
Back of the castle	1:00	No	0:00	Original	
Citadel viewpoint	0:46	No	0:00	Original	
Fire presentation	1:12	No	0:00	Original	
Grabbing apples	0:40	No	0:00	Original	
Rampart 2	1:49	No	0:00	Original	
Rampart 3	0:56	No	0:00	Original	
Saint Bartholomew viewpoint	1:04	No	0:00	Original	
Saint Bartholomew viewpoint 2	1:30	No	0:00	Original	
Top of the castle tower 2	1:14	No	0:00	Original	
Top of the castle tower corner	1:07	No	0:00	Original	
Welcome to Bragança	1:27	No	0:00	Original	
Within the borders	0:43	No	0:00	Original	

Videos amount used in final video	Videos amount	Recorded duration used in final video	Total recording duration
8	21	1:28	21:53

[1] Edited video is in fast motion; [2] Edited video is in slow motion

Table 4.1: Recordings in the castle.

Because the goal was to show some customs from Bragança's past, the actors who took part in the recordings wore traditional clothing and performed actions to entice the viewer. The story telling was done by the staff of Centro Ciência Viva de Bragança [143], beginning with videos that took in the castle from afar, the parts outside the castle borders, as well as the border itself, then nearby, inside, and on top of the castle tower.

The scenes were intended to attract attention to the video, so there were interactions with fire, colorful clothing, a lot of movement from the artists, and a lot of trying to get

the best angles to important places or that seemed to have a good visual harmony for some scene. For an artistic matter, the concept of time lapse was used, which is a video that was recorded for a long period of time and then accelerated to last a few seconds, with the one used in the project being recorded for one hour and then accelerated to last 27 seconds. Furthermore, fast and stop motion were used to demonstrate the video's acceleration or deceleration, respectively, for some purpose.

For the part of the video that portrays the present, made at the Caretos parade in Podence, 16 videos were recorded and 8 videos remained in the final version, which can be seen in Table 4.2, along with their durations (in minutes and seconds) and direct YouTube links to the original and edited video (edited videos have a different duration than the respective original ones, as revealed in the Section 4.2.4). Furthermore, the total amount and duration of the recorded videos, as well as the amount and duration of the videos that remained until the final video, are provided at the end of the Table.

Because of the large number of people attending the event, the camera had to be placed in strategic locations to provide an overview of what was going on, always focusing on something related to the caretos, such as the masks, the big careto, or the caretos themselves. So as many scenes as possible were recorded in order to show any interesting attitude coming from the characters. Some videos were recorded to show more locations of the event by placing the camera over the head, with the help of a tripod, passing through the crowd and stopping at points of interest. Because no stabilization equipment was available, this had to be done in post-production, as discussed in Subsection 4.2.4.

Because the caretos are already lively, have very colorful and colorful clothes, walk around with a bell that is always ringing, make a lot of confusion, and play with the people around them, they attract a lot of attention to themselves, which is essential to the focus of disclosure. The main focus was on their movements, as well as the burning of the big careto, the most expected moment of the event. Some videos used the fast motion technique to show a large amount of information without overly extending the scenes, while others used stop motion to show the effects of a fire scene (Fire next to masks).

Something that always happens in audiovisual productions is that there are a large

Video name	Duration	Used in final video		Direct link	
Beginning of the big careto burning[1,3]	4:10	Yes	0:10 + 0:08	Original	Edited
Big careto burn walking[1,3]	2:14	Yes	0:21 + 0:28	Original	Edited
Big careto burn walking 2	1:32	Yes	0:05	Original	Edited
Big careto burn walking 3	2:06	Yes	0:15	Original	Edited
Caretos walking by	1:43	Yes	0:06	Original	Edited
Fire next to big careto	2:07	Yes	0:02	Original	Edited
Fire next to masks[2]	3:11	Yes	0:05	Original	Edited
Procession[1]	1:02	Yes	0:32	Original	Edited
Big careto burning	0:46	No	0:00	Original	
Next to masks	1:40	No	0:00	Original	
Next to masks 2	0:44	No	0:00	Original	
Next to big careto	0:24	No	0:00	Original	
Waiting big careto burn	1:21	No	0:00	Original	
Waiting caretos walk by	0:55	No	0:00	Original	
Waiting caretos walk by 2	0:55	No	0:00	Original	
Waiting caretos walk by 3	0:40	No	0:00	Original	

Videos amount used in final video	Videos amount	Recorded duration used in final video	Total recording duration
8	16	2:12	25:30

[1] Edited video is in fast motion; [2] Edited video is in slow motion;
[3] Edited video used twice, at different times

Table 4.2: Recordings in Podence.

number of videos with long durations, but only a few of them and even a small portion from that recording are used. This is what happened with the project recordings, as the final video takes up 7.74% of the total time recorded. Table 4.3 provides more information on these points.

	Recorded	Used	Used videos percentage	Time	Time used	Time used percentage
Castle	21	8	38.1%	21:53	1:28	6.7%
Caretos	16	8	50%	25:30	2:12	8.63%
Total	37	16	43.24%	47:23	3:40	7.74%

Table 4.3: Recording and usage data.

Some videos were not used in the final version due to their simplicity, or because there

was some very complex editing to be done, or because there was no corrective solution (better discussed in Section 4.2.4), because there was another similar scene that would be better for the video, and also due to time, which is an important factor to consider in an audiovisual production.

The most difficult aspects of recording the videos were the scene composition and imagining how it would be edited and appear in the video. This was done to make the editing process easier rather than more difficult by telling the story coherently and showing as many details as possible. As a result, issues with lighting, sounds, and objects were regarded but could not be fully worked around, necessitating the completion of additional tasks during the editing phase.

4.2.3 Stitching

Several files are generated and saved in the camera's memory card at the end of the recording stage. These files are sent to a computer, and six video files (called "origin_Number.mp4", with Number substituted by numbers ranging from 0 to 5) are created, one for each of the six Insta360 Pro cameras.

These videos are in Two-Dimensional (2D) fisheye format and are shown horizontally, as shown in Figure 4.1. In addition, there is another file called "preview.mp4" that shows a preview of the video from all the cameras together, in low quality and few FPS, and is also the file used for mobile phone app verification of the recorded video, as well as another file called "gyro.dat", which contains information for gyro management, and "pro.prj", which contains information from the recording project and is needed for the next step called stitching. The only files with sound are "origin_0" and "origin_1", meaning that the preview lacks this aspect.

This phase requires the use of the software Insta360 Pro Stitcher, which is used to combine the videos recorded by each of the six cameras into one 360-degree, 30 FPS in 8K (7680 by 4320 pixels) video. The folder containing the aforementioned files is imported into the program that permits stitching settings to be made. All of the recording files

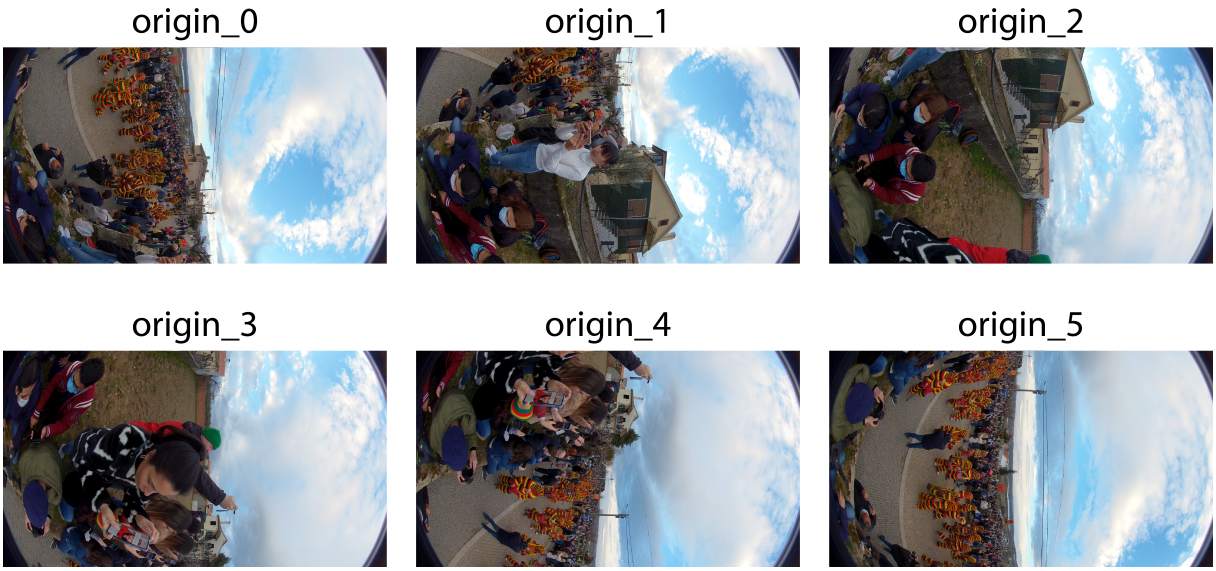

Figure 4.1: Insta360 Pro's distinct cameras.

were processed at the greatest quality available, with Blender Type Cuda, the option to use the GPU for processing, and Codec Type h264. After processing all of the files, the videos could be watched on the computer and within the VR glasses, and the editing process could begin.

4.2.4 Videos editing

After an analysis to determine which videos would be the most fascinating to utilize in the project, the editing process began, with the goal of refining each video independently in numerous aspects in order to construct a new sequence of storytelling. Adobe After Effects [111] was used to manage this stage, allowing control over lighting, coloring, object removal, scene reconstruction, stabilization, and bug correction, among other things that will be discussed in the next Subsections. For each video, a composition of the same dimensions as the video was built, measuring 7680 by 3840 pixels and set to 30 FPS. When creating such a composition in After Effects, it was possible to use the VR tools.

Environment setting

360-degree videos are typically very heavy, and most computers would struggle to render the video inside an editing software quickly, so it would have to process a long time every time you need to preview the video inside After Effects, making the editing process super difficult. The use of proxies, which are the videos themselves rendered in low quality (also rendered with Adobe Media Encoder), is a great way to approach the problem because the preview is only in a small part of the screen, so the videos run normally and the original content is exported, in other words, the proxies only serve to assist in the editing process.

To facilitate the editing of the 360-degree videos, the VR Comp Editor tool was used, which allows for two types of editing, 2D and 3D. The 2D edition is based on the creation of an additional composition to treat the VR videos in 2D rather than 360-degree, which enables for much easier editing due to the distortion that 360-degree videos have to be placed in a 360-degree environment. The 3D editing tool was used for stabilization edits, and it will be discussed in greater detail in Subsection 4.2.4.

Despite the greater ease with editing in 2D videos, it was discovered during the process that such a transformation was not always required. Because only the top and bottom edges of the 360-degree video are distorted, edits in the middle of the video could be done in 360-degree, reducing the number of new compositions to be created in the software.

Because it is a 2D portion of the video, a size for such editing is defined, which in this case was Full HD (1920 by 1080 pixels). As a result, it is required to identify a region of the video to be modified, and once defined, it must not be changed because if altering it, after scene editions, it would cause all modifications to be moved to the new specified 2D area. This enabled to deal with specific parts of the scene, especially with objects removal.

Objects removal

Despite all the planning for the recording and the scenery, it is always possible that an unexpected situation will arise, that an unwanted object will go unnoticed, or that something physical in the scene will be immovable. As a result, digital editing has advanced to the point where it can alter the scene in a variety of ways. Many objects, such as the camera tripod, were considered undesirable in the video. Although it is possible for the viewer to understand how the scene was filmed, this can serve as a distraction in their experience and make the video appear less professional. The scenes filmed in the castle represented the past, where there would be no modern objects such as cars, people dressed in modern clothing, traffic signs, and so on, mischaracterizing and disconnecting the viewer from the purpose of the scene in the history. Unwanted objects in the Podence carnival scenes with the caretos included the camera tripod itself, shadows cast by the camera and tripod, and dirt on the streets, among other things.

Because of all of these details, a method to remove them digitally was investigated, and it had to be ensured that such changes would go unnoticed by the viewer. Content-Aware Fill is a tool introduced recently by Adobe in its products that is based on identifying elements close to the object selected as undesirable and removing them from the scene. What actually happens is that to remove an object from the scene, an image is created that simulates how it would be if the object were not in that location, as if it were a patch, and this image only covers the area of the object by using editing layers, in other words, the video would be in the lower layer and the image (replicated many times in the same amount of FPS as the video, becoming the concept of video) would be in the upper layer, overlaying the undesirable object. As a result, it is possible to recreate a portion of the scene, tricking the viewer into thinking the edited scene was the real one.

Although Content-Aware Fill has fine accuracy, it requires a lot of processing because it analyzes the video frame by frame around the selected undesired object, which takes a long time, but the tool still does not have a high accuracy for complex cases, making partially correct replacements, which was not useful due to the need for imperceptible

changes in the video. Using the Create Reference Frame option may help the tool produce a better result. This command exports the video frame to Photoshop, allowing it to create a reference frame with its most powerful tools before returning to After Effects. However, Content-Aware Fill did not perform very well and took too long for the video, making such a solution unfeasible.

Nonetheless, it was discovered that selecting the option to create a reference frame would generate an image from Photoshop, where the patch could be edited in greater detail and overlaid on the video without the use of Content-Aware Fill. The patches are created by copying nearby points that are similar to the reconstruction location, if done with the help of the AI to adjust lighting and coloring, which does not always work perfectly, necessitating additional adjustments with other Photoshop tools. As a result, despite some adjustments that will be discussed in Subsection **??**, all of the edits of removing objects and recomposing the scene became feasible, easier, and faster to complete.

Figure 4.2: (A)Original (B)Patches (C)Edited.

Figure 4.2 (A) shows the original recorded scenes, selecting the area that contains the unwanted objects, which can be generated an overlay image simulating the scene without such objects using Photoshop's Spot Healing and Healing Brush Tool, the scene patches (B), generating a new image, without such objects and imperceptible modification (C). Many different objects were removed from the scenes, among them a metal structure, airplane smoke trails, cars, lampposts, people, signs, sunlight spots, the camera tripod, traffic signs, trash cans, and other objects.

Although the removal and scene reconstruction tools are very advanced because they

use AI and have a high degree of accuracy, it is necessary to exercise severe caution so that the result is reliable and does not cause visual strangeness. Some images will be shown in the following Subsections and will have more object removals, but all images, original and edited, will be available in the Shared folder, [151].

Videos adjustments

Regardless of how high the quality of the video footage is and how visually appealing the majority of it is, a camera rarely captures the correct colors and lighting of the environment. To avoid this, it is possible to control them digitally in order to intensify and correct details that add beauty and prominence to the work. Important visualization settings such as lighting, contrast, and coloring must be corrected to accomplish this.

These corrections were made using two effects, CC Color Offset and Lumetri Color. CC Color Offset allows to edit the image's colors by setting intensity values for the colors red, green, and blue, as well as how the colors will blend in the video. Lumetri Color provides essential settings such as temperature, exposure, contrast, highlights, shadows, whites, blacks, and saturation, as well as the ability to edit the colors red, green, and blue through curves, or set the predominant color for highlights, midtones, or shadows in the video, among other things.

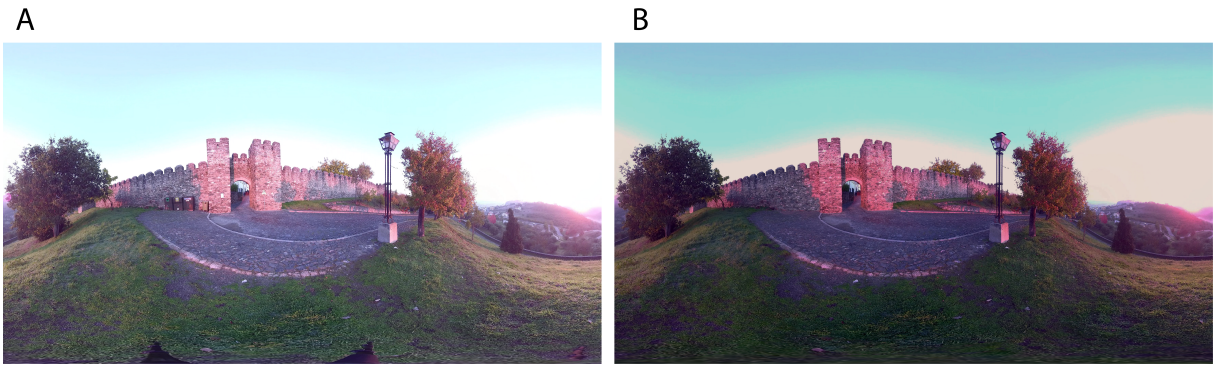

Figure 4.3: (A)Normal (B)Adjusted.

Figure 4.3 demonstrates one of these editions, which considers not only the coloring to highlight the sky, but also the lighting control to avoid areas that are too dark or bright,

making the scene more cinematic, understandable, and appealing to the viewer. Figure 4.3 (A) portrays the scene without editing and (B) shows it after editing, being the video of the time lapse recording, with the right parameter adjustments controlling the beginning that was too dark and the end that was too bright. All of these settings were defined for each video and tested on both the computer and the VR glasses. Some scenes were recorded without proper camera settings, resulting in parts of the video around the sun being completely white and losing information. This spoils the video a bit, and although readjusted, it is not in an excellent result.

Patches adjustments

Although the patch configuration is imperceptible, as discussed in Subsection 4.2.4, the idea is not to recognize and adapt to each frame of the video, which means that if it happens in the scene, it can reveal the patch, distinguishing it from what is around it. Figure 4.4 shows two cases that explain such information, where in (A) a person is walking in the original video while there is a patch on top, which is noticed due to the disappearance of his body, while in the second part, there is a difference in lighting in the scene due to the fire, revealing the patch removing an object. The first part is the original video (B), which had a patch (F), generating (C), but as mentioned, the scene can change color and lighting, necessitating a patch readjustment. In this case, the scene has a period where there is no fire, causing the scene to darken, and the patch does not match with the new image (D), necessitating the creation of a new patch (G) to properly form (E).

Although it is possible to replace the patch, it is impractical due to the high number of FPS and also because the patch must remain consistent over time and not allow new objects to appear or disappear. To accomplish this, the patch can be subjected to the previously mentioned lighting and coloring configurations. This allows you to define changes to the video timeline by using key frames, which are points on the timeline with configuration settings that can be connected by smooth transitions, allowing the lighting and coloring of the patch to vary gradually. This allows to set up key points in the

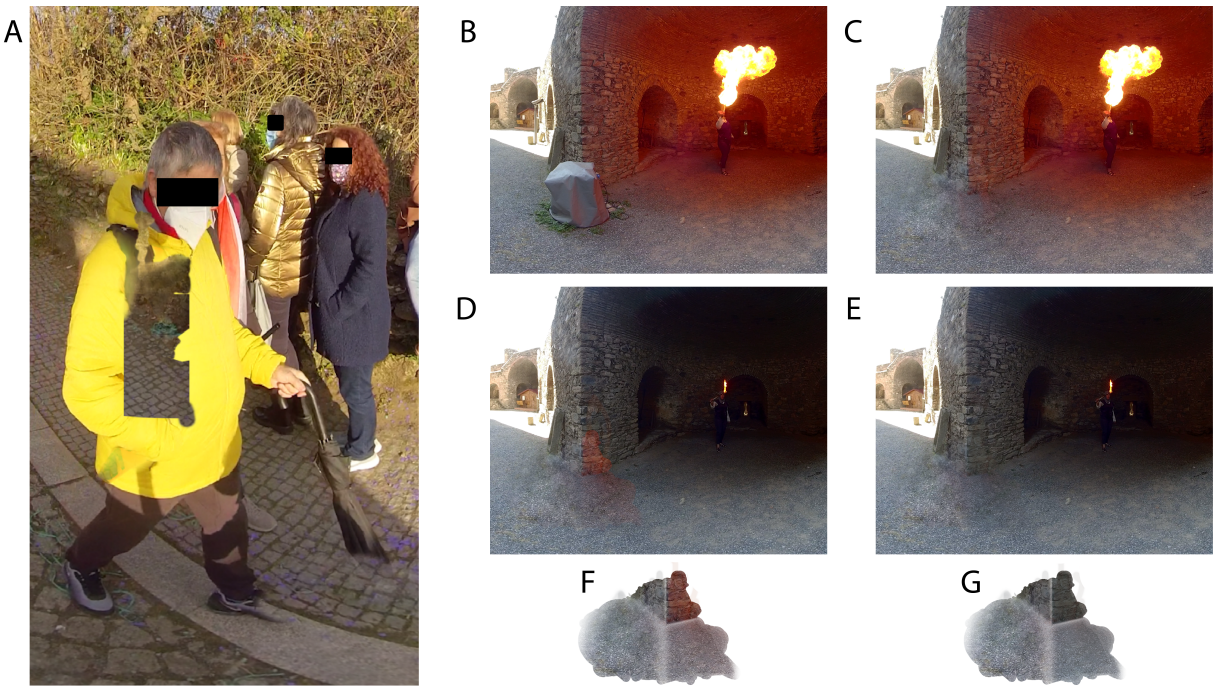

Figure 4.4: (A)Patch overlapping (B)Original (C)Patch (D)Wrong patch (E)Adjusted patch (F)First patch (F)Corrected patch.

scene, such as parts (C) and (E) of Figure 4.4, and adjust the transition between them to coincide with the presence and absence of fire.

Because the patch may be on multiple environments at the same time, they may require different lighting, coloring, and transition times in each Section. The patch is divided into four parts in Figure 4.4, with the wall and floor being the exteriors and the same internally an environment. Each behaves differently, especially when there is fire, and the internal areas are more altered, while the exterior remains slightly altered.

Scene reconstruction

Although the removal of small objects is already a complex scene reconstruction, it may not be so arduous based on where it is located, if there are many details to be reconstructed. However, when the object occupies a large area in the scene, the reconstruction process becomes extremely difficult because you need areas of the video that are similar to what you want to reconstruct. Nonetheless, material from the internet can be used as

a basis, but it must match what is in the original scene, which is always used as the basis for the reconstruction.

Because of the large number of elements to remove, one of the most difficult and challenging scenes was shot on top of the tower of the Bragança castle. However, a large green metallic structure was in evidence, which significantly hampered the scene portraying the past.. The scene is significant because of the castle's location. This was an exciting challenge because it would be a complex task that would take a significant amount of time to complete. Although tools and software are becoming more robust, particularly with the assistance of AI, for the editors it still takes a significant amount of time to make such edits go unnoticed, given the vast amount of detail to be redone.

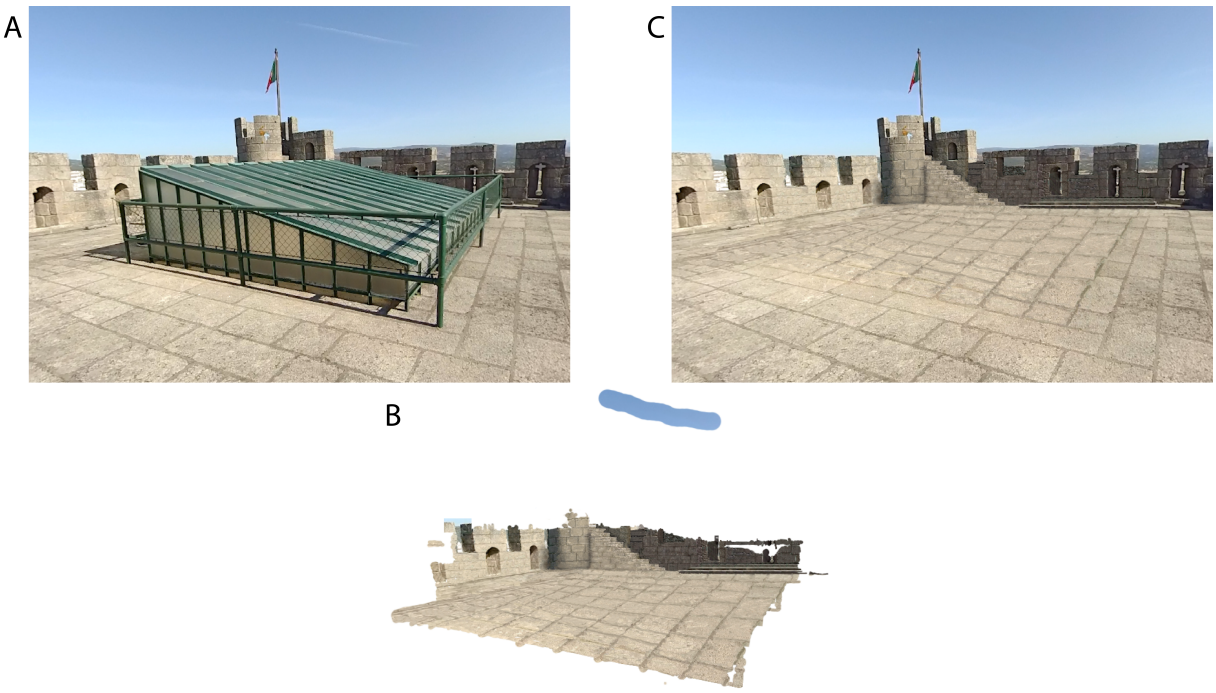

Figure 4.5: (A)Original tower (B)Patch (C)Edited tower.

Figure 4.5 demonstrates such a castle location, displaying the original scene with the green metallic structure (A), the large patch for scene reconstruction (B), and how the two appeared when overlaid (C). Although many people may not notice such a change, a significant difficulty was encountered in replicating the perspective of the scene, as it

applies differently in each part of the scene due to the position of the camera, the lines of the objects and the ground. The reconstruction had a very interesting level of result, but it was not possible to go further due to time constraints and a lack of knowledge of tools that could further facilitate the process, leaving a good level of realism but not going unnoticed by people with good perception of details.

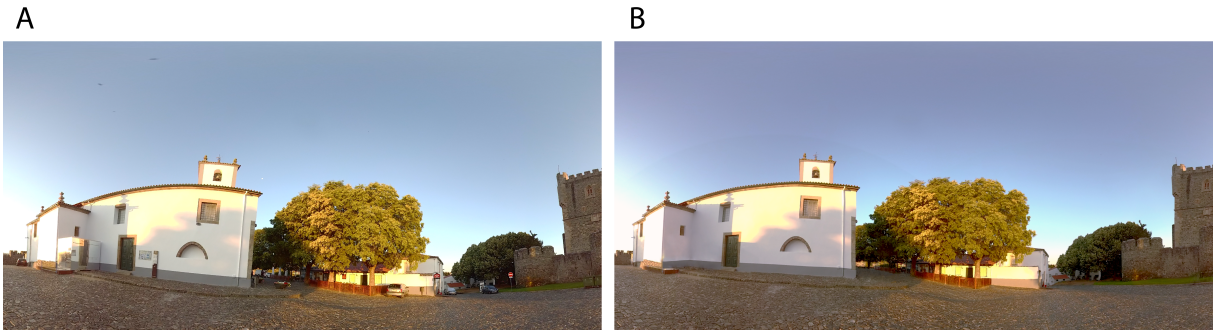

Figure 4.6: (A)Santa Maria church original (B)Santa Maria church edited.

However, it is possible to produce much more interesting results that even people with high detail perception may miss, such as the Figure 4.6, which removes several objects from the scene to place it in the past, without cars or traffic signs.

Motion sickness

A very common concern that has to be mentioned in the use of VR devices is the high possibility of the spectator experiencing motion sickness, which is nausea caused by the movement of the head and eyes in another reality, and the brain many times cannot understand such difference, even if the person is aware that he is using a VR device. This is an extremely important factor to consider in any VR production, as it is necessary to adapt each content to ensure the comfort of the spectator.

People can normally wear VR glasses for 15 to 30 minutes without feeling nauseated or tired. The video's production took this into account with a short duration, caring with fast movements on the screen, fast transitions or with many effects, and camera movement, which can cause a lot of discomfort because the person is physically still but moving in VR, usually making the viewer progressively nauseous.

Stabilization

Knowing this, it is important to note that the video's frenetic movement would cause great discomfort in the viewer, causing them to feel sick and stop watching the video. Some videos were shaky because the camera was raised above the head using a tripod without any stabilization tools, necessitating a digital solution.

This was accomplished with the Comp Editor tool, as mentioned earlier in Subsection 4.2.4, and the Add 3D Edit option, which enables new advanced video settings based on the three-dimensional position simulated by After Effects. By selecting such a 3D edit, a new 2D composition with a size of 1920 by 1080 pixels is created, and a new option in the Comp Editor tool that allows new commands appears. One of these is the ability to use 3D camera tracking, which creates a virtual camera for the scene, as well as the track scene option, which maps the entire scene and perceives equal points in the scene in each frame of the video, identifying the camera's movement by the displacement of these points.

Scene tracking necessitates a significant amount of processing and time, which varies depending on the amount of FPS, video quality, duration, and effects. It took between 5 and 10 hours to complete the stabilization each video for the project. After that, in the same menu, you can apply stabilize footage, which will generate some files that control the 3D camera created, moving it in such a way to compensate for the movement made by the real camera, leaving the video with little movement and stabilizing it.

Despite this, some edits are hampered by video stabilization. The tool generates several 2D compositions and performs a display simulation, implying that stabilization occurs only in the rendering, which must be at high settings for good quality stabilization. When this does not occur well, the stabilization process must be restarted. Despite the fact that it required many tests to determine the best setting, took a long time to process, and frequently did not deliver what was expected, it was very useful and saved the shaking videos, becoming one of the most important tools for editing videos. You can compare the videos in the YouTube playlist link [150], where the original files come after the edited

ones.

Making-of

Despite the large amount of information provided, it is highly difficult to convey all of the technical and artistic information of a video. To confront this difficulty, a making-of video will be released, demonstrating the editing of each video in greater detail, demonstrating the montage of the scenes with patches and scene reconstructions, lighting changes, coloring, stabilization, and other important details. This content will be available on the YouTube playlist link [150] as well.

4.2.5 Videos exportation

Following the editing procedure, the editable files must be converted back to video files. For this, Adobe's Media Encoder software was used, which speeds up the export process when compared to older Adobe After Effects renderers.

Initially, the videos were not exported in the highest quality available because they appeared to be of good quality. When viewed through the VR glasses, the video appeared pixelated. Because of this characteristic, the most prevalent critique in the first round of tests was that the video definition quality was low and it was unable to view details in the video, as discussed in more depth in Chapter 5, Usability Evaluation.

Several tests were performed, and it was discovered that the issue was in the content's export phase. These tests revealed that the best settings for the videos in Media Encoder would be to check "Render at Maximum Depth" and "Use Maximum Render Quality", set the Bitrate encoding settings to "VBR, 1 pass", leave the Target Bitrate at the maximum possible, which is 60, and finally set the Quality field to "Highest (slowest)". Also, the default settings would be to mark the "Video is VR" option with a monoscopic frame layout and the output format with the codec "HEVC (H.265)", because this codec reduces the weight of the ".mp4" files and facilitates viewing and further editing of the videos, but some video players do not support it.

Such a setting significantly increased the rendering processing time, resulting in videos lasting between 8 and 9 hours to render. This is due to the large pixel count of an 8K video (7680 by 4320 pixels) at 30 FPS. Taking into account the desktop computer setups given in Subsection 3.2.2, it is clear that this type of content necessitates a high level of computing processing.

The GPU utilized has considerable processing capacity and stands out among the existing ones on the market, but new graphic cards are being launched that can outperform the one used in the project, thus these cards may be employed in future projects for better editing and rendering of the content.

The majority of the videos were exported without sound, because this was subistituted by songs. The "Careto burning" video, one of the videos of the parade in Podence, was exported with sound since it is the ending of the video and it was intended to exhibit the feeling at the start of burning a huge Careto, mainly due to the usage of fireworks. The audio was configured with AAC format and codec, with 48000 Hz, Stereo channels, and a bitrate of 320. After this phase, the videos could be watched on both the computer and the VR glasses, allowing for some testing to find potential improvements.

4.2.6 Videos testing

A series of tests were performed on each video to determine its suitability for inclusion in the new composition. The main details were to analyze the lighting of the scene, ensuring total visibility and not having too light parts, coloration, identifying points that could be highlighted or if they had become strange to the natural, object removals or reconstruction of the scenery, checking if such change had become unperceivable and if it was matching with the environment, motion sickness, checking if there was anything that caused motion sickness while watching, and image quality, ensuring that the export was correctly done.

Although all of the above things appear to be valid, there is always the risk that watching a video will make you feel uncomfortable. This is frequently when some change has been made, and while it appears real, it produces an uneasy feeling of unreality.

This is referred to as the Uncanny Valley [152]. In such circumstances, attempts have been made to work around any oddities, either by correcting a badly placed object or by readjusting the wrong illumination. In this sense, while the technique is frequently correct, the sensation that comes easily to the human eye is considerably more valuable. If this weirdness bothers the viewer in a 2D video on a PC, it intensifies significantly in VR with 3D videos or environments, and should always be considered.

After all of these aspects were double-checked and examined by a few different people, the videos would go to the next stage of constructing an idealization version of the final video, even without all of the meticulous changes.

4.2.7 Audios editing

One of the most important aspects of a video, after its visual component, is its audio aspect. Sounds and music create an atmosphere and must be completely connected to what the video is trying to convey, changing the rhythm of what is seen in harmony with what is heard. Although it was considered to include narration and subtitles in the video, it was realized that it would be far more interesting to include music from Bragança's culture, demonstrating the region's rich cultural music. It was also considered using narration and subtitles in addition to the songs, but this would reduce the immersiveness of the experience and lengthen the video. Finally, the information from the video will be available in the VR application, as noted in Section 4.4.

Two songs were licensed for this purpose from their respective composers. The first is "Minha Mãe Mandou-Me à Fonte e Jota" by Las Çarandas [153], [154], a song that makes an impression with its style and harmonious rhythm with scenes portraying life near the castle in ancient times. The second is "Nós Tenemos Muitos Nabos" by Galandum Galundaina [155]–[157], a more agitated song that blended well with the rhythm of the caretos and the carnival of Podence. Both songs were used in accordance with the video's expectations, defining its rhythm, storytelling, and feelings.

Because the video is 3 minutes and 40 seconds long, with the portrait of the past

lasting 1 minute and 28 seconds and the second part lasting 2 minutes and 12 seconds, certain parts of each song had to be cut and connected to create a smooth transition between them, as well as the visual issue. To achieve this, audio fade transitions were used, where one fades gradually and the other appears gradually, resulting in a smooth transition. Some parts of the music were connected to other parts at the intersection of a similar melody, which went unnoticed after many tests and checks of the rhythm of the music beats. Two sounds were also added to the final version of the video, the sound of fire, to emphasize the effect and sensation of fire, and the sound of birds, to place the viewer in areas where there were many birds flying. These sounds were kept low in order to blend in with the background.

4.2.8 Compositions editing and exporting

Even though the separate videos were not in their most enhanced form after the edits and tests, they were compiled to create a composition that resembled the final composition. Because it is a different experience than watching each video on its own, this also serves as testing for the final product. Furthermore, it is common for videos to go through changes designed for the final video, primarily to guide the storytelling down a desired path.

However, with each version, it is stipulated to improve in some aspect, to verify if the specified characteristics are fulfilled, and to conduct experience tests, usually with an idea of how the final product will be and how the final target audience will behave with that content. Such a task is complex, and it is necessary to watch the video several times in order to consider all of the possible details of the video in order to avoid something undesirable going unnoticed, as well as the viewing of several people to increase the agility and accuracy of bringing the product closer to the focus objective.

Following this, the project went through a series of tests and modifications with the goal of getting the most out of both the story telling and the equipment used. This implies that the versions were critical for artistic and technical testing. To that end, eleven versions were created, with the final one serving as the work's final product. Table

4.4 contains the name, duration, format, and direct link for each version of composition, and such videos can also be viewed via the YouTube playlist link, [150].

Video name	Duration	Format	Direct link
Sequence v1	2:54	2D	Link
Sequence v2	2:26	2D	Link
Sequence v3	1:30	360-degree	Link
Sequence v4	2:06	360-degree	Link
Sequence v5	3:33	360-degree	Link
Sequence v6	3:41	360-degree	Link
Sequence v7	3:36	360-degree	Link
Sequence v8	5:01	360-degree	Link
Sequence v9	5:01	360-degree	Link
Sequence v10	4:01	360-degree	Link
Final Sequence	3:40	360-degree	Link

Table 4.4: Compositions.

As mentioned, each version had a specific goal, with version one focusing on discovering what could be edited in a 360-degree video, realizing that it was possible to control rotations, insert subtitles anywhere, as well as movement, rotation, zoom, color, sound, and so on. Version two already included one of the project's songs, which would define the rhythm of future editions due to the ambiance and care with the emotions through sound and video, as well as aiding in the selection of which videos to include and in what order. This version also included the second song and the time lapse. Both versions were in 2D because they were easier to understand, but the subsequent ones were in 360-degree to better learn how to make composition edits, as it is very different from watching a 2D video.

Sequence three begins the tests in 360-degrees, defining an important concerns of defining the center of the video, leaving the main focus of the scene always in the same position of the video (better explained in Subsection 4.2.4), in addition to bringing writing on the screen, music, video acceleration, and tests of all existing transition effects, this to watch in the glasses and comprehend which transition would be the most appropriate.

Version four marked a significant milestone in the realization of more complex edits in 360-degree videos. This is due to the achievement of removing the garbage collectors and

traffic signs from the time lapse scene. It was considered the beginning of editing studies when it was discovered that such editing was possible and still worked in such a way that no difference could be detected. This sequence also introduces the video's entrance with a fade style transition, which is the smooth appearance of the scene by increasing opacity, also known as fade-in. It was also determined what the video transition would be, which was a slight cross fade based on a scene disappearing while the next one appears, in addition to bringing improvements in sound control, increasing or decreasing at opportune moments, and the overall volume not to be too high or low, with the VR glasses as the final analysis. These videos were shown to the other project participants for internal evaluation.

The scenes for sequence five had already been recorded with the caretos at the Podence carnival, which provided tests in the transition from the past to the future, something that did not seem to convey the idea for such a version. It also included song adaptations to ensure a smooth transition that did not distract the viewer's attention. Some scenes were sped up to make the video flow better. It was also crucial for the analysis of scenes that required extensive editing, such as digital stabilization, and the decision to end the video with the same transition as the beginning, but to gradually disappear the scene by decreasing the opacity, also known as fade-out. Versions six and seven concentrated on updating the scene sequence in order to make the storytelling more harmonious, and the latter used the concept of slow motion for the first time.

Version eight was one of the most significant because the most complex edits began, including the removal of objects, scene reconstruction, editing the colors of the video to make them more vivid, cinematographic, and to show how the experience was lived at the time, as well as taking care of brightness, shadows, contrast, and other settings that are better explained in Subsection 4.2.4. It was decided to begin such complex edits, but not those with a high level of difficulty. Another major edition was to begin testing the stabilization of scenes that were shaking due to the camera being held by hand, which had a great result immediately but was improved later. For the first time, 3D objects were placed at the end of the video, allowing viewers to imagine how they would look and

contribute to a more robust product. Also, this was the first version tested with people outside the development team, which greatly aided the subsequent versions, as discussed in greater detail in Chapter 5.

Version nine focused on organizing the composition, improving the aforementioned video settings, and removing more objects. Version ten was a test of the final video, determining which details should or should not be changed, one of which was the video transition, which was still not to our liking and appeared on a regular basis. Because the previous composition had many scenes and a long running time, tests on the progress of the video were performed in order to present it more quickly. It also included removing new objects. The next Subsection will discuss version eleven.

Although the separate videos were edited in Adobe After Effects and exported using Adobe Media Encoder, the sequences were produced using only Adobe Premiere Pro. With Premiere, the junction of the videos was edited, as well as changing the center of the scene, inserting music and sounds, putting transitions, and even exporting, because they are lighter files and Premiere's renderer develops a fast and effective work, as discussed in more detail in Subsection 4.2.4.

4.2.9 Final version

Sequence eleven, the final one made and named Final sequence, exposed in Table 4.4, was the version that defined which scenes would remain or not in the final product exhibition, commented in Section 4.4, as well as the decision of doing or not doing the more complex edits, commented in Subsection 4.2.4, and defined the best transition between scenes, being the same previously used, but without many brightness effects, only remaining a simple cross fade when slowly fading-out with a scene and appearing the next one.

Aside from scene transitions, the most important transition was that of storytelling, which divided past and present and conveyed such idea to the viewer. This occurred with the use of the spitting fire scenes, when the "Spitting fire at the castle" scene ended and transitioned to the "Fire next to masks" scene at the Podence carnival. By changing the

environment from the old castle to the modern city, the costumes, and the music, such a transition managed to convey the idea of a change in time and the preservation of cultural attitudes.

Music became a good complement, defining the difference from something slower and calmer, despite a slight acceleration at the end of the videos in the castle with the song "Minha Mãe Mandou-Me à Fonte e Jota" by Las Çarandas [153], [154], showing some fun, to something more agitated with the caretos, with the song "Nós Tenemos Muitos Nabos" by Galandum Galundaina [155]–[157], something that is commented on further in Subsection 4.2.7. Although it was possible to put explanations about the video's moments with narration and subtitles, lowering the music at certain points and increasing it after an explanation, this would break the rhythm of the songs and break the viewer's immersion, so it was decided to only keep the songs and their explanations in the VR application.

Some scenes were cut due to poor recording, overly complex edits, or the need for extensive editing time, which was not possible due to the finalization dates. This resulted in the video being cut by a few seconds, which was not viewed negatively given the need for a dynamic video.

Edits chosen to be made involved correcting videos that were distorted in perspective, causing the viewer to watch a distorted video when they turn their head, fixing bugs due to the stitching of the videos, which cannot redo the scene with complete certainty, reconstructing a large part of the scene, requiring great attention to detail and perspective, and so on, making the version the most complete, best edited and best composed. Each video will be discussed separately in Subsection 4.2.4.

A VRSciT project meeting occurred shortly before the final version of the video was produced, bringing some interesting features. As a result of the future development of a VR application that would unite all partners' videos and make it easier to apply 3D information and models, the 3D objects were removed from the video, as they were only an image, as discussed in Section 4.3. It was previously thought that instead of using an image, an application should be developed, but this was not the current focus of development. This allowed the video to focus solely on audiovisual entertainment,

whereas the application will include interactions with objects in various scenarios, which can be seen in Section 4.4.

4.2.10 Future editing and producing

Despite the significant difference between the final version and the initial version, which has been edited and improved in many ways, the possibilities for additional editing are limitless. Editors have a common understanding that there is always something to improve, so they choose a point of satisfaction with the product that determines its completion.

Nonetheless, the video could be improved by editing the more complex scenes, experimenting with different tools to achieve new results, and utilizing future technologies to evolve the project in novel ways. As suggested in the video testing survey, new recordings could be made in other locations, covering more of Bragança's culture. As a result, if feasible, the project could evolve in a variety of ways.

In addition, a making-of video will be produced in sequence, displaying the edited details in a demo video, making it easier to see what the details of each scene were. This video will be accessible through the YouTube playlist link [150].

4.3 3D models

To complement video and the dissemination of Portuguese culture, it was proposed to use 3D objects that were representative for the country. This is due to the complementary delivery of historical and cultural characteristics, which uses the reach of VR to provide a compelling and immersive experience. Several models were considered and listed, but they needed to be tested to see how they would look on the glasses. Figure 4.7 (A) depicts the arrangement of the elements in a 360-degree image, which was used in versions 8 to 10, but was removed in the final version because these objects will appear in the VR application containing the video, as shown in Section 4.4. This image has seven 3D elements in a circle that were created to surround the video's viewer, and the scene was

created in Blender [121] and exported in 8K (7680 by 4320 pixels) with its renderer called Cycles, which took approximately eight hours.

Figure 4.7: (A)360-degree image (B)Careto and mask (C)3D objects (D)Bragança castle pillory.

In addition, an entire 3D careto, as well as a separate model of its mask, are thought to be shown, as shown in Figure 4.7 (B), provided by Casa do Careto [158]. This part of the Figure has a slightly different mask because there are more places with a similar culture to the caretos, each with its own customization, material, and dress style, all of which would be excellent evidence of cultural richness.

The VRSciT project brought together several 3D objects for study of the art, and each partner created their cultural models. Figure 4.7 (C) demonstrates some of these developed models from Portugal's team, and the majority of them were also used to compose part (A). These elements can be viewed and downloaded from the VRSciT website or from Sketchfav page of CeDRI, being the majory of the models made by the Silk House, which is from Centro Ciência Viva de Bragança, a project partner [143], [159]–[161].

Figure 4.7 (D) shows a photograph of the pillory of Bragança, which was built in the

13th century next to the castle. It is a medieval monument carved in granite [162] and is one of the objects in the modeling process that will be included in the final version of the project's VR application, and such models are typically modeled and textured in Blender [121]. Although there are other pillories in Bragança, its location next to the castle makes it stand out and is more likely for tourists to see it.

4.4 Final product

After all of the project partners have finished recording, editing, testing, arriving at the final definitive video, and modeling their 3D objects, it will all be combined into one VR application. The environment's goal is to facilitate the viewing of content from all countries by integrating all of the key elements in one location, enabling the immersive and fun interaction that VR can provide, in English and in the native language of all partners, which are Italian, Lithuanian, Portuguese, and Spanish. This application is currently in development and is conducted by byAR company.

4.4.1 ByAR

byAR [163] creates digital environments in Augmented Reality (AR), as well as other technologies like VR and real-life scenarios, to provide experiences in both realities, typically for museums and tourist attractions, among others. The company works with digital content in 2D, 3D, and 360-degree, along with other formats, for a variety of systems and devices, including AR and VR glasses, which fit properly with the project's overall purpose.

Figure 4.8 demonstrates prototype screenshots of the VR application, where part (A) depicts how its menu would look, with options to view 360-degree videos of all partners as well as learn more about their cultures. Part (B) exemplifies how the configuration of the virtual game would be inside the application, which is another form of entertainment in addition to the others mentioned. The 3D models, such as the careto and its mask, could be used to reinforce objects and stories from the countries' cultures.

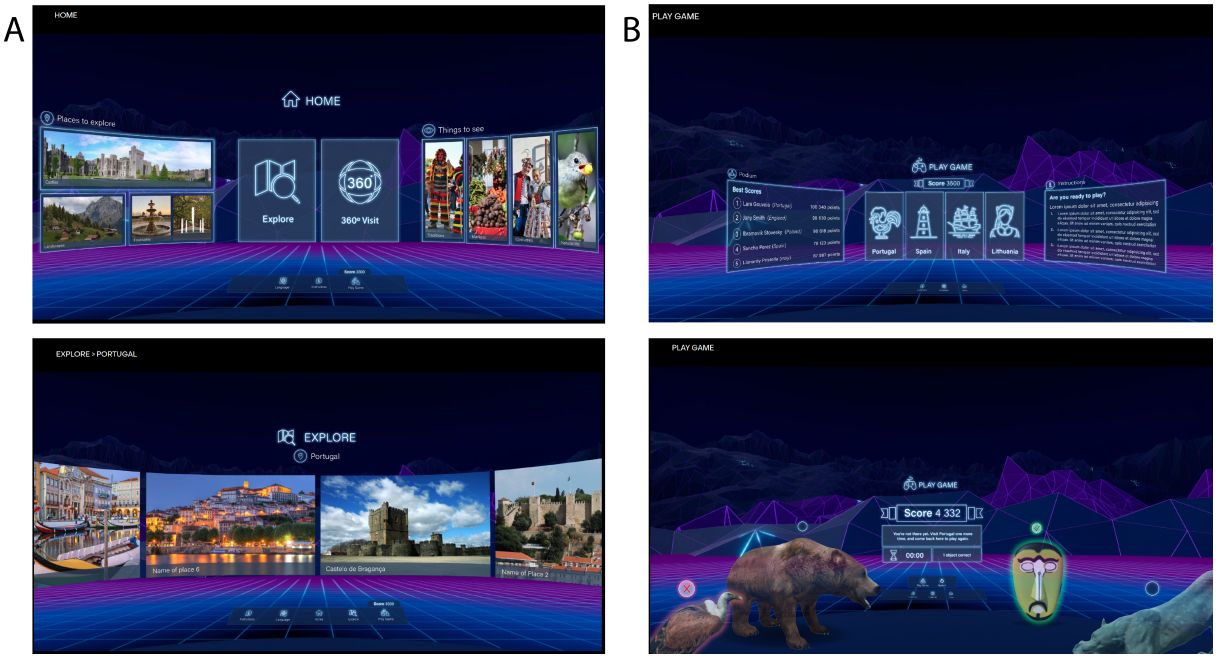

Figure 4.8: (A)Menus (B)Game.

4.4.2 Real environment in Portugal

As previously stated, the company offers the development of real-world scenarios to supplement the virtual experience. For Portugal it was prototyped an environment in the shape of an igloo with colors themed to the caretos, which can be seen in Figure 4.9 (A). Internally it would contain some glasses that would be hung on the top of the environment and masks would be attached in front of them, giving the idea that the viewer was wearing such cultural masks (B), which would generate many photos and fun.

The module would include the area with the VR glasses and a touch screen that would allow the visualization of the application externally, seen in part (C) of Figure 4.9, together with the other elements of the prototype, which is primarily aimed at people who are uncomforTable or unable to use the glasses, as well as something that would facilitate the visualization while there are many people in the environment. As the colors of Podence's caretos are very eye-catching, the physical module would also stand out, inviting visitors to experience all the elements developed. These modules will be placed in the Centro Ciência Viva de Bragança [143], which the inauguration is scheduled February

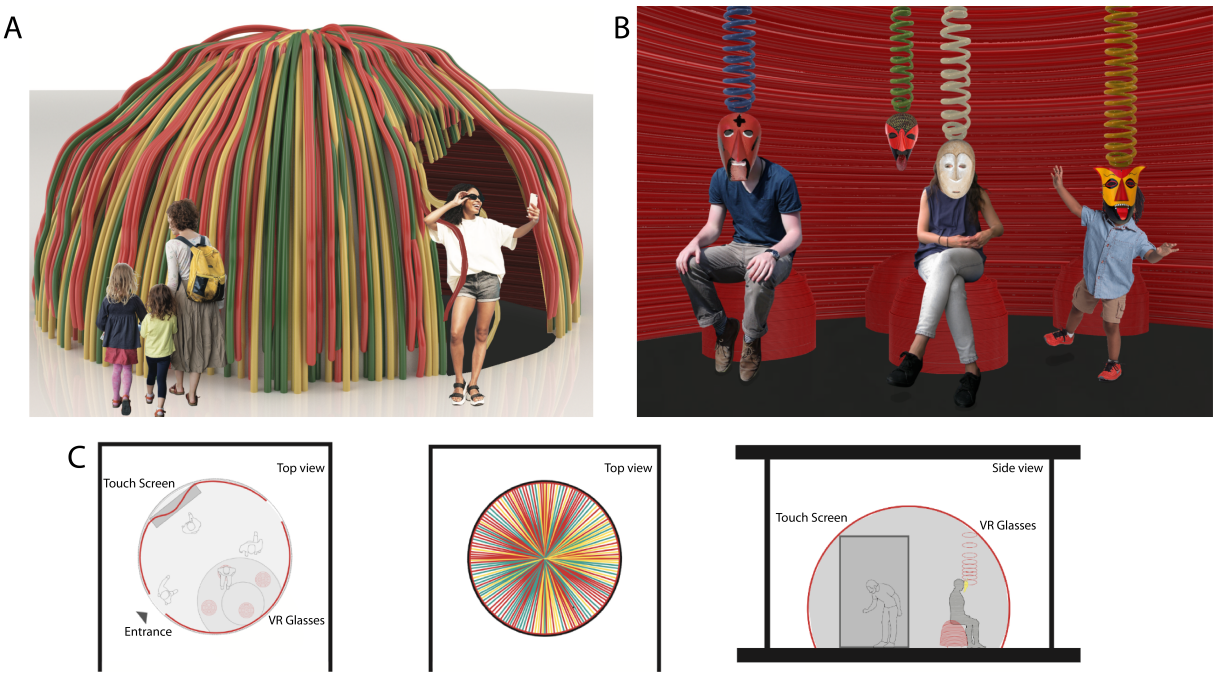

Figure 4.9: (A)Environment (B)Masks (C)Prototype.

2023.

Chapter 5

Usability evaluation

As previously said, 10 versions were produced before reaching the final composition, which was the most progressed in terms of quality, effects, storytelling, and sounds. To get to this stage, however, a series of tests and changes were required, causing the project to evolve in many parts throughout its development.

Internal tests performed by the developers and project team members were briefly remarked on in Subsection 4.2.6. However, multiple opinions, of various ages and experiences, were required so that the project had higher robustness and recognized the demands of numerous people, trying to discover a better adaptation for the true target audience, being diverse people of diverse nationalities, cultures, ages, and experiences. Several tests were carried out on the IPB campus, which has many international students, and at Silk House, a technological museum in Bragança that welcomes visitors from all over the world.

Then, in version 8, the first tests with people outside the project were conducted to see how they would react, and each person was invited to complete a questionnaire with simple questions about their experience. These specifics will be covered in greater depth in the next Sections.

5.1 First validation

The project was first explained to each individual in order for them to comprehend the goal of educational tourism and the promotion of the region of Bragança, Portugal. This explanation was required so that people may understand how the project works and prepare for the experience of taking an immersive tour using VR glasses, as well as perceive details more easily in order to offer the best evaluation and aid in the survey.

After explaining the concept, the person would put on the VR glasses and begin seeing the video in 360-degree. If necessary, the participant was requested to turn their head to any side in order to observe multiple . People were encouraged to remain sat during the experiment, even though it was not strictly necessary, because there was no requirement for body movement. Typically, the chair rotated, which aided the ease of the video viewer.

At the end of the video we reminded the person to be as truthful as possible when filling out the survey, highlighting the vital need for data collecting that may lead to an improvement in the video. To promote understanding, it was stated that the viewer of the video might express things he liked or disliked, make recommendations on technical improvements, and explain what they would like to be included in the video, either on audiovisual production concerns or on the progress of the storytelling.

5.1.1 Survey

To obtain feedback on the VR experience, each participant was given a link to an online form with questions divided into five Sections: one for questions about the 360-degree video, another for questions about the 3D models, another for questions about the integration of VR with tourism, and the final one for general comments or suggestions.

The total number of participants who watched the video presentation and completed the survey was 40, with 21 men and 19 women. Five were under the age of 16, fifteen were between the ages of 16 and 25, eight were between the ages of 26 and 35, eleven were between the ages of 36 and 50, and one was over 50. Their nationalities included one Armenian, sixteen Brazilians, one Congolese, nine Spanish, eleven Portuguese, one

Czech, and one Tunisian. According to the survey, 31 of them had prior VR experience, while 9 had not.

When asked what they liked about the video, many people said they liked the music, the images, the immersiveness, the Bragantina and Portuguese culture, representations in an old style (like small theaters), and seeing the carnival with the Caretos for the first time. There were also interesting comments such as liking the feeling of being at the event or in another time, the composition of the scenes, the smooth transitions between the videos, and making contact with a 360-degree video.

When asked what they didn't like, several responses included some transitions being a little fast, feeling uncomfortable when using the VR glasses together with a normal one, wanting a more informative video about what is being exhibited, the speed of certain parts in the video, not liking the scenes in which the camera is higher (feeling of flying, even being a little weak because of being seated on a chair), few scenarios shown, the music, the simplicity with which the 3D models are presented, some scenes being dark, seeing the big Careto in flames, no needs of bodily movement and remain without the ability to move within the video, and a certain discomfort in using the VR glasses. It was also noted that the video has no the depth caracteristic, which could decategorize it as VR, which will be discussed further in Section 5.2.

Furthermore, the main complaint was that the video was pixelated and difficult to see some details. This was due to the low quality of the video export, which was discovered after some testing. Once the cause of the problem was identified, it was resolved by increasing the export settings to their maximum, as previously discussed in Subsection 4.2.5.

A big interest was in the feeling that the VR experience would provide for each participant, Table X displays the amount of people who reported having each feeling, either good or bad.

These data indicate that people are very curious and excited about VR, and it is interesting to note that when using such technology, one experiences happiness, surprise, and even tranquillity in some cases. This allows us to conclude that the experience of

Good feelings				
Curiosity	**Excitement**	**Happiness**	**Surprise**	**Tranquility**
32	19	11	21	20

Bad feelings						
Anxiety	**Claustrophobia**	**Fear**	**Irritation**	**Motion sickness**	**Rage**	**Sadness**
2	0	1	0	4	0	0

Table 5.1: Feeling experience.

using VR in tourism has produced positive results. On the other hand, there are negative feelings when having the experience, which must be analyzed for improvement not only in the composition of 360-degree videos, but also in the use of VR as a form of entertainment.

Despite the low number of participants who had negative feelings, it is important to remember that too much information or too fast movement on the screen can cause motion sickness, which is frequently felt due to a lack of cerebral habit of moving the head inside a VR, or for other reasons. Some participants may have experienced anxiety as a result of the video's excitement or the sensation of wearing the glasses, while others may have experienced fear as a result of the high altitude in some recordings.

For questions related to the VR experience, Table 5.2 will show the question and the number of answers for each, ranging from 1 to 5, where 1 is an unsatisfactory experience level and 5 is a great one.

Question	**1**	**2**	**3**	**4**	**5**
Comfort watching the video	0	0	2	9	29
Storytelling quality	1	0	3	22	14
Story immersiveness	0	1	5	19	15
Video quality	0	2	7	14	17
Sound quality	0	0	5	9	26
Effectiveness combining VR and tourism	0	1	3	12	24
Amusement combining VR and tourism	0	2	4	12	22

Table 5.2: Experience level.

According to the data gathered, the vast majority of people enjoyed the audiovisual production and the combination of educational tourism promotion using VR. Although some data show that certain issues were disliked by participants, this is useful information

for the project's development because it is still in the early stages and it is necessary to understand what needs to be improved. Furthermore, there were several points that were thought to be changed, which were reinforced by the answers obtained, indicating that the tests were fruitful.

There were also questions about the 3D models, which are shown in Table 5.3, but they were more about whether the participants were excited about visualizing and interacting with such models (moving, rotating, moving specific parts of each model as in real life, and so on, as well as seeing animations on the objects.

Question	Yes	Maybe	No
Is it interesting to see 3D models of the country's culture?	36	4	0
Is it interesting to see animated 3D objects?	37	3	0
Is it interesting to interact with 3D objects?	38	2	0

Table 5.3: 3D models interaction.

The data shows that the integration of 3D objects, with or without animation, and with or without interaction, captivates the participants' interest. This is excellent information, since it is possible to fully explore the great possibilities that VR provides, including the ability to integrate multiple types of art into a single content focus, which allows for greater artistic freedom. This also implies that VR can be explored in a variety of areas, with interaction with other technologies, and will be well accepted by the vast majority of the public, implying a high future investment potential and greater applicability.

For the answers "Maybe", it was identified a certain indecision in some participants since they could not imagine how the application of 3D models would look like, or because they did not realize if this would improve the delivery of information or the storytelling. This is also a positive idea, since there is a need to show this technology and its capabilities to more people. Due to the lack of response denying the use of 3D objects and potential additional features, their implementation became more meaningful.

In addition to these issues, when asked if they had any suggestions or complaints for something that could have been done, demonstrated, or explained differently, the answers were positive regarding a complete and creative work, as well as suggestions to

show more of the vast wealth of local culture, not just focusing on the castle and the carnival of Podence, while others asked for more scenes from different angles, or to show more 3D objects from other regions of Portugal, along with more explanations about each object, as well as showing where the video's focus is, because they frequently want to look around the scene and lose focus on the video's predominant target. This is in addition to previously mentioned issues, such as the video quality problem, which was the most important feature to be resolved.

During the tests, one feature that was noticed was the use of fade transitions, which are based on the progressive increase or decrease of the opacity of what is being viewed, which in the case of the video was sometimes used with the total darkening of the screen, leaving it black, and smoothly reappearing and transitioning to the next scene. Typically, the participants thought the video had ended. Also, the Oculus Quest 2, the VR glasses used in the project, would occasionally display the video playback menu because it assumed the video was over, requiring it to be closed using the buttons on the controls. Since most people don't understand how to close or that the menu isn't supposed to be displaying, they would watch the video normally and miss several details, sabotaging the project, so the fade transition was removed.

All of the previously mentioned information provided valuable learning as well as several new possibilities for the project's future. Without a doubt, the interaction with the target audience was the best experience for the developers and the project itself, which sought to meet the majority of the characteristics informed by the participants, which will be approached further in Subsection 5.1.2, Product enhencement.

Since the Portuguese people who were born and lived their entire lives in the Bragança region participated, several questions, curiosities, and historical stories about the region were discovered. Because their perspective on the experience is much more detailed, this added a much more intense aspect to the project. Nonetheless, the other participants who did not belong to this group, also brought diverse perspectives of their own and expressed great interest in the project's evolution. Although the survey documents the answers

already directed to a better understanding of the current work and expands the possibilities for future updates, the best feedback was given voluntarily by participants who made a point of detailing their thoughts, which was received in an extremely gratifying and enthusiastic manner, defining this phase as the most interesting of all.

It is clear that telling a people's story requires a great deal of respect and care, being the spokesperson for their culture provided the project with far more than academic or professional challenges and results. Having said that, the following Section will discuss the steps taken to improve the video, followed by more details about the final version and the project's difficulties.

5.1.2 Product enhencement

Following the stage of testing and verification with people outside the development group, an analysis was made of what would be feasible or not to be given focus, knowing that such decisions would affect the overall outcome of the project. To that end, each response, particularly the constructive "negative" ones, was carefully considered and discussed by the team throughout the remaining development.

The questions about comfort, feelings, level of immersion, what they liked and disliked, quality of the story, video, and sound provided improvements in editing, as well as suggestions to the other project partners, along with presenting such perspectives to the team that will continue the project, as commented in Subsection 4.4.

The edits focused on better volume control and music changes, improved transitions, the removal of missing objects, stabilization, the speed of certain videos, and the resolution quality of all videos, as well as the story, which was focused on a better transition from the past to the present, and the story was covered more in Subsections 4.2.4 and 5.1.1. For videos that would wish to be redone or enhanced, the concerns of deadlines, events, and participants to make this happen, no possibility was found to record again or replace the videos that caused some discomfort, or that could be better in some aspects, but it is something that is likely to happen in a continuation of the project.

Regarding video-related suggestions, consideration was given to improving the explanations of what was happening in. Although the decision to use music made it impossible to use narration, together with the respective subtitles, the project determined to fill this gap in the VR application that will contain the video, as discussed in Section 4.4. Despite the removal of the 3D objects in the final version of the video, this was also moved to the VR application, which will bring in more details and with more interactions, animations, and sounds, as well as a VR game with these models, which was approached more thoroughly in the Subsection **??** and Sections 4.3 and 4.4. Concerning the effectiveness and enjoyment of combining VR and tourism, it was essential to recognize the positive feedback to the point of investing more time in actions that had the intended outcomes.

5.2 Difficulties encountered

The majority of the work went perfectly, but there were a few hitches that were either difficult to work around or had no solutions discovered. When wearing the VR glasses, some scenes appeared distorted, when the spectator turned his head, the scene appeared sideways, changing its perspective. We were able to solve one scene using Photoshop's perspective reorientation tools because there were no moving people, but we couldn't solve the others. Another dilemma was the difficulty in conducting tests with the glasses. This was due to the need to take the glasses to people to watch them, because most people do not have the device, or to be used in places where many people pass, which made testing difficult. Because there were 40 people answering the questionnaire, this caused some fatigue and took a long time.

Furthermore, the time spent developing the idea and designing the edits slowed the project's progress, as did the lengthy processing time required for each video. Another issue was the late realization that the videos had not been recorded with the camera depth option. Because of this issue, the videos are entirely in 360-degree, but not in VR, due to the lack of depth.

Finally, the most intriguing issue was the inability to change the video's FOV. While

changing the zoom (FOV) of videos in a video player is very common, it was discovered that this setting cannot be changed when editing to 360-degree. Several attempts have been made to work around the problem, but none have been successful, and there are no commented solutions on the internet. It appears that changing the FOV, which is a device-to-device setting, is not possible. A previously unexplored solution would be to use the Unity software, a game development engine among other systems, to create a 360-degree video player that changes the FOV in real time inside the glasses, transforming it from a video to a VR application. This experiment will be tested later to avoid this problem.

Chapter 6

Conclusions

Despite its long history, virtual reality is still in its early years as a great technology. It still requires significant investment and research, but it has a high potential to be highlighted as a digital and social device, and it may become the new way for societies to communicate in the coming decades. Tourism suffered significantly during the pandemic years, but quickly restructured itself in innovative ways. Integration with virtual reality has demonstrated that it can make tourism and education even more accessible.

This work allowed for research in a developing area, as VR is a technology in ascension with numerous possibilities and applications to be explored. Tourism is a developed industry, but it shows signs of being improved and explored further. The combination of the two areas allows for the creation of several interesting contents, such as the focus of the work in a 360-degree audiovisual production, which presented several challenges and proved to be highly appealing to the target audience. 3D modeling integrates and complements all of these technologies, serving as an artistic form with significant entertainment value.

Many of the technologies tested have performed admirably and are highly marketable. With each new ambitious project, the immersiveness of VR provides new experiences. Nonetheless, several challenges persist, including the need for high processing and storage for 360-degree audiovisual productions, motion sickness within the virtual world, and the need for complex configurations, among others. However, it was stunning how effectively

the test participants reacted to the project's intent, becoming involved and voluntarily suggesting ideas for the project's future.

There has been a strong desire for 3D models, as well as their eye-catching animations and interactions, to be used to supplement VR and educational tourism. People are naturally curious about such technologies and want to learn more about them. The tests also revealed a lot of positive emotions, making people happy, excited, and more interested in the information. However, feelings of fear and motion sickness were also present, indicating the need for further VR evolution.

Such analysis leads us to believe that the entire development process has been very beneficial and that it can achieve even better results with continued and growing popularization. The need to adapt to the technological environment is becoming more important as it allows for social interaction, work, leisure, and a variety of experiences. VR is revolutionizing tourism, and studies show that it will only grow in the future. This encourages investors, and the technologies are becoming more widely available, boosting the market.

The range of possibilities for these interactions is very broad, video editing can overcome human perception levels and transform current scenarios into old ones, allowing for more works with the same idea and opening the door for others to join in. Although content production and editing are complete, the project can always find new ways to renew itself, reaching even further, increasing the amount of information passed, tourist spots to visit, and diversifications of educational tourism immersive and fun for everyone.

Bibliography

[1] A. C. de Souza Vieira Marilene Ferreira Machado Lima, *Do nomadismo ao sedentarismo*, https://sme.goiania.go.gov.br/conexaoescola/ensino_fundamental/do-nomadismo-ao-sedentarismo/, 2022.

[2] Wikipedia, *Nomadismo*, https://pt.wikipedia.org/wiki/Nomadismo, 2021.

[3] E. de Freitas, *Transformação no espaço geográfico*, https://mundoeducacao.uol.com.br/geografia/transformacao-no-espaco-geografico.htm, 2022.

[4] História, *Turismo: Como começou o turismo na história?* https://canalhistoria.pt/blogue/turismo-como-comecou-o-turismo-na-historia/, 2020.

[5] T. Olimpia, *O que é migração?* https://brasilescola.uol.com.br/o-que-e/geografia/o-que-e-migracao.htm, 2022.

[6] T. G. Šnajdar, *History of travelling: How people started to travel*, https://culturetourist.com/cultural-tourism/history-of-travelling-how-people-started-to-travel/, 2020.

[7] R. Onomics, *How did people travel in the past*, https://realonomics.net/how-did-people-travel-in-the-past/, 2022.

[8] Wikipedia, *History of transport*, https://en.wikipedia.org/wiki/History_of_transport, 2022.

[9] N. Jayapalan, *An Introduction to Tourism*. Atlantic Publishers & Dist, 2001.

[10] UNWTO, *Unwto*, https://www.unwto.org/, 2022.

[11] W. T. Organization, *Glossary of tourism terms*, https://www.unwto.org/glossary-tourism-terms, 2022.

[12] U. Gyr, "The history of tourism: Structures on the path to modernity," *Deutsche Nationalbibliothek*, 2010.

[13] Wikipedia, *Thomas cook*, https://en.wikipedia.org/wiki/Thomas_Cook, 2022.

[14] T. Cook, *Thomas cook company*, https://www.thomascook.com/, 2022.

[15] Wikipedia, *Cook's travellers handbooks*, https://en.wikipedia.org/wiki/Cook%27s_Travellers_Handbooks, 2022.

[16] R. Purwaningsih, F. Agusti, S. N. W. Pranomo, A. Susanty, and B. Purwanggono, "Assessment sustainable tourism: A literature review composite indicator," vol. 202, EDP Sciences, Nov. 2020. DOI: 10.1051/e3sconf/202020203001.

[17] T. Bausch, T. Schröder, V. Tauber, and B. Lane, "Sustainable tourism: The elephant in the room," *Sustainability (Switzerland)*, vol. 13, 15 Aug. 2021, ISSN: 20711050. DOI: 10.3390/su13158376.

[18] W. T. Organization, *Sustainable development*, https://www.unwto.org/sustainable-development, 2022.

[19] UNESCO, *Unesco*, https://www.unesco.org/en, 2022.

[20] ——, *World heritage*, https://whc.unesco.org/en/about, 2022.

[21] ——, *World heritage list*, https://whc.unesco.org/en/list, 2022.

[22] Wikipedia, *Heritage tourism*, https://en.wikipedia.org/wiki/Heritage_tourism, 2022.

[23] eTravel, *What is heritage (historical) tourism?* https://www.etravel.com/explore/travel-industry/what-is-heritage-tourism/, 2022.

[24] O. L. Dictionaries, *Phenomenon*, https://www.oxfordlearnersdictionaries.com/definition/english/phenomenon?q=phenomenon, 2022.

[25] A. Bitušíková, "Cultural heritage as a means of heritage tourism development," *Muzeologia a Kulturne Dedicstvo*, vol. 9, pp. 81–95, 1 2021, ISSN: 24539759. DOI: 10.46284/mkd.2021.9.1.5.

[26] UNWTO, *International tourism consolidates strong recovery amidst growing challenges*, https://www.unwto.org/news/international-tourism-consolidates-strong-recovery-admidst-growing-challenges, 2022.

[27] WTTC, *Wttc*, https://wttc.org/, 2022.

[28] ——, *Travel tourism could grow to $8.6 trillion in 2022, says wttc*, https://wttc.org/News-Article/Travel-and-Tourism-could-grow-to-8-point-6-trillion-USD-in-2022-say-WTTC, 2022.

[29] Statista, *Statista*, hhttps://www.statista.com/, 2022.

[30] F. Richter, *International travel tipped to bounce back in 2022*, https://www.statista.com/chart/21793/international-tourist-arrivals-worldwide/, 2022.

[31] Statista, *Tourism recovery gains momentum as restrictions ease and confidence returns*, https://www.unwto.org/news/tourism-recovery-gains-momentum-as-restrictions-ease-and-confidence-returns, 2022.

[32] ——, *2020: Worst year in tourism history with 1 billion fewer international arrivals*, https://www.unwto.org/news/2020-worst-year-in-tourism-history-with-1-billion-fewer-international-arrivals, 2021.

[33] UNWTO, *International tourism and covid-19*, https://www.unwto.org/tourism-data/international-tourism-and-covid-19, 2021.

[34] ——, *The first global dashboard for tourism insights*, https://www.unwto.org/tourism-data/unwto-tourism-dashboard, 2021.

[35] O. Economics, *Oxford economics*, https://www.oxfordeconomics.com/, 2022.

[36] E. T. Commission, *European travel commission*, https://etc-corporate.org/, 2022.

[37] T. Economics, *European tourism - trends prospects*, https://resources.oxfordeconomics.com/etc-european-tourism-trends-and-prospects, 2022.

[38] E. Union, *European union*, https://european-union.europa.eu/index_en, 2022.

[39] ——, *Attitudes of europeans towards tourism*, https://europa.eu/eurobarometer/surveys/detail/2283, 2022.

[40] ——, *Nextgenerationeu*, https://europa.eu/next-generation-eu/index_en, 2022.

[41] CNN, *Cnn*, https://edition.cnn.com/travel, 2022.

[42] C. Travel, *Travel to portugal during covid-19: What you need to know before you go*, https://edition.cnn.com/travel/article/portugal-travel-covid-19/index.html, 2022.

[43] I. N. de Estatística, *Instituto nacional de estatística*, https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main, 2022.

[44] ——, *Tourism statistics 2021: Recovery of tourist activity, but still below 2019 levels*, https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main, 2022.

[45] E. Commission, *European commission*, https://ec.europa.eu/info/index_en, 2022.

[46] ——, *Economic forecast for portugal*, https://economy-finance.ec.europa.eu/economic-surveillance-eu-economies/portugal/economic-forecast-portugal_en, 2022.

[47] ——, *Portugal's travel tourism could surpass pre-pandemic levels in 2023*, https://wttc.org/news-article/portugals-travel-and-tourism-could-surpass-pre-pandemic-levels-in-2023, 2022.

[48] OECD, *Oecd*, https://www.oecd.org/portugal/, 2022.

[49] ——, *Economic forecast summary (june 2022)*, https://www.oecd.org/economy/portugal-economic-snapshot/, 2022.

[50] T. Economics, *Trading economics*, https://tradingeconomics.com/, 2022.

[51] ——, *Portugal tourism revenues*, https://tradingeconomics.com/portugal/tourism-revenues, 2022.

[52] P. Resident, *Portugal resident*, https://www.portugalresident.com/, 2022.

[53] N. Donn, *Portugal resident*, https://www.portugalresident.com/brussels-bullish-over-portugals-2022-gdp-growth/, 2022.

[54] G. T. Portugal, *Go to portugal*, https://gotoportugal.eu/en/things-to-do-in-portugal//, 2022.

[55] P. UNESCO, *Portugal unesco*, https://whc.unesco.org/en/statesparties/pt/, 2022.

[56] Wikipedia, *Bragança (portugal)*, https://pt.wikipedia.org/wiki/Bragan%C3%A7a_(Portugal), 2022.

[57] ——, *Lista de património edificado no distrito de bragança*, https://pt.wikipedia.org/wiki/Lista_de_patrim%C3%B3nio_edificado_no_distrito_de_Bragan%C3%A7a#Bragan%C3%A7a, 2020.

[58] I. P. de Bragança, *Instituto politécnico de bragança*, https://ipb.pt, 2022.

[59] C. M. de Bragança, *A afirmação de bragança como ecocidade e smart city*, https://www.cm-braganca.pt/pages/832, 2021.

[60] ——, *Bragança saudável - percursos pedestres*, https://www.cm-braganca.pt/servicos-e-informacoes/desporto-e-juventude/braganca-saudavel-percursos-pedestres, 2021.

[61] ——, *Bragança desafia as famílias portuguesas a (re)descobrir a liberdade | bragança. naturalmente!* https://www.cm-braganca.pt/servicos-e-informacoes/noticias/noticia/braganca-desafia-as-familias-portuguesas-a-re-descobrir-a-liberdade-braganca-naturalmente, 2021.

[62] ——, *Bragança acolhe reunião do "rurban link"*, https://www.cm-braganca.pt/servicos-e-informacoes/noticias/noticia/braganca-acolhe-reuniao-do-rurban-link, 2021.

[63] C. Martins, A. R. R. Prada, E. Mendes, *et al.*, *Acessibilidade e Inclusão na Arte e no Património - "Cultura para todos Bragança": reflexões preliminares sobre a avaliação de acessibilidade de espaços culturais - Encontro Acessibilidade e Inclusão na Arte e no Património: livro de resumos.* 2022, pp. 40–43, ISBN: 9789898944665.

[64] F. A. Pança, "Bragança avaliação dos benefícios ambientais de soluções baseadas na natureza com o software i-tree-o caso da zona industrial de bragança-portugal," 2022.

[65] A. R. F. L. Pinto, "Gestão de resíduos urbanos versus economia circular: O contributo da resíduos do nordeste, eim, s.a," 2021.

[66] Wikipedia, *Castelo de bragança*, https://pt.wikipedia.org/wiki/Castelo_de_Bragan%C3%A7a, 2022.

[67] V. Portugal, *Museu militar / castelo de bragança*, https://www.visitportugal.com/pt-pt/content/museu-militar-castelo-de-braganca, 2022.

[68] S. de Informação para o Patrimônio Arquitetônico, *Castelo de bragança / castelo e cerca urbana de bragança*, http://www.monumentos.gov.pt/site/app_pagesuser/sipa.aspx?id=5158, 2021.

[69] T. C. M. de Bragança, *Museu militar de bragança*, https://turismo.cm-braganca.pt/tradicoes-e-experiencias/museus/geo_artigo/museu-militar-de-braganca, 2021.

[70] C. N. da UNESCO, *Carnaval de podence*, https://unescoportugal.mne.gov.pt/pt/temas/proteger-o-nosso-patrimonio-e-promover-a-criatividade/patrimonio-cultural-imaterial-em-portugal/carnaval-de-podence, 2022.

[71] N. Unidas, *Caretos de podence, de portugal, são patrimônio imaterial da humanidade da unesco*, https://news.un.org/pt/story/2019/12/1697801, 2019.

[72] Wikipedia, *Careto*, https://pt.wikipedia.org/wiki/Careto, 2022.

[73] T. W. S. Journal, *The wall street journal*, https://www.wsj.com/, 2022.

[74] A. Wolfe, *Palmer luckey: Making virtual reality a reality*, https://www.wsj.com/articles/palmer-luckey-making-virtual-reality-a-reality-1438959172?mod=e2tw, 2015.

[75] Scopus, *Scopus*, https://www.scopus.com, 2022.

[76] Elsevier, *Elsevier*, https://www.elsevier.com/, 2022.

[77] W. of Science, *Web of science*, https://www.webofscience.com, 2022.

[78] B. Format, *Bibtex format*, http://www.bibtex.org/Format/, 2022.

[79] Bibliometrix, *Bibliometrix*, https://www.bibliometrix.org/home/, 2022.

[80] R, *R*, https://www.r-project.org/, 2022.

[81] RStudio, *Rstudio*, https://www.rstudio.com/, 2022.

[82] Bibliometrix, *Bibliometrix introduction*, https://www.bibliometrix.org/vignettes/Introduction_to_bibliometrix.html, 2022.

[83] M. Talafubieke, S. Mai, and N. Xialifuhan, "Evaluation of the virtual economic effect of tourism product emotional marketing based on virtual reality," *Frontiers in Psychology*, vol. 12, Nov. 2021, ISSN: 16641078. DOI: 10.3389/fpsyg.2021.759268. [Online]. Available: https://www.scopus.com/record/display.uri?eid=2-s2.0-85120913535&origin=resultslist&sort=r-f&src=s&st1=Evaluation+of+the+Virtual+Economic+Effect+of+Tourism+Product+Emotional+Marketing+Based+on+Virtual+Reality&sid=845633ae054edcc8701428f4add2d214&sot=b&sdt=b&sl=120&s=TITLE-ABS-KEY%5C%28Evaluation+of+the+Virtual+Economic+Effect+of+Tourism+Product+Emotional+Marketing+Based+on+Virtual+Reality%5C%29&relpos=0&citeCnt=2&searchTerm=.

[84] D. Lee, P. M. L. Ng, and T. M. Wut, "Virtual reality in festivals: A systematic literature review and implications for consumer research," *Emerging Science Journal*, vol. 6, no. 5, pp. 1153–1166, 2022, Cited by: 0; All Open Access, Gold Open Access. DOI: 10.28991/ESJ-2022-06-05-016. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85136290507&doi=10.28991%5C%2fESJ-2022-06-05-016&partnerID=40&md5=b349b1e4f0c8efaa43318f3d47a6c49e%7D.

[85] S. Verma, L. Warrier, B. Bolia, and S. Mehta, "Past, present, and future of virtual tourism-a literature review," *International Journal of Information Management Data Insights*, vol. 2, no. 2, 2022, Cited by: 3; All Open Access, Gold Open Access. DOI: 10.1016/j.jjimei.2022.100085. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85131954370&doi=10.1016%5C%2fj.jjimei.2022.100085&partnerID=40&md5=cc3b4d9d7fc2262ddd2f76d5dc45f4c1%7D.

[86] Z. Fan, C. Chen, and H. Huang, "Immersive cultural heritage digital documentation and information service for historical figure metaverse: A case of zhu xi, song dynasty, china," *Heritage Science*, vol. 10, no. 1, 2022, Cited by: 0; All Open Access, Gold Open Access, Green Open Access. DOI: 10.1186/s40494-022-00749-8. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85138734175&doi=10.1186%5C%2fs40494-022-00749-8&partnerID=40&md5=1f8c278dd951a983c1cd47c6ca41c29f%7D.

[87] C. P. Ortet, A. I. Veloso, and L. Vale Costa, "Cycling through 360° virtual reality tourism for senior citizens: Empirical analysis of an assistive technology," *Sensors*, vol. 22, no. 16, 2022, Cited by: 0; All Open Access, Gold Open Access, Green Open Access. DOI: 10.3390/s22166169. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85137127229&doi=10.3390%5C%2fs22166169&partnerID=40&md5=9ce01ea00512cfe492325c3081a7f6dd%7D.

[88] A. Rueda Márquez de la Plata, P. A. Cruz Franco, and J. A. Ramos Sánchez, "Architectural survey, diagnostic, and constructive analysis strategies for monumental preservation of cultural heritage and sustainable management of tourism," *Buildings*, vol. 12, no. 8, 2022, Cited by: 1; All Open Access, Gold Open Access. DOI: 10.3390/buildings12081156. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85137358117&doi=10.3390%5C%2fbuildings12081156&partnerID=40&md5=42b73dada5c4f574c11a2e01162c7e57%7D.

[89] M. Alyahya and G. McLean, "Examining tourism consumers' attitudes and the role of sensory information in virtual reality experiences of a tourist destination," *Journal of Travel Research*, vol. 61, no. 7, pp. 1666–1681, 2022, Cited by: 5; All Open Access, Green Open Access, Hybrid Gold Open Access. DOI: 10.1177/00472875211037745. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85114507143&doi=10.1177%5C%2f00472875211037745&partnerID=40&md5=98b5c693ac2cc60206f2740e0da0384e%7D.

[90] V. De Luca, G. Marcantonio, M. C. Barba, and L. T. De Paolis, "A virtual tour for the promotion of tourism of the city of bari," *Information (Switzerland)*, vol. 13, no. 7, 2022, Cited by: 0; All Open Access, Gold Open Access. DOI: 10.3390/info13070339. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85136061988&doi=10.3390%5C%2finfo13070339&partnerID=40&md5=f72d74ec6ad6ba85196c5bdad43875a6%7D.

[91] L. Geng, Y. Li, and Y. Xue, "Will the interest triggered by virtual reality (vr) turn into intention to travel (vr vs. corporeal)? the moderating effects of customer segmentation," *Sustainability (Switzerland)*, vol. 14, no. 12, 2022, Cited by: 1; All Open Access, Gold Open Access. DOI: 10.3390/su14127010. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-

s2.0-85132565434&doi=10.3390%5C%2fsu14127010&partnerID=40&md5=f77f53cc0c3d397dffebb02614c3c8d0%7D.

[92] I. Oncioiu and I. Priescu, "The use of virtual reality in tourism destinations as a tool to develop tourist behavior perspective," *Sustainability (Switzerland)*, vol. 14, no. 7, 2022, Cited by: 2; All Open Access, Gold Open Access. DOI: 10.3390/su14074191. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85127969644&doi=10.3390%5C%2fsu14074191&partnerID=40&md5=1f613852f515a15e8bb539a41ae19c76%7D.

[93] S.-N. Zhang, Y.-Q. Li, W.-Q. Ruan, and C.-H. Liu, "Would you enjoy virtual travel? the characteristics and causes of virtual tourists' sentiment under the influence of the covid-19 pandemic," *Tourism Management*, vol. 88, 2022, Cited by: 21; All Open Access, Bronze Open Access. DOI: 10.1016/j.tourman.2021.104429. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85122093005&doi=10.1016%5C%2fj.tourman.2021.104429&partnerID=40&md5=74d200f6b746611b59a9d509b2280f1a%7D.

[94] V. Filimonau, M. Ashton, and U. Stankov, "Virtual spaces as the future of consumption in tourism, hospitality and events," *Journal of Tourism Futures*, 2022, Cited by: 0; All Open Access, Gold Open Access. DOI: 10.1108/JTF-07-2022-0174. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85138636945&doi=10.1108%5C%2fJTF-07-2022-0174&partnerID=40&md5=cc8584fc9c6d0567266f49aed1badb30%7D.

[95] M. S. Siddiqui, T. A. Syed, A. Nadeem, W. Nawaz, and A. Alkhodre, "Virtual tourism and digital heritage: An analysis of vr/ar technologies and applications," *International Journal of Advanced Computer Science and Applications*, vol. 13, no. 7, pp. 303–315, 2022, Cited by: 0; All Open Access, Gold Open Access. DOI: 10.14569/IJACSA.2022.0130739. [Online]. Available: %5Curl%7Bhttps://www.scopus.com/inward/record.uri?eid=2-s2.0-85135785118&doi=10.14569%

5C%2fIJACSA.2022.0130739&partnerID=40&md5=9bc1b0e7d972764b39b668fb13b05134%7D.

[96] Pikwhip, *What are 360-degree videos?* https://www.pikwhip.com/en/article/6/40/what-are-360-degree-videos/, 2022.

[97] Wikipedia, *360-degree video*, https://en.wikipedia.org/wiki/360-degree_video, 2022.

[98] ——, *Omnidirectional (360-degree) camera*, https://en.wikipedia.org/wiki/Omnidirectional_(360-degree)_camera, 2022.

[99] Y. VR, *Youtube vr*, https://vr.youtube.com/, 2022.

[100] Meta, *Introducing 360 video on facebook*, https://about.fb.com/news/2015/09/introducing-360-video-on-facebook/, 2022.

[101] Vimeo, *Vimeo 360: A home for immersive storytelling*, https://vimeo.com/blog/post/introducing-vimeo-360/, 2022.

[102] Google, *360° videos*, https://artsandculture.google.com/project/360-videos, 2022.

[103] T. M. Page, *Arc length*, https://www.themathpage.com/aTrig/arc-length.htm, 2022.

[104] D. Heaney, *How virtual reality positional tracking works*, https://venturebeat.com/games/how-virtual-reality-positional-tracking-works/, 2019.

[105] iT.eam, *O que é a realidade virtual, como ela funciona e quais suas aplicações?* https://it-eam.com/realidade-virtual/, 2021.

[106] Heizenrader, *The 3 types of virtual reality*, https://heizenrader.com/the-3-types-of-virtual-reality/, 2022.

[107] Wikipedia, *Head-mounted display*, https://en.wikipedia.org/wiki/Head-mounted_display, 2022.

[108] Insta360, *Insta360 stitcher*, https://www.insta360.com/download/insta360-pro2, 2022.

[109] ——, *Insta360*, https://www.insta360.com/, 2022.

[110] ——, *Insta360 stitcher tutorial: Stitch insta360 pro 2 photos, videos timelapses*, https://blog.insta360.com/insta360-pro-stitcher/, 2020.

[111] A. Inc., *Adobe after effects*, https://www.adobe.com/products/aftereffects.html, 2022.

[112] ——, *Adobe inc.* https://www.adobe.com/, 2022.

[113] Wikipedia, *Adobe after effects wikipedia*, https://en.wikipedia.org/wiki/Adobe_After_Effects, 2022.

[114] A. Inc., *Adobe photoshop*, https://www.adobe.com/products/photoshop.html, 2022.

[115] ——, *Adobe photoshop express*, https://www.adobe.com/products/photoshop-express.html, 2022.

[116] Wikipedia, *Adobe photoshop wikipedia*, https://en.wikipedia.org/wiki/Adobe_Photoshop, 2022.

[117] A. Inc., *Adobe premiere pro*, https://www.adobe.com/products/premiere.html, 2022.

[118] Wikipedia, *Adobe premiere pro wikipedia*, https://en.wikipedia.org/wiki/Adobe_Premiere_Pro, 2022.

[119] A. Inc., *Adobe media encoder*, https://www.adobe.com/products/media-encoder.html, 2022.

[120] ——, *Adobe media encoder overview*, https://helpx.adobe.com/media-encoder/using/overview-media-encoder-user-interface.html, 2022.

[121] B. Foundation, *Blender*, https://www.blender.org/, 2022.

[122] ——, *Blender foundation*, https://www.blender.org/about/foundation/, 2022.

[123] ——, *About blender*, https://www.blender.org/about/, 2022.

[124] Insta360, *Insta360 pro*, https://www.insta360.com/product/insta360-pro/, 2022.

[125] ——, *Insta360 pro downloads*, https://www.insta360.com/download/insta360-pro, 2022.

[126] ——, *Insta360 pro tutorial*, https://onlinemanual.insta360.com/pro1/en-us/basic/prepare/1?r_from=%2Fpro1%2Fen-us%2F, 2022.

[127] NVidia, *Nvidia quadro rtx-4000*, https://www.nvidia.com/content/dam/en-zz/Solutions/design-visualization/quadro-product-literature/quadro-rtx-4000-data-sheet-us-nvidia-830682-r6-web.pdf, 2022.

[128] AMD, *Amd ryzen 7 3700x*, https://www.amd.com/en/products/cpu/amd-ryzen-7-3700x, 2022.

[129] Urano, *Urano vx*, https://www.nox-xtreme.com/en/power-supplies/urano-vx-650w-bronze, 2022.

[130] HyperX, *Hyperx fury ddr4*, https://media.kingston.com/pdfs/HX_FURY_DDR4_BR.pdf, 2022.

[131] Windows, *Windows 10 pro*, https://support.microsoft.com/en-us/windows/windows-10-system-requirements-6d4e9a79-66bf-7950-467c-795cf0386715, 2022.

[132] M. P. Inc., *Meta quest 2*, https://www.meta.com/quest/products/quest-2/, 2022.

[133] ——, *Meta*, https://www.meta.com/, 2022.

[134] Wikipedia, *Meta quest 2 wikipedia*, https://en.wikipedia.org/wiki/Meta_Quest_2, 2022.

[135] R. Lima, *Meta quest 2 especificações*, https://canaltech.com.br/outros-acessorios/analise/review-meta-oculus-quest-2-conheca-o-headset-vr-mais-popular-do-mercado/, 2022.

[136] TestHMD, *Testhmd*, http://testhmd.com/, 2022.

[137] M. Rakver, *Oculus quest 2 fov comparison with other headsets*, https://smartglasseshub.com/oculus-quest-2-fov/, 2022.

[138] R. Brown, *Oculus quest 2 specs*, https://vr-compare.com/headset/oculusquest2, 2022.

[139] M. P. Inc., *Meta quest downloads*, https://www.meta.com/quest/setup/, 2022.

[140] VRSciT, *Virtual reality science tour*, https://vrscit.pixel-online.org/, 2022.

[141] E. Commission, *European education and culture executive agency*, https://www.eacea.ec.europa.eu/index_en, 2022.

[142] A. N. E. E. e Formação, *Portuguese national agency for the erasmus+ programme*, https://erasmusmais.pt/, 2022.

[143] C. C. Viva, *Centro ciência viva*, https://braganca.cienciaviva.pt/, 2022.

[144] Pixel, *Pixel*, https://www.pixel-online.net/, 2022.

[145] U. of Teramo, *University of teramo*, https://www.csgunitem.it/, 2022.

[146] eMundus, *Emundus*, https://www.emundus.eu/, 2022.

[147] T. M. L. E. History, *The museum lithuanian education history*, https://www.lsim.lt/, 2022.

[148] U. de Léon, *Universidad de léon*, https://www.unileon.es/, 2022.

[149] Scayle, *Scayle*, https://www.scayle.es/, 2022.

[150] Youtube, *Vr and educational tourism - study case - youtube playlist*, https://www.youtube.com/playlist?list=PLKsGth9iH3EwD_MFVMb3Tf6zkf3Ed-P5i, 2022.

[151] I. Cloud, *Vr and educational tourism - study case - shared folder*, https://cloud.ipb.pt/d/b7911ecde3bc41a4aab6/, 2022.

[152] Wikipedia, *Uncanny valley*, https://en.wikipedia.org/wiki/Uncanny_valley, 2022.

[153] Facebook, *Las çarandas facebook*, https://www.facebook.com/las.carandas/, 2022.

[154] Spotify, *Las çarandas spotify*, https://open.spotify.com/artist/1MkQqABQZdZuCHWfRgTMwg, 2022.

[155] G. Galundaina, *Galandum galundaina site*, http://www.galandum.co.pt/, 2022.

[156] Facebook, *Galandum galundaina facebook*, https://pt-pt.facebook.com/GalandumGalundaina/, 2022.

[157] Spotify, *Galandum galundaina spotify*, https://open.spotify.com/artist/77Yw6rgTWEaCv3SkLwGIzq, 2022.

[158] C. do Careto, *Casa do careto*, https://www.caretosdepodence.pt/casadocareto, 2022.

[159] VRSciT, *Vrscit new 3d objects*, https://vrscit.pixel-online.org/new-objects.php, 2022.

[160] Sketchfab, *Cedri sketchfab*, https://sketchfab.com/CeDRI, 2022.

[161] ——, *Silk house*, https://braganca.cienciaviva.pt/3515/%3Cfont-color=green%3Eplataforma-%3Cbr/%3Esilkhouse%3C/font%3E, 2022.

[162] R. Themes, *Pelourinho de bragança*, http://www.portugalnotavel.com/pelourinho-braganca/, 2022.

[163] byAR, *Byar*, https://www.byar.pt/en/, 2022.