sustainability

MDPI

Article

Enhancing the Sustainability of Intangible Cultural Heritage Projects: Obtaining Efficient Digital Skills Preservation through Binocular Half Panoramic VR Maps

Ruixuan Yang [1], Yuzhi Li [1], Yiting Wang [1], Qiaolian Zhu [2], Ning Wang [3], Ying Song [1], Feng Tian [1,*] and Haojun Xu [1,*]

[1] Shanghai Film Academy, Shanghai University, Shanghai 200072, China; yrx1230@shu.edu.cn (R.Y.); shadowmcv@shu.edu.cn (Y.L.); john2000123@126.com (Y.W.); hata419@163.com (Y.S.)
[2] School of Foreign Languages, Shanghai University, Shanghai 200072, China; gjky@shu.edu.cn
[3] Shanghai Academy of Fine Arts, Shanghai University, Shanghai 200072, China; warning714@shu.edu.cn
* Correspondence: ouman@shu.edu.cn (F.T.); sacross_k@shu.edu.cn (H.X.)

Abstract: Intangible cultural heritage is a people-centered living cultural heritage. Preservation, promotion, and talent cultivation are important aspects of intangible cultural heritage protection and also crucial guarantees for sustainable development. However, traditional video recordings lack three-dimensional spatial information, and the high cost of digital scanning and reconstruction still leaves no convenient, efficient, accurate, realistic, and low-cost solution for the preservation and dissemination of intangible cultural heritage projects. Here we introduce the binocular 180-degree panoramic display method, through which a platform for recording, showcasing, disseminating, and teaching intangible cultural heritage projects in the Sanlin Old Street of Shanghai was implemented. The platform requires only VR filming without the need for 3D modeling technology. The participants can freely select intangible cultural heritage projects on the map and immerse themselves in watching the Sanlin "Three Excellence" porcelain carving, local cuisine, and embroidery. They can also enjoy the dragon dance, experience the textile craftsmanship of Sanlin's "Three Specialties", and even observe the production process and details of the works from the perspective of the inheritor in the first person. The results show that compared to traditional video recordings and digital scanning reconstruction, the binocular 180-degree panoramic display provides a one-to-one, face-to-face, and low-cost solution for the preservation and dissemination of projects. It allows students to increase their knowledge of intangible cultural heritage and enhance their interest in inheritance.

Keywords: Sanlin Old Street; Intangible Cultural Heritage Oasis; sustainable development; monocular 360° panoramic view; binocular 180° panoramic view

Citation: Yang, R.; Li, Y.; Wang, Y.; Zhu, Q.; Wang, N.; Song, Y.; Tian, F.; Xu, H. Enhancing the Sustainability of Intangible Cultural Heritage Projects: Obtaining Efficient Digital Skills Preservation through Binocular Half Panoramic VR Maps. *Sustainability* **2024**, *16*, 5281. https://doi.org/10.3390/su16135281

Academic Editors: Francesca Di Turo and Giacomo Fiocco

Received: 15 May 2024
Revised: 16 June 2024
Accepted: 17 June 2024
Published: 21 June 2024

1. Introduction

Culture is considered one of the driving factors of sustainable development as it can support socio-economic development and enhance social inclusivity. Intangible cultural heritage, as an important component of culture, reflects the interaction between human beings and the environment, nature, and history through intergenerational transmission and continuous recreation. It is an expression of cultural diversity. Therefore, the protection of intangible cultural heritage is also one of the drivers of achieving sustainable development in human society. The Operational Directives for the Implementation of the Convention for the Safeguarding of the Intangible Cultural Heritage by UNESCO also call for greater attention to the significant role of intangible cultural heritage [1–4].

The protection of intangible cultural heritage and the achievement of sustainable development also face many challenges. Particularly, with the acceleration of urbanization, the traditional transmission methods and practice environment of intangible cultural heritage are under pressure. For example, the Shanghai Port Dock hauling chants are traditional songs sung by dock and cargo workers in the Shanghai area, recognized as one

of the national-level intangible cultural heritages. With the progress of modern industrial civilization and the increasing mechanization of port production, heavy physical labor has gradually been replaced by machines. The Shanghai dock workers who used to carry goods on their shoulders or by hand are now aging, and the chants they sang while moving goods are gradually disappearing. Shikumen, a type of architecture in Shanghai, is a new style of building that integrates Western culture with traditional Chinese residential characteristics. The construction technique of Shikumen alleys is also recognized as one of the national-level intangible cultural heritages. However, with the urbanization process, various high-rise buildings have sprung up, and there has been selective demolition of Shikumen architecture clusters. Traditional Shikumen alley constructions are no longer commonly built.

Of course, a large number of intangible heritage projects continue in communities. For example, Sanlin Town, located in Pudong New Area, Shanghai, has a history of over a thousand years. Endowed with outstanding people and rich resources, it is known as the hometown of Chinese folk art. It has a large number of operational intangible cultural heritage projects. Sanlin boasts "Three Treasures", "Three Excellences", and "Three Specialties". The "Three Treasures" include pickled melons, pigskin, and pickled vegetables, while the "Three Excellences" refer to porcelain carving, local cuisine, and embroidery. Additionally, there are the "Three Specialties", namely, the dragon dance, the March 15th temple fair, and the City God's patrol. The Sanlin community and primary and secondary schools are actively promoting the educational dissemination of Sanlin's intangible cultural heritage projects, which have gained popularity among young people, contributed to productive employment, and promoted economic development. This aligns with the United Nations' 2030 Agenda for Sustainable Development.

There are many problems in the digital retention and dissemination of intangible cultural heritage projects. Similarly to many intangible heritage inheritors both domestically and internationally, the inheritors in Sanlin Town are mostly aged 60 and above. Although they are able to carry out intangible cultural heritage teaching within the community and nearby primary and secondary schools, they are limited by age and physical stamina, making it difficult for them to handle high workloads or teach over long distances. The government has also supported the production of various micro-documentaries and series of educational films on intangible cultural heritage, but flat videos lacking spatial perception fall far short of the effects of real-time teaching in a four-dimensional space. Consequently, the limitations of both flat videos and real-time teaching have led to the objectives, significance, and value of this study.

The learning application investigated in this study is called "On Intangible Cultural Heritage Oasis". It is the virtual reality (VR) environment developed by our research team. The goal of the Intangible Cultural Heritage Oasis is to allow more students to experience the fun and interest of various intangible cultural heritage projects and to cultivate attitudes towards sustainable intangible cultural heritage environment and knowledge of cultural diversity. In the current study, the Oasis includes multiple intangible cultural heritage projects from Sanlin Town. We conducted a multidimensional comparison of three conditions: traditional video, monocular 360° panoramic view, and binocular 180° panoramic view, and evaluated visual perception and aesthetic pleasure of the three conditions through additional experimental procedures. Finally, we conducted surveys in front of the intangible cultural heritage venues to validate the promotional effect of the Intangible Cultural Heritage Oasis.

2. Related Research on Digital Technology in Cultural Heritage

There are now many shooting devices available, including professional cameras, DSLR cameras, mobile phones, etc., all of which can serve as hardware devices for recording videos of intangible cultural heritage projects. Therefore, in China, almost every intangible cultural heritage project has one or several forms of long documentaries, micro-documentaries, educational documentaries, project promotional videos, short videos, etc.

At the same time, the dissemination channels of intangible cultural heritage are constantly innovating, such as VR advertising, micro videos, and other media that lead the fashion of visual cultural consumption, which can further expand the dissemination and influence of intangible cultural heritage [5]. Intangible cultural heritage is inseparable from its surrounding environment. In this section, we comprehensively discuss digital recording technologies other than traditional flat videos in both intangible cultural heritage and material cultural heritage projects.

2.1. Three Dimensional Reconstruction of Cultural Heritage

In the past decade, in addition to traditional two-dimensional video shooting and panoramic video shooting, virtual reality has also been used in the recording and protection of cultural heritage. The 3D acquisition in virtual reality can be divided into laser scanning and photo modeling, and the record of the physical movements of the inheritors can be captured using motion capture for 3D acquisition.

Laser scanning is a common method for reconstructing historical buildings. Examples are as follows: Aso Hajirasouli et al. [2] proposed a digitization theory framework and application for endangered heritage based on virtual reality. Naci Yastikli et al. [6] proposed the use of digital photogrammetry and laser scanning to record cultural heritage. Tallis Rubens et al. [7] also utilized laser scanning to digitize the Nossa Senhora do Rosário Church. Ahmad Baik et al. [8] applied laser scanning methods to record heritage buildings in Old Jeddah. Karsten Lambers et al. [9] combined photogrammetry and laser scanning to record the Parpa Late Intermediate Period site in Peru. Amparo Núñez Andrés et al. [10] also used laser scanning to generate virtual models of cultural heritage, such as the Gate of Antioch in Syria. Yahya Alshawabkeh et al. [11] conducted a case study of historical buildings in Jordan using laser scanners. Gehan Selim et al. [12] conducted a historical and cultural practice study of the Gadara archaeology in Jordan.

Photo modeling is a common method for reconstructing historical artifacts. Examples are as follows: Daniel Alejandro Loaiza Carvajal et al. [13] implemented a digitization case of the Argentine museum collections using existing photography modeling technology. Jiaming Xu [14] conducted research on three-dimensional reconstruction of cultural relics based on photo images. Domicele Jonauskaite et al. [15] used photography modeling models in the study of enhancing user aesthetic experiences in digital interactive artworks. Qiaoliang Xu et al. [16] proposed that virtual reality can enhance spatialized scenes by embedding intangible aspects such as historical information into the landscape. This makes VR a way to experience and increase understanding of heritage landscapes. Lingyi Wu et al. [17] detailed the process of photo modeling technology in the design of chime experiences. For standalone historical buildings in open spaces, Arnadi Murtiyoso et al. [18] proposed cases of heritage building using close-range unmanned aerial vehicle image dense matching and three-dimensional reconstruction. Multi-image three-dimensional reconstruction is becoming more common in the virtual reconstruction of cultural relics [19–21].

Motion capture is a common method for reconstructing the body movements of intangible cultural heritage inheritors. Examples are as follows: Iudova-Romanova et al. [22] described the scenario of theater actresses conducting motion capture for virtual performances. Maria Skublewska-Paszkowska et al. [23] provided a detailed overview of technologies in intangible cultural heritage preservation, mentioning cases of using motion capture to fully record the work processes of craftsmen.

In addition to traditional shooting and panoramic shooting, whether it is laser scanning, photo modeling, or motion capture, this consumes a lot of pre- and post-production time and cost.

2.2. Cultural Heritage Visual Presentation

In virtual reality, exhibition display equipment can be divided into traditional flat-panel displays, 3D projection screens, AR, and VR. Content resources include traditional

videos, panoramic videos, and real-time rendering models. In recent decades, a large number of virtual reality applications have been running on traditional flat-panel displays, and cultural heritage projects based on 3D projection screens were also seen ten years ago [24]. Currently, in addition to flat-panel displays, the more mainstream exhibition applications are still on mobile AR, AR headsets, and VR headsets.

Mobile AR is the most popular way of exhibition presentation. Examples are as follows: Silvia Blanco-Pons et al. [25] launched a mobile AR application for prehistoric rock art paintings, proving that AR helps people identify themes in rock art. Valerio De Luca et al. [26] developed a virtual application for the Church of San Elia in Rugiano, southern Italy, using mobile AR technology, demonstrating its usability and high level of interest. More AR cultural heritage applications are also being developed [27–29].

AR headsets, due to their relatively high cost, have fewer developed applications. Additionally, they are relatively concentrated in virtual museum applications because they are not suitable for outdoor operation under sunlight. Examples are as follows: Néill O'dwyer et al. [30] conducted museum narratives using AR headsets applied within the Trinity College Library in Dublin. Ramy Hammady et al. [31] developed an AR-based tour guide system for the Egyptian Museum. More AR cultural heritage applications have also been developed [32–34].

The research and development based on head-mounted VR devices are the most popular, suitable for the presentation of both scenic and artifact-based heritage. Farzan Baradaran Rahimi et al. [35] conducted a comparative study on the presentation effects of physical museums, video museums, and VR museums. Kihong Kim et al. [36] demonstrated that the VR-enhanced environment brings novel museum experiences, resulting in greater impact and enjoyment for visitors in terms of learning. There are numerous similar studies on VR cultural heritage [37–41].

There is relatively little research conducted using 360-degree videos in VR, which may be due to the lack of interactivity in videos. Our research team has used various brands of panoramic cameras, such as the Jaunt VR camera hardware released in 2015, which had high initial and post-production costs but achieved a 4K stereoscopic effect. The Nokia OZO 360-degree camera, despite its high cost, could only maintain a frontal stereoscopic effect, and after 2020, most of these cameras have been discontinued. Currently, we use low-cost monocular 6K 360 panoramic cameras. In terms of research, Jihyung Kim et al. [42] conducted a comparative study on the application of 360-degree videos in undergraduate education. Marta Rusnak et al. [43] used eye-tracking technology to explore the similarity and visual differences between two-dimensional photos and panoramic photos in architectural heritage. Osten Bang Ping Mah et al. [44] used temple spherical images captured by a 360-degree camera to integrate intangible elements of cultural heritage into a unified interface. They also enhanced the accessibility of heritage practitioners using both 360 cameras and digital single-lens reflex cameras, providing convenient applications for the future.

Osten Bang Ping Mah et al. [44] confirms that the selected software has relatively low prices. So why are there so many studies on the application of 3D scanning, while applications using 360-degree technology for heritage preservation and dissemination are rare? Although there are numerous studies on VR/AR based on 3D models, why are there so few real-world applications? Most importantly, why are there more digital preservation efforts for tangible cultural heritage rather than virtual preservation efforts for intangible cultural heritage? The reason can be attributed to the fact that the cases reported in the literature are based on monocular 360-degree videos, which have poor visual effects. They lack stereopsis, resulting in a significant disparity from the real world, and the lack of depth perception causes deformation of the heritage's size. The development cost of applications based on 3D models is high, making it difficult to establish a large-scale series of 3D data. Even if sampled, it is challenging to quickly disseminate the data on the Internet due to its large volume. The workload for the static 3D reconstruction of tangible cultural heritage is already substantial, and this approach cannot meet the requirements for dynamically

recording intangible cultural heritage. Dynamic intangible cultural heritage performances and craft making are not suitable for laser scanning or static 3D reconstruction from photos. Relying on motion capture to collect data and then binding them to cartoon models removes the performers' expressions, resulting in the detachment of intangible cultural heritage projects from the inheritors' images, which is not authentic and contradicts the principle of synchronously protecting people and projects.

However, the application of panoramic videos has emerged with the development of hardware. In order to meet the low-cost, high visual effect, and easily accessible needs for both the preservation and dissemination of intangible cultural heritage, this paper utilizes a novel binocular 180-degree panoramic camera to establish a VR map of intangible cultural heritage, namely, the Intangible Cultural Heritage Oasis, and analyze its effectiveness in preserving and disseminating intangible cultural heritage.

3. Materials and Methods

This research employed an experimental approach to measure the immersion, interaction, visual effects, enjoyment, and aesthetics (dependent variables) of participants in response to selected environments (independent variables). To control the environments, the scenarios were designed using 2D traditional video, monocular 360-degree panoramic video, and binocular 180-degree panoramic video.

3.1. Data Acquisition, Processing, and Modeling

3.1.1. Video Shooting Content

The Sanlin Old Street gathers the majority of intangible cultural heritage projects in Sanlin Town. As shown in Figure 1, within a 500-m range of the old street, we conducted interviews and shooting sessions for Sanlin-style cloth dyeing, embroidery, porcelain carving, local cuisine, and dragon lantern making projects. Among them, the Pudong dragon lantern making project is a national-level intangible cultural heritage project. Other city-level and district-level intangible cultural heritage projects incorporate dragon design elements, such as making dragon dolls with cloth dyeing, embroidering dragon patterns, carving dragon shapes in porcelain, and cooking dragon-themed dishes like oil-blasted lobster.

Figure 1. (**a**) A panoramic view of Sanlin Old Street taken from aerial perspective. (**b**) Entrance gate of the old street. (**c**) Festivities in Sanlin Old Street during the Lantern Festival.

3.1.2. Video Shooting Methods

The digital collection of cultural heritage is divided into three categories: traditional video, monocular 360-degree panoramic video, and binocular 180-degree panoramic video shooting. As shown in Figure 2, the traditional video is captured using a regular DSLR camera and stabilizer. The monocular panoramic video is filmed using an Insta360 camera and selfie stick, while the binocular panoramic video is captured using a 3D180VR camera and tripod.

Figure 2. First row: Entrance to five intangible cultural heritage project sites; Second row: Camera position setup; Third row: Traditional video shooting; Fourth row: 180VR video shooting.

3.1.3. Video Content Production

The traditional video shooting resolution is 4K. After editing and color correction, it is played on a regular screen based on the PC version of the Intangible Cultural Heritage Oasis. The resolution of the monocular 360-degree panoramic video is 6K. In order to reduce the visual variables compared to 180-degree stereoscopic panoramic views and because the performances are all within a 180-degree range, only the front 180-degree image is retained. After editing and color correction, it is played in VR headsets using the VR version of the Intangible Cultural Heritage Oasis developed by our team. The resolution of the binocular 180-degree panoramic video is 8K. After adjustments in bitrate, resolution, editing, and color correction, the playback resolution is set at 6K×2, and the bitrate is set at 80 Mbps. It is played in VR headsets using the VR version of the Intangible Cultural Heritage Oasis developed by our team.

3.2. Oasis System Design

The framework is shown in Figure 3. In this study, the captured 2D traditional videos, monocular 180° panoramic videos, and binocular 180° panoramic videos are respectively applied to the monocular/binocular 180 panoramic environment system based on the VR version of the Intangible Cultural Heritage Oasis and the PC version of the Intangible Cultural Heritage Oasis. The monocular/binocular 180° panoramic environment system based on the VR version of the Intangible Cultural Heritage Oasis consists of three main parts: eye-tracking calibration, scene selection and navigation based on gesture recognition, and video playback scenes. The PC version of the Intangible Cultural Heritage Oasis includes two main parts: scene selection and navigation and video playback scenes. In the VR headset, the system supports hand recognition and gesture recognition, allowing viewers to use their hands to drive virtual hands to perform map queries, panoramic video playback, and scene switching.

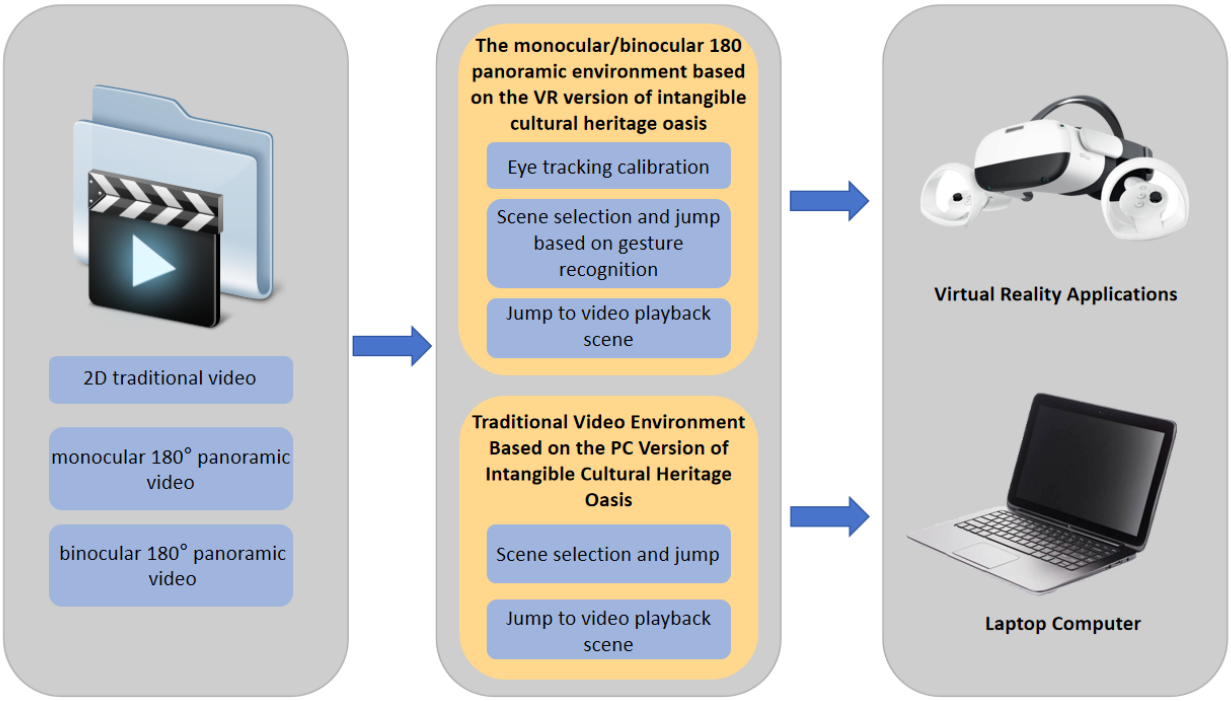

Figure 3. System Design Framework.

3.2.1. Eye-Tracking Calibration

Eye tracking calibration is a crucial step aimed at ensuring that the device can accurately capture the user's eye movements. As shown in Figure 4a, when the user gazes at the screen, the small dot in the screen moves with the user's gaze. However, there are individual differences among different subjects. Therefore, we provide more accurate gaze tracking ability for each subject by the eye-tracking calibration. We ensure that the user's gaze position is consistent with the displayed position of the dot by having them gaze at the screen and moving the joystick to represent the line of sight in order to improve tracking accuracy.

Figure 4. (**a**) Calibration of eye tracking. (**b**–**d**) Application of eye tracking.

3.2.2. Scene Selection and Navigation Based on Gesture Recognition

After the eye-tracking calibration is completed, the user enters the scene selection phase. In this paper, a user-friendly interface is designed, allowing users to achieve quick system responses through real-time gesture recognition. As shown in Figure 5, by adding specific button recognition logic during gesture recognition, the system can identify the gestures when the buttons are pressed. Once a button press event is recognized, the system should be able to navigate to the corresponding scene based on the user's selection.

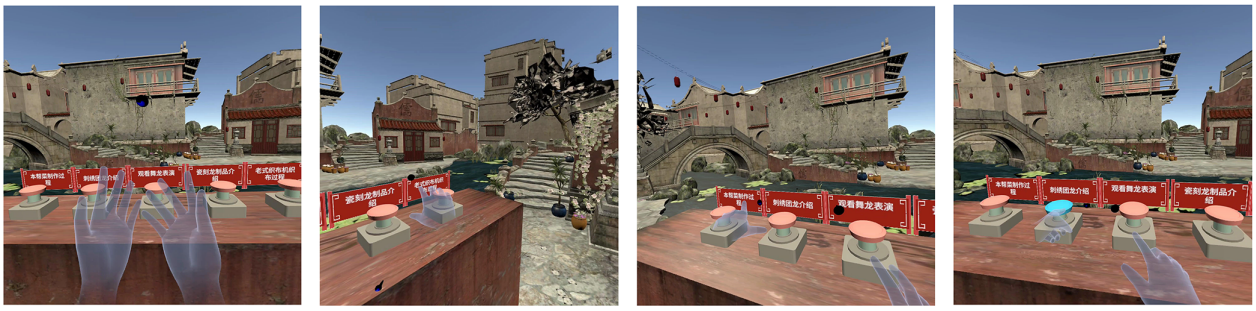

Figure 5. Scene Selection Phase.

3.2.3. Video Playback Scenes

After switching to a new scene, the system automatically plays the video associated with that scene. After watching the video, users can press a button to return to the scene selection phase, as shown in the Figure 6.

Figure 6. Video Playback Scene.

3.3. Conditions

In this study, apart from the Sanlin Old Street intangible cultural heritage series base, no additional indoor venues need to be added. The study adopts the following three conditions: 1. Traditional video environment based on the PC version of the Intangible Cultural Heritage Oasis (a rectangular plane exhibition based on video clips). 2. Monocular 180° panoramic environment based on the VR version of the Intangible Cultural Heritage Oasis (a panoramic plane exhibition based on the VR platform). 3. Binocular 180° panoramic environment based on the VR version of the Intangible Cultural Heritage Oasis (a three-dimensional space exhibition based on the VR platform).

Under C1, performances and heritage videos are played on a regular screen. C2 and C3 were interactive exhibitions based on the Intangible Cultural Heritage Oasis that could be freely selected and played according to the audience's preferences for each intangible cultural heritage project. C2 plays monocular 180° panoramic videos in the Intangible Cultural Heritage Oasis. C3 plays binocular 180° panoramic videos in the Intangible Cultural Heritage Oasis. The content experienced and played in C1–3 includes Sanlin's "Three Superb" porcelain carving, local dishes, embroidery, the dragon dance in Sanlin's "Three Specialties", and Sanlin's standard cloth textile skills, including explanations by Sanlin's geographic and historical guides, intangible cultural heritage project guides, heritage presenter demonstrations, and heritage presenter artistic performances. The intangible cultural heritage video content in C1–3 corresponds one-to-one. Although the video formats are different, the voiceover sequences are consistent, and the audience in C1–3 is required to watch in place.

The exhibition was equipped with the following hardware: One Pico4 with Android, One iPad with iOS. We implemented the system using Unity 2021.3.15.

3.4. Experiment Design

This study ultimately aims to be implemented at the Sanlin Old Street intangible cultural heritage conservation base, where audiences can appreciate and experience various digital visual effect conditions. Therefore, a two-stage experiment was designed. The experiment was approved by the Ethics Committee of Shanghai University (ECSHU 2024-007). The experiment was conducted in March 2024, with the first group being the questionnaire experience group and the second group being the semi-open experience group. According to the pre-exposure results, all participants had not visited the Sanlin Old Street intangible cultural heritage conservation base before the experiment.

The first group of experimental subjects consists of 17 students and teachers from our school, as shown in Figure 7. After introducing and clarifying the research purpose, we provided the participants with consent forms and conducted digital exhibition tasks for C1–3 at the on-campus experimental site. The three types of exhibition experiences could be freely arranged. For C2–3, on-site guidance was provided to participants on how to select intangible cultural heritage content within the VR space of the Intangible Cultural Heritage Oasis. At the end of Experiment 1, the participants responded to the post-exposure questionnaire and ranked the three types of interaction and visual effects. The issues raised in the questionnaire drew inspiration from two references [36,42,45,46] that focused on VR guidance, covering 6 aspects:

Satisfaction: How satisfied were the audiences with the Sanlin intangible cultural heritage in the 3 modes?

Cognitive Effectiveness: Can digital technology help audiences understand the inheritors, craftworks, and performance forms of the Sanlin intangible cultural heritage?

Flow Experience: How focused were audiences during appreciation in the 3 modes?

Cognitive Accessibility: Is it easy for audiences to operate digital devices?

Immersion: How much do the audiences ignore the external environment or interference?

Interactivity: Did audiences feel a sense of usability?

Figure 7. Participants are undergoing the experiment.

The questions of 6 aspects on the questionnaire are shown in the Table 1.

Table 1. The questions relating to the 6 aspects.

Satisfaction
1. How much do you score in terms of experience and satisfaction with the video presentation format you have experienced? 2. I think the sensory information provided by this presentation form is very vivid, rich, and detailed. 3. I am very interested in using this presentation format and feel very happy, excited, and interesting. 4. I like to use this presentation format to carefully appreciate the Sanlin Intangible Cultural Heritage project. 5. I will recommend this video presentation format to other classmates. 6. I think it is necessary to use this presentation form to appreciate the intangible cultural heritage of Sanlin outside the old street of Sanlin.
Visual Cognitive Effectiveness
1. I think this presentation format brings a richer depth of field, allowing me to better distinguish the environmental relationships of Sanlin Old Street. 2. I think this presentation format brings a more realistic image of the inheritor and the relationship between the performance space. 3. I believe that this presentation format brings a more complete three-dimensional spatial structure and design to the work. 4. Using this presentation format allows me to watch quietly. After watching, I marvel at the ingenuity of the inheritor and appreciate their exquisite performances and works. 5. I think this presentation format is consistent with the visual effects of real scenes.
Streaming Experience Interaction
1. When I watch, I am completely focused on intangible cultural heritage content, and I am fully immersed in the works and performances. 2. When I watch the production process, works, and performances, I feel like time flies and time seems to pass quickly. 3. When I watch, all my senses are focused on the production process, the work, and the performance. 4. During my viewing period, I did not have any unrelated thoughts or external interference. 5. During my viewing, I forgot the time, as if everything had come to a stop. The only thing that came to my mind was the work and performance.
Cognitive Accessibility
1. When I use this form of presentation, I must invest more energy and mental effort to understand the spatial actions of the inheritor and the three-dimensional structure of the work. 2. When I use this form of presentation for experiential appreciation, visual effects put a lot of pressure on me. 3. When I use this presentation format, I cannot concentrate on experiencing and appreciating it.
Immersion
1. When watching, I often forget the passage of time. 2. When watching, I am unaware of the surrounding environment and immersed in the work and performance. 3. During my viewing period, I am completely focused on the performance or work. 4. During the viewing period, I am more invested in the performance or work than any other idea. 5. During the viewing period, I felt like I was in a real environment where I could hardly distinguish between what was virtual and what was real.
System availability
1. I am willing to use this presentation format. 2. I found that this presentation form is not complicated at all. 3. I think this presentation format is easy to use. 4. I feel very confident when using this presentation system. 5. I think most people can quickly learn to use this presentation system. 6. I do not need to learn a lot before using this presentation system. 7. I do not think I need the help of professionals to use this presentation system.

Additionally, aesthetic pleasure/empathy level was added. What is the aesthetic pleasure level of the audience in the three modes of the Three Forest Intangible Cultural Heritage, including 7 aspects:

Perception: For me, the Sanlin Intangible Cultural Heritage is important, relevant, and interesting.

Resting state: Do you feel that you spend a long time gazing at the intangible cultural heritage series and performing the intangible cultural heritage dragon dance?

Imagine: Can you feel the bustling commercial atmosphere of Sanlin Town in Pudong during the early Ming Dynasty from dragon dance performances?

Lenovo: Do you experience the unique pursuit and intelligent creation of life by the ancient residents of Sanlin through our dishes?

Understanding: Do you think you draw inspiration and deepen your understanding of beauty from fabrics, porcelain carvings, and embroidery works?

Philosophy: Have you experienced the sustainable development concept of inheriting, integrating, and developing the intangible cultural heritage of the Three Forests?

Empathy: Would you be willing to travel to the ancient town of Sanlin in the early Ming Dynasty and see activities such as the Sanlin "March Half" Holy Temple Fair and the City God's Tour?

The second group of experimental subjects is a social audience, with a total of 19 participants. After introducing and clarifying the research objectives for the temporary recruitment of tourists on Sanlin Old Street, we verbally read out the consent form to the participants, and we conducted a digital exhibition task at the entrance of the Intangible Cultural Heritage Museum. Similar to the first experimental process, the social audience randomly experienced the other three virtual exhibitions. At the end of the experiment, participants did not take a questionnaire and only discussed and ranked the three types of interactions and visual effects, followed by detailed and enthusiastic semi-structured interviews.

4. Results

4.1. Questionnaire Experience Group

4.1.1. Questionnaire Results

To test the evaluation of participants on the interaction and special effects of three video modes, a Likert scale was used for evaluation, divided into seven dimensions: satisfaction, visual effect cognitive effectiveness, streaming experience interaction, aesthetic pleasure/empathy, cognitive accessibility, immersion, and system availability. We perform a Friedman test on each dimension. Each question in each dimension has five answers: "strongly agree", "agree", "not necessarily", "disagree", and "strongly disagree", recorded as 1, 2, 3, 4, and 5, respectively. For each dimension of the problem, we added up the scores obtained, and the total score can indicate the strength of the participants' attitudes in this dimension. For the statistical results in each dimension, the pairwise results are compared using p-values, and all the results are presented in charts and tables of test data. The statistical significance levels were reported using standard notation: * ($p < 0.05$) indicating a significant difference, ** ($p < 0.01$) indicating a highly significant difference, and *** ($p < 0.001$) indicating an extremely significant difference.

The Friedman test results of satisfaction are shown in the first row of Table 2, and the participants believe that there are differences between these three patterns, and there are differences between pairwise and pairwise. This dimension includes six questions, with a maximum score of 30 points, as shown in the average value in the first column of Figure 8. The participants are more willing to learn about the Three Forest Intangible Cultural Heritage project through binocular 180° panoramic videos.

The Friedman test results for visual cognitive validity are shown in the second row of Table 2, and the participants believe that there are differences between these three patterns, and there are differences between both pairs. This dimension includes five questions, with a maximum score of 25 points, as shown in the average value in the second column of Figure 8. Participants believe that binocular 180° panoramic videos can bring a richer depth of field and more complete spatial relationships.

The Friedman test results of flow experience interaction are shown in the third row of Table 2, and the participants believe that there is a difference between the three, and there is a difference between two pairs. This dimension includes five questions, with a maximum score of 25 points. As shown in the average value in the third column of Figure 8, the participants have depth perception ability in the binocular 180° panoramic video mode,

which is beneficial for them to better integrate into the surrounding environment and focus more on intangible cultural heritage content.

Table 2. Overall user experience results.

	Traditional		Monocular		Binocular	
Perspective	**Score**	**SD**	**Score**	**SD**	**Score**	**SD**
Satisfaction ***	14.12	4.54	22.24	3.09	28.94	1.92
Visual Cognitive Effectiveness ***	15.24	4.98	22.12	3.69	29.00	1.58
Streaming Experience Interaction ***	12.59	4.18	18.06	3.42	22.59	2.29
Aesthetic Pleasure ***	18.82	6.22	26.82	4.59	31.88	3.98
Cognitive Accessibility **	11.65	2.71	8.29	2.14	7.18	3.15
Immersion ***	11.82	3.71	18.82	2.98	23.23	2.49
System Availability ***	25.71	5.62	29.82	3.28	32.29	3.42

**: $p < 0.01$, ***: $p < 0.001$.

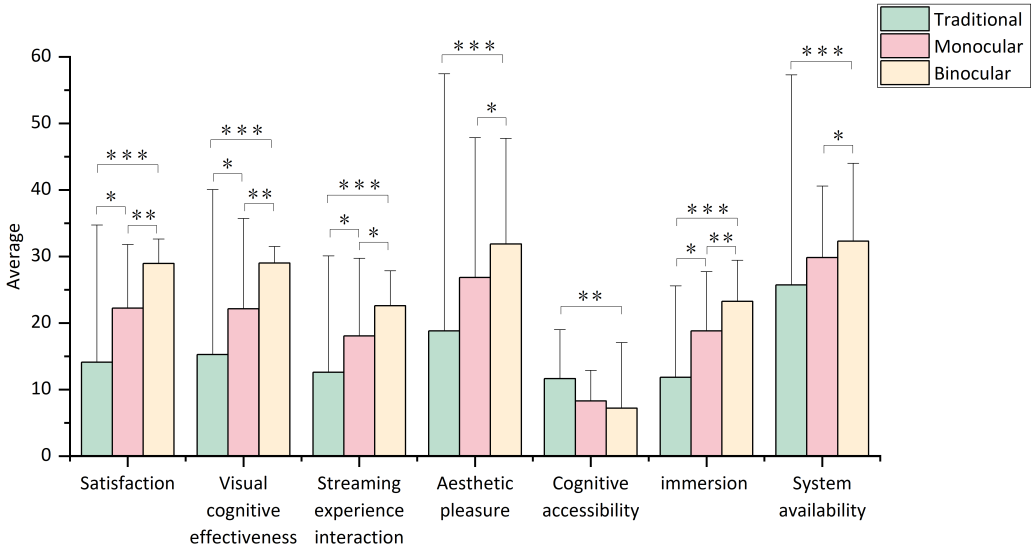

Figure 8. Average values of three modes in seven dimensions.

The Friedman test results of aesthetic pleasure/empathy are shown in the fourth row of Table 2. Participants believe that there is a difference between the three, but the difference between monocular mode and traditional mode is not significant. This dimension includes seven questions, with a maximum score of 35 points, as shown in Figure 8. Participants generally believe that in binocular panoramic mode, they can deepen their perception of beauty.

The Friedman test results for cognitive accessibility are shown in the fifth row of Table 2. Participants believe that there are differences among the three modes, but there is no significant difference between the traditional mode and the monocular mode or the monocular mode and the binocular mode. This dimension includes three questions, with a maximum score of 15 points, all of which are negative questions. The higher the score, the more energy the audience needs to spend on appreciating in this mode. As shown in the five column of Figure 8, participants can obtain more environmental information in binocular mode, providing a better visual experience, which allows them to spend less energy watching and concentrate more on experiencing appreciation.

The Friedman test results for immersion are shown in the sixth row of Table 2, and participants believe that there are differences between the three modes, and there are differences between the pairwise results. This dimension includes five questions, with a maximum score of 25 points, as shown in the six column of Figure 8. The participants

experience the highest level of immersion in binocular panoramic mode, as binocular panoramic videos can provide a wide field of view and high-resolution image quality, allowing viewers to immerse themselves more deeply into the environment and feel a more realistic immersion.

The Friedman test results for system availability are shown in the seventh row of Table 2. The participants believe that there are differences among the three modes, while there is not much difference between traditional video and monocular video. This dimension includes seven questions, with a maximum score of 35 points, as shown in the seven column of Figure 8. The participants generally believe that systems using binocular panoramic videos are simpler and easier to use.

4.1.2. Eye Tracking Results

The eye tracking technology used in this article can reveal the audience's concentration position during the viewing process, as shown in Figure 4b–d. These data help us understand which aspects of intangible cultural heritage are most attractive or culturally significant to the audience. Integrating eye tracking technology into panoramic videos of intangible cultural heritage, by utilizing the insights provided by eye tracking data, we can create a more attractive, informative, and accessible experience for the audience.

4.2. User Interviews

We went to the venues of five intangible cultural heritage projects to recruit tourists from the old street and have collected feedback from users who are willing to accept further interviews, as shown in Figure 9.

An aunt sitting in front of an old loom is learning step by step from the inheritor's 180° video with two eyes in the VR helmet, "just like the inheritor explained in front of me, the loom in the picture is very lifelike, just like in reality".

At the restaurant that specializes in local cuisine, we invited one of our customers to watch and give feedback. Regarding the 180° binocular video, she commented, "Being able to observe the cooking process so closely with the kitchen and explore the kitchen around is an unprecedented experience.". Regarding the traditional video on the iPad, her comment was, "I only saw a part of the picture, it seems like something was missing.".

In front of the embroidery workshop, we invited passing volunteers for face-to-face interviews. "The effect of the single 180° video is relatively dull, and the embroidery dragon in the double 180° video is not as lifelike.".

Overall, the audience's response to displaying intangible cultural heritage through different video formats may vary due to personal preferences, cultural background, and previous exposure to immersive technology. Although binocular stereoscopic videos are often praised for their immersive quality and depth perception, monocular stereoscopic videos and traditional videos can still provide valuable insights and perspectives, despite varying levels of interaction and immersion.

Figure 9. We have collected feedback from users who are willing to accept further interviews from five intangible cultural heritage sites.

5. Discussion

5.1. Sustainability

Compared to monocular 180° panoramic videos that lack deep understanding of binocular vision, the binocular 180° panoramic video mode mimics human binocular vision, providing a 3D immersive experience that allows viewers to perceive depth and dimension, enhancing their participation in cultural heritage. For example, in the context of traditional dragon dance performances, binocular 180° panoramic videos can reproduce the atmosphere and spatial dynamics, providing a more immersive and realistic viewing experience. This model preserves the essence of cultural practice while utilizing technology to make the experience more vivid and impactful. However, traditional videos are passive media, and the audience has almost no interactivity. In this video mode, the audience is limited to one perspective and cannot fully capture the spatial depth and atmosphere of the recorded cultural heritage. Unlike traditional videos that provide predetermined narrative or event sequences, binocular 180° panoramic videos allow viewers to explore the surrounding environment and control their perspective. This interactivity provides viewers with a more comprehensive spatial background and an immersive viewing experience.

With the development of the Internet and information technology, more and more cultural and educational resources are being produced, distributed and accessed in a digital form [47]. Binocular 180° panoramic video provides a dynamic and immersive way to record and protect digital intangible cultural heritage. They not only capture visual information but also capture spatial, auditory, and sensory elements of cultural practices, rituals, performances, and traditions, ensuring accurate representation and protection of intangible cultural heritage, contributing to the sustainability and resilience of cultural heritage.

The cultural sustainability of binocular 180° panoramic videos in protecting cultural heritage is reflected in their ability to capture and convey the emotional resonance and cultural significance of cultural heritage. A binocular 180° panoramic video provides viewers with an immersive and existential experience, allowing them to virtually experience cultural heritage, rituals, performances, and traditions as if they were personally present. This immersive quality establishes a profound connection between the audience and cultural experience, enhances the emotional resonance of the recorded heritage, evokes emotional responses from the audience, and cultivates cultural empathy.

Its economic sustainability is reflected in the fact that binocular 180° panoramic videos can be used for tourism promotion, virtual tourism, cultural activities, and digital storytelling activities, generating revenue sources to support the protection and revitalization of intangible cultural heritage. In addition, the production and distribution of these videos can create employment opportunities and stimulate the entrepreneurial spirit of the cultural sector.

Essentially, integrating binocular 180° panoramic videos into the inheritance of intangible cultural heritage can contribute to sustainable development by protecting, promoting, and revitalizing cultural practices in an inclusive, accessible, and economically feasible manner. By utilizing the power of technology while respecting the authenticity and values of cultural heritage, communities can ensure that their traditions continue to prosper and develop for future generations.

5.2. Cost Advantage Comparison

As shown in Figure 10, compared with other methods of reproducing historical relics or inheritors' physical movements such as photo modeling and motion capture, the cost advantage of binocular 180° panoramic video makes it a more cost-effective solution for protecting cultural heritage.

Photo modeling and binocular 180° panoramic videos are common methods for reproducing historical relics and sites. Compared to photo modeling methods, the initial investment in panoramic video equipment may be lower in terms of equipment cost compared to high-quality photogrammetric and motion capture equipment. Secondly,

in terms of labor costs, compared to photo modeling, panoramic video production typically requires less labor-intensive post-processing. Generating 3D models from photos typically involves complex stitching, alignment, and mesh reconstruction processes, which can be time-consuming and require skilled professionals. In contrast, panoramic video clips may require minimal editing or stitching, thereby reducing labor costs.

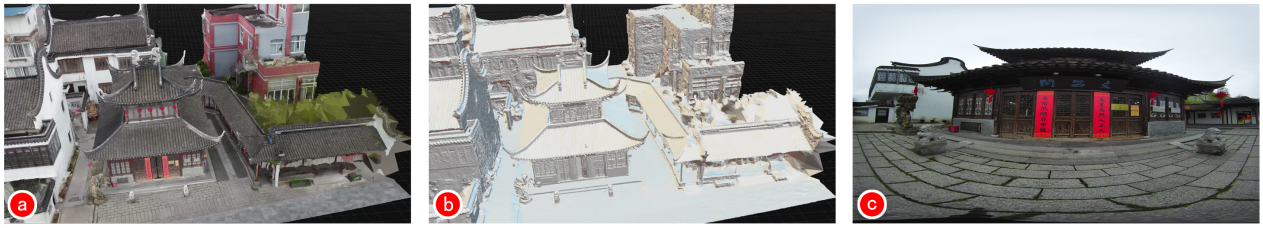

Figure 10. (**a**) The Wenchang Pavilion model generated from photos with added texture information. (**b**) The lost foam pattern of Wenchang Pavilion generated from photos. (**c**) A panoramic photo of the Wenchang Pavilion taken using 360VR.

Compared with the static model generated through photo modeling, the panoramic video captures the dynamics of the cultural heritage site, allowing viewers to experience the atmosphere of the cultural heritage site in real time. This dynamic presentation adds depth and richness to the viewing experience, making it more engaging and unforgettable.

Motion capture technology is a commonly used method for reproducing the body movements of inheritors [48]. Compared with motion capture technology, binocular 180° panoramic videos are usually more cost-effective in reproducing the body movements of inheritors. Firstly, in terms of equipment cost, motion capture typically involves more expensive equipment and professional facilities, while panoramic video equipment is more expensive. Secondly, in terms of shooting environment, motion capture needs to be carried out in a controlled environment, usually requiring the use of specialized sensors and camera equipment, as well as precise calibration and calibration processes. However, binocular 180° panoramic videos do not require complex environments and can be shot at any time. Finally, in terms of labor costs, motion capture technology requires a significant amount of time and human resources for data collection and processing. In contrast, the production cost of shooting binocular 180° panoramic videos is lower, requiring only some basic post-processing.

As shown in Figure 11, compared with the inheritor's body movements generated by motion capture, the binocular 180° panoramic video provides a more realistic and immersive representation of cultural heritage sports. Through panoramic videos, viewers can experience actions from various angles and perspectives, simulating the feeling of the scene. This immersive experience enhances the audience's understanding and appreciation of cultural heritage.

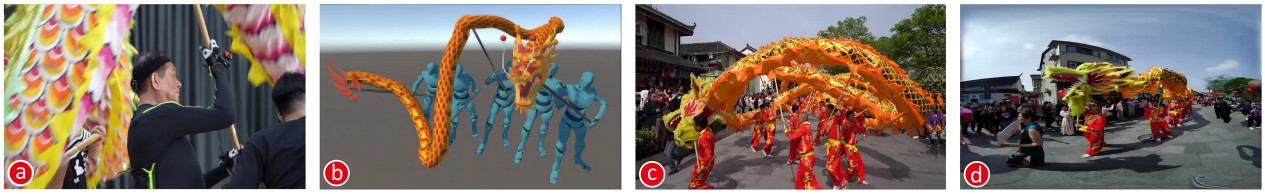

Figure 11. (**a**) The professional dragon dancers we hired for motion capture are currently performing. (**b**) We convert the captured dragon dance movements into digital data and animation and apply them to cartoon characters. (**c**) The dragon dance performance photos we took at the Sanlin Temple Fair. (**d**) A frame from the panoramic video of the dragon dance performance taken using 3D180VR.

5.3. Challenges

Although binocular 180° panoramic videos provide innovative opportunities for the inheritance of cultural heritage, there may be some challenges in their application.

The binocular 180° panoramic video provides an immersive experience, while ensuring accessibility and inclusiveness for all viewers, including those with disabilities or limited access to technology, is a challenge. Meeting different needs and preferences while maintaining a high-quality immersive experience may require careful planning and investment.

In addition, ensuring the long-term sustainability and maintenance of binocular panoramic videos as heritage assets poses challenges. Heritage organizations and communities need to develop strategies for regularly updating and maintaining content, and strive for funding for ongoing conservation work.

Addressing these challenges requires collaboration among heritage professionals, technicians, community stakeholders, and policy makers. By identifying technical, financial, ethical, and cultural solutions, applying binocular panoramic videos to the inheritance of material cultural heritage can contribute to the protection, interpretation, and sustainable management of future generations.

6. Conclusions and Future Work

Historical buildings and cultural relics are still life, and people are eager to appreciate them from various perspectives, with the characteristic of appreciating stillness through movement. The production and performance process of intangible cultural heritage inheritors is dynamic, with several optimal experiential perspectives that are characterized by static appreciation and dynamic performance. This lays a visual psychological foundation for the fixed pilot of three-dimensional panoramic visual effects.

In the process of rebuilding intangible cultural heritage projects, the use of 3D scanning and motion capture technology can abstractly replicate the actions, works, and environment of inheritors. However, the virtual reconstruction method is costly, has limited reconstruction accuracy, lacks real light and shadow, and lacks the realism of characters and environments. The use of the three-dimensional panoramic video shooting method in this article can realistically restore the appearance, expressions, actions, and real environment of characters under the premise of low-cost production. The only drawback is the fixed viewpoint viewing. However, on the basis of a static and dynamic visual psychology, fixed viewpoints are still the visual psychological habit of most viewers watching production and performance.

Oasis is a place to archive and showcase intangible cultural heritage, so that future generations can continue to use production and performance techniques. Our findings provide a new perspective for technology in the field of intangible cultural heritage protection and emphasize the necessity of incorporating VR technology into the promotion of intangible cultural heritage.

The future research will further explore the application of technology, investigate the use of oasis technology by students and audiences to experience the learning interest of intangible cultural heritage projects, and evaluate its effectiveness in the intangible cultural heritage education environment, especially in enhancing students' hands-on learning experience.

Author Contributions: Conceptualization, R.Y.; methodology, R.Y. and F.T.; software, R.Y.; validation, H.X.; formal analysis, R.Y.; investigation, Y.W.; writing—original draft preparation, R.Y. and F.T.; writing—review and editing, Y.L. and Q.Z.; resource, Y.S.; visualization, N.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article material, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Di Giovine, M.A. *The Heritage-Scape: UNESCO, World Heritage, and Tourism*; Lexington Books: Lanham, MD, USA , 2008.
2. Hajirasouli, A.; Banihashemi, S.; Kumarasuriyar, A.; Talebi, S.; Tabadkani, A. Virtual reality-based digitisation for endangered heritage sites: Theoretical framework and application. *J. Cult. Herit.* **2021**, *49*, 140–151. [CrossRef]
3. Ch'Ng, E.; Li, Y.; Cai, S.; Leow, F.T. The effects of VR environments on the acceptance, experience, and expectations of cultural heritage learning. *J. Comput. Cult. Herit. (JOCCH)* **2020**, *13*, 1–21. [CrossRef]
4. Corrales-Serrano, M.; Merchán, P.; Merchán, M.J.; Pérez, E. Virtual Reality Applied to Heritage in Higher Education—Validation of a Questionnaire to Evaluate Usability, Learning, and Emotions. *Heritage* **2024**, *7*, 2792–2810. [CrossRef]
5. Duan, Z. Research on the Sustainable Development of Image recording Intangible Cultural Heritage in the context of Visual Culture. In Proceedings of the 2020 2nd International Conference on Humanities, Cultures, Arts and Design (ICHCAD 2020), Sydney, Australia, 18–20 December 2020.
6. Yastikli, N. Documentation of cultural heritage using digital photogrammetry and laser scanning. *J. Cult. Herit.* **2007**, *8*, 423–427. [CrossRef]
7. Rubens, T.; Ribeiro, G.; Moreira, E.; Vieira, M.; Mesquita, E. Digitization of historical heritage: Nossa Senhora do Rosário Church, Aracati-CE. *J. Build. Pathol. Rehabil.* **2023**, *8*, 71. [CrossRef]
8. Baik, A.; Almaimani, A.; Al-Amodi, M.; Rahaman, K.R. Applying digital methods for documenting heritage building in Old Jeddah: A case study of Hazzazi House. *Digit. Appl. Archaeol. Cult. Herit.* **2021**, *21*, e00189. [CrossRef]
9. Lambers, K.; Eisenbeiss, H.; Sauerbier, M.; Kupferschmidt, D.; Gaisecker, T.; Sotoodeh, S.; Hanusch, T. Combining photogrammetry and laser scanning for the recording and modelling of the Late Intermediate Period site of Pinchango Alto, Palpa, Peru. *J. Archaeol. Sci.* **2007**, *34*, 1702–1712. [CrossRef]
10. Andrés, A.N.; Pozuelo, F.B.; Marimón, J.R.; de Mesa Gisbert, A. Generation of virtual models of cultural heritage. *J. Cult. Herit.* **2012**, *13*, 103–106. [CrossRef]
11. Alshawabkeh, Y.; El-Khalili, M.; Almasri, E.; Bala'awi, F.; Al-Massarweh, A. Heritage documentation using laser scanner and photogrammetry. The case study of Qasr Al-Abidit, Jordan. *Digit. Appl. Archaeol. Cult. Herit.* **2020**, *16*, e00133. [CrossRef]
12. Selim, G.; Jamhawi, M.; Abdelmonem, M.G.; Ma'bdeh, S.; Holland, A. The virtual living museum: Integrating the multi-layered histories and cultural practices of Gadara's archaeology in Umm Qais, Jordan. *Sustainability* **2022**, *14*, 6721. [CrossRef]
13. Carvajal, D.A.L.; Morita, M.M.; Bilmes, G.M. Virtual museums. Captured reality and 3D modeling. *J. Cult. Herit.* **2020**, *45*, 234–239. [CrossRef]
14. Xu, J.; Du, Q.; Xue, J. Digital Virtual Museum. In Proceedings of the 2020 International Conference on Virtual Reality and Visualization (ICVRV), Recife, Brazil, 13–14 November 2020; pp. 344–345.
15. Jonauskaite, D.; Dael, N.; Baboulaz, L.; Chèvre, L.; Cierny, I.; Ducimetière, N.; Fekete, A.; Gabioud, P.; Leder, H.; Vetterli, M.; et al. Interactive digital engagement with visual artworks and cultural artefacts enhances user aesthetic experiences in the laboratory and museum. *Int. J. Hum.-Interact.* **2024**, *40*, 1369–1382. [CrossRef]
16. Brown, A.; Xu, Q.; Moleta, T.; Schnabel, M.; Rogers, M. Inhabiting'Prosperous Suzhou'through Smart VR-Interrogating an Ancient Artwork and Documents to manifest Tangible and Intangible Heritage. In Proceedings of the 25th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA), Online, 5–8 August 2020; Volume 2, pp. 173–182.
17. Wu, L.; Yu, R.; Su, W.; Ye, S. Design and implementation of a metaverse platform for traditional culture: The chime bells of Marquis Yi of Zeng. *Herit. Sci.* **2022**, *10*, 193. [CrossRef]
18. Murtiyoso, A.; Grussenmeyer, P. Documentation of heritage buildings using close-range UAV images: Dense matching issues, comparison and case studies. *Photogramm. Rec.* **2017**, *32*, 206–229. [CrossRef]
19. Atik, M.E.; Duran, Z.; Yanalak, M.; Seker, D.Z.; Ak, A. 3D modeling of historical measurement instruments using photogrammetric and laser scanning techniques. *Digit. Appl. Archaeol. Cult. Herit.* **2023**, *30*, e00286. [CrossRef]
20. Sapirstein, P. Accurate measurement with photogrammetry at large sites. *J. Archaeol. Sci.* **2016**, *66*, 137–145. [CrossRef]
21. McCarthy, J. Multi-image photogrammetry as a practical tool for cultural heritage survey and community engagement. *J. Archaeol. Sci.* **2014**, *43*, 175–185. [CrossRef]
22. Iudova-Romanova, K.; Humenyuk, T.; Horevalov, S.; Honcharuk, S.; Mykhalov, V. Virtual reality in contemporary theatre. *ACM J. Comput. Cult. Herit.* **2023**, *15*, 1–11. [CrossRef]
23. Skublewska-Paszkowska, M.; Milosz, M.; Powroznik, P.; Lukasik, E. 3D technologies for intangible cultural heritage preservation—literature review for selected databases. *Herit. Sci.* **2022**, *10*, 3. [CrossRef]
24. Carrozzino, M.; Bergamasco, M. Beyond virtual museums: Experiencing immersive virtual reality in real museums. *J. Cult. Herit.* **2010**, *11*, 452–458. [CrossRef]
25. Blanco-Pons, S.; Carrión-Ruiz, B.; Lerma, J.L.; Villaverde, V. Design and implementation of an augmented reality application for rock art visualization in Cova dels Cavalls (Spain). *J. Cult. Herit.* **2019**, *39*, 177–185. [CrossRef]

26. De Luca, V.; Barba, M.C.; D'Errico, G.; Nuzzo, B.L.; De Paolis, L.T. A user experience analysis for a mobile Mixed Reality application for cultural heritage. *Virtual Real.* **2023**, *27*, 2821–2837. [CrossRef]
27. Panou, C.; Ragia, L.; Dimelli, D.; Mania, K. An architecture for mobile outdoors augmented reality for cultural heritage. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 463. [CrossRef]
28. Güleç, Ö.; Nagakura, T.; Vlavianos, N. Augmented reality (AR) of historic environments: Representation of parion theater, Biga, Turkey. *ITU A | Z* **2016**, *13*, 185–193. [CrossRef]
29. Duguleana, M.; Voinea, G.D. Enhancing the experience of visiting outdoor heritage sites using handheld AR. In *HCI International 2018–Posters' Extended Abstracts, Proceedings of the 20th International Conference, HCI International 2018, Las Vegas, NV, USA, 15–20 July 2018*; Proceedings, Part III 20; Springer: Cham, Switzerland, 2018; pp. 184–191.
30. O'dwyer, N.; Zerman, E.; Young, G.W.; Smolic, A.; Dunne, S.; Shenton, H. Volumetric video in augmented reality applications for museological narratives: A user study for the long room in the library of trinity college dublin. *J. Comput. Cult. Herit. (JOCCH)* **2021**, *14*, 1–20. [CrossRef]
31. Hammady, R.; Ma, M.; Strathern, C.; Mohamad, M. Design and development of a spatial mixed reality touring guide to the Egyptian museum. *Multimed. Tools Appl.* **2020**, *79*, 3465–3494. [CrossRef]
32. Chen, H.R.; Lin, W.S.; Hsu, T.Y.; Lin, T.C.; Chen, N.S. Applying smart glasses in situated exploration for learning english in a national science museum. *IEEE Trans. Learn. Technol.* **2023**, *16*, 820–830. [CrossRef]
33. Hammady, R.; Ma, M.; Al-Kalha, Z.; Strathearn, C. A framework for constructing and evaluating the role of MR as a holographic virtual guide in museums. *Virtual Real.* **2021**, *25*, 895–918. [CrossRef]
34. Aoki, S.; Itabashi, N.; Adha, R.; Sameshima, S.; Kinoshita, Y.; Kotoku, T. Mixed Reality Guided Museum Tour: Digital Enhancement of Museum Experience. In Proceedings of the 2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), Shanghai, China, 25–29 March 2023; pp. 809–810.
35. Rahimi, F.B.; Boyd, J.E.; Levy, R.M.; Eiserman, J. New media and space: An empirical study of learning and enjoyment through museum hybrid space. *IEEE Trans. Vis. Comput. Graph.* **2020**, *28*, 3013–3021. [CrossRef]
36. Kim, K.; Kwon, O.; Yu, J. Evaluation of an HMD-based Multisensory Virtual Museum Experience for Enhancing Sense of Presence. *IEEE Access* **2023**, *11*, 100295–100308. [CrossRef]
37. De Paolis, L.T.; Faggiano, F.; Gatto, C.; Barba, M.C.; De Luca, V. Immersive virtual reality for the fruition of ancient contexts: The case of the archaeological and Naturalistic Park of Santa Maria d'Agnano in Ostuni. *Digit. Appl. Archaeol. Cult. Herit.* **2022**, *27*, e00243. [CrossRef]
38. Rizvic, S.; Boskovic, D.; Bruno, F.; Petriaggi, B.D.; Sljivo, S.; Cozza, M. Actors in VR storytelling. In Proceedings of the 2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Vienna, Austria, 4–6 September 2019; pp. 1–8.
39. Alatrash, S.; Arnab, S.; Antlej, K. Communicating engineering heritage through immersive technology: A VR framework for enhancing users' interpretation process in virtual immersive environments. *Comput. Educ. X Real.* **2023**, *3*, 100040. [CrossRef]
40. Mulders, M.; Träg, K.H. Presence and Flow as Moderators in XR-Based Sustainability Education. *Sustainability* **2023**, *15*, 16496. [CrossRef]
41. Vlizos, S.; Kotsopoulos, K.; Christodoulou, D. Enhancing Cultural Sustainability: Making Rescue Excavations Accessible through Educational Applications and Virtual Reality. *Sustainability* **2024**, *16*, 1439. [CrossRef]
42. Kim, J.; Kim, K.; Kim, W. Impact of immersive virtual reality content using 360-degree videos in undergraduate education. *IEEE Trans. Learn. Technol.* **2022**, *15*, 137–149. [CrossRef]
43. Rusnak, M. 2D and 3D representation of objects in architectural and heritage studies: In search of gaze pattern similarities. *Herit. Sci.* **2022**, *10*, 86. [CrossRef]
44. Mah, O.B.P.; Yan, Y.; Tan, J.S.Y.; Tan, Y.X.; Tay, G.Q.Y.; Chiam, D.J.; Wang, Y.C.; Dean, K.; Feng, C.C. Generating a virtual tour for the preservation of the (in) tangible cultural heritage of Tampines Chinese Temple in Singapore. *J. Cult. Herit.* **2019**, *39*, 202–211. [CrossRef]
45. Verhulst, I.; Woods, A.; Whittaker, L.; Bennett, J.; Dalton, P. Do VR and AR versions of an immersive cultural experience engender different user experiences? *Comput. Hum. Behav.* **2021**, *125*, 106951. [CrossRef]
46. Cai, S.; Wang, X.; Chiang, F.K. A case study of Augmented Reality simulation system application in a chemistry course. *Comput. Hum. Behav.* **2014**, *37*, 31–40. [CrossRef]
47. Ruan, J.; McDonough, J.P. Preserving born-digital cultural heritage in virtual world. In Proceedings of the 2009 IEEE International Symposium on IT in Medicine & Education, Jinan, China, 14–16 August 2009; Volume 1, pp. 745–748.
48. Chan, J.C.; Leung, H.; Tang, J.K.; Komura, T. A virtual reality dance training system using motion capture technology. *IEEE Trans. Learn. Technol.* **2010**, *4*, 187–195. [CrossRef]