

# Immersive VR Museums: The Experience Pathways and Future Prospects in the Digital Dissemination of Cultural Heritage

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**Abstract:** With the continuous advancement of digital technology, Virtual Reality (VR) is gradually becoming an essential tool for the presentation and dissemination of cultural heritage. This paper focuses on the application of immersive VR in museum settings, exploring its practical value in digital reconstruction, interactive experience, and intelligent navigation. Through case studies and user experience research, it reveals how immersion, personalized recommendation, and social interaction contribute to enhancing communication effectiveness. It also identifies several challenges, including hardware barriers, limited interactivity, and difficulties in maintaining authenticity. Finally, the paper proposes future-oriented strategies such as lightweight technology development, AI integration, and accessibility optimization, aiming to offer practical pathways and theoretical guidance for the digital transformation of cultural heritage.

## 1 INTRODUCTION

Nowadays, tangible cultural heritage such as historic buildings, artifacts, and artworks faces multiple threats, including aging, war, natural disasters, and human-caused damage. For example, the fire at Notre-Dame Cathedral on April 15, 2019 caused severe structural damage. Without proper attention to digital preservation, more physical heritage may be permanently lost. Traditional preservation methods are often insufficient when dealing with large-scale and diverse cultural assets. As a result, digital technologies have emerged as crucial tools for the preservation and dissemination of cultural heritage. Virtual Reality (VR) focuses on constructing entirely virtual environments, enabling users to feel as though they are transported into another world. VR breaks traditional spatial limitations, placing greater emphasis on using interaction to enhance users' understanding and perception of their surroundings. This leads to a more deeply immersive experience (Malraux, 1974). This study aims to examine the experiential value and communication potential of immersive VR museums in the digital transformation of cultural heritage. It begins with an exploration of the definition and development of immersive VR museums, followed by case analyses of VR museum practices worldwide. The study also explores their

technical features and user experience, as well as the challenges currently faced by VR technology, and discusses its potential future directions. These questions will be addressed through case studies, user experience research, and literature review. Finally, the study proposes future development directions and optimization strategies based on existing findings. On one hand, the research involves reviewing relevant domestic and international studies, policy documents, and projects, to summarize the current state of technology and implementation approaches; on the other hand, it draws on feedback and user data from representative VR museum projects, to analyze user perception and behavior within virtual cultural spaces.

## 2 DEFINITION AND CURRENT DEVELOPMENT STATUS OF IMMERSIVE VR MUSEUMS

### 2.1 Concept and Types of VR Museums

With the rapid advancement of technology especially Virtual Reality (VR) many traditional museums have begun offering digital tours, creating their own "virtual museums." Visitors can use VR headsets and

similar devices to explore and experience museums. Museums vary in type and house diverse collections, serving as significant symbols of human cultural achievements. However, no single museum in the world can encompass the entirety of global culture and history. Many artifacts and artworks are difficult to transport or preserve due to their fragile materials or structural complexity—such as stained glass or wall frescoes. Others have changed hands over time due to historical transitions or power shifts, such as art collections formed during colonial periods. These factors have led major museums around the world to develop unique collections and cultural identities, shaped by their specific historical and regional contexts (Shitao,2015). It is evident that museums worldwide each possess distinct characteristics. For ordinary individuals, visiting museums in different countries poses challenges not only in terms of time but also financially. The adoption of VR and similar technologies in museums, brings exciting opportunities for the public. Those who enjoy visiting museums can now experience them from home, without the need to travel across the globe. Digital media refers to forms of media that record, process, distribute, and receive information in digital formats. It includes digitized forms of text, images, graphics, audio, video, animations, and other media types, collectively referred to as “logical media.” It also encompasses the physical media used to store, transmit, and display such digital content. Digital media relies on several core technologies, such as information acquisition and output, content processing and generation, network transmission, as well as information retrieval and security mechanisms. These technologies transform abstract information into formats that are perceptible, operable, and interactive for users, thereby enabling more efficient communication and application (Zhang,2020).

## **2.2 The Main Form of VR Museum**

### **2.2.1 Virtual Navigation**

Within the overall positioning of a museum, guided tours are not only a key component of professional service, but also serve as tools for image-building and cultural branding. An appealing institutional image can effectively attract the general public to visit. Detailed and thoughtful guided explanations help establish the museum’s authority in educational communication, thereby fulfilling the goal of combining education with entertainment. To ensure a smooth tour experience, the explanatory features

embedded in the guidance process are especially important, as they enable visitors to efficiently grasp the cultural and historical meanings of exhibits within a limited time frame (Dai,2010). The emergence of virtual tours not only helps reduce the cost of human staffing, but also ensures that every visitor receives equally professional and standardized service. With virtual tour systems in place, the guidance process becomes smoother, allowing visitors to efficiently comprehend the cultural and historical narratives conveyed by the exhibits.

### **2.2.2 Interactive Experience**

It is evident that the core technologies of digital museums—such as information acquisition and output, network communication, and content generation—transform data into systems that are easy for users to operate. These systems enable seamless human-computer interaction. Interactive media facilitate multisensory communication, supporting the contextualized presentation of cultural artifacts, and enabling the visualization of dynamic historical or cultural processes, thereby enhancing the vitality of exhibitions and enriching the overall museum experience (Yu,1999). The emergence of digital cultural heritage allows extracted information to be re-presented in forms more readily accepted by users, and its capacity for multisensory interaction marks a significant milestone, allowing heritage to be experienced in new and engaging digital forms.

## **2.3 Technical Support of VR Museum**

### **2.3.1 3D Modeling**

There are generally two main approaches to constructing digital models: The first involves using 3D scanning devices to capture physical objects with high precision, directly producing digital 3D models. This method excels at reproducing fine physical details, but it requires costly equipment and demands a high level of technical expertise for post-processing, and is therefore more commonly used in professional fields such as visual effects. The second approach is to manually construct models using 3D modeling software. While this method requires relatively minimal hardware and software investment, it places greater demands on the spatial awareness and modeling skills of the designer. It is commonly employed in architecture, exhibition planning, and film production. For digital museum applications, combining 3D scanning with software-based modeling techniques provides a balance between

model quality, cost, and efficiency, and is currently considered one of the most practical modeling strategies (Wang,2015). Although 3D scanners are convenient and capable of high-fidelity reproduction, they require substantial financial investment and present challenges in data processing. Therefore, for most 3D museums, the most feasible modeling approach is manual creation using modeling software.

### 2.3.2 Panoramic Image

Panoramic imaging is a technique that captures real-world scenes from multiple angles and stitches them together to create immersive visual content. Compared with traditional static images, this technology offers a full 360-degree field of view, and comprehensively presents authentic details of the physical environment. As a result, viewers experience an enhanced sense of space and presence. Owing to its ability to reproduce every corner of a scene with high fidelity, it is widely applied in tourist attractions, cultural exhibitions, and display environments. Viewers feel as though they are standing at the center of the exhibition, surrounded by artifacts and spatial structures. This creates a powerful immersive experience (Lin & Fang,2022). It can thus be concluded that this technology significantly enriches the visitor experience, enabling a compelling presentation of cultural heritage. It not only overcomes the limitations of static imagery, but also offers a practical and cost-effective solution for immersive digital exhibition.

### 2.3.3 AI Guide

As VR museums continue to evolve, Artificial Intelligence (AI)-powered guide systems have emerged as a key component of smart services, gradually reshaping how visitors engage with exhibitions. For instance, the “Elegant Gathering AR Experience” project at the National Palace Museum in Taiwan illustrates this trend. This service integrates 5G high-speed connectivity with AI-based spatial recognition, using Microsoft HoloLens smart glasses to deliver a wearable Augmented Reality (AR) tour experience. By incorporating machine learning features supported by Google TensorFlow, the system can identify exhibit spaces and artifacts, accurately detecting the user’s location and object of interest. It then transmits relevant audio explanations and visual content back to the wearable device via the 5G network, enabling a responsive and immersive storytelling experience around the artifacts (Kennedy,2015). This reflects a shift from traditional museum tours that rely on human guides or fixed

audio devices, toward intelligent systems featuring “automatic recognition + real-time response.” AI-guided systems are becoming essential in enhancing visitor interaction within digital museum environments. Compared to conventional methods dependent on staff or pre-recorded audio, AI systems demonstrate superior environmental awareness and real-time responsiveness. They can automatically determine a visitor’s location and focus based on their movement and gaze direction, and actively deliver corresponding audio, image, or animated content for interpretation.

## 3 CASE STUDY: THE PRACTICE OF VR MUSEUMS WORLDWIDE

### 3.1 VR at the British Museum: Remote Access and Digital Interaction

In August 2015, the British Museum hosted its first Virtual Reality (VR) themed weekend event, allowing visitors to immerse themselves in a reconstructed Bronze Age roundhouse from approximately 4,000 years ago. The event aimed to integrate authentic artifacts with advanced 3D modeling technology in order to enhance visitors’ engagement with and understanding of the museum’s collections. This initiative was also part of the museum’s broader efforts to explore the educational potential of VR environments for children, teenagers, and families (Edwards & Wajid,2016). This demonstrates that the integration of 3D modeling with physical artifacts yields impressive results, enabling the British Museum to go beyond the constraints of traditional exhibitions, offering visitors an immersive experience of historical scene reconstruction, which perfectly illustrates the value of immersive technology in cultural institutions.

### 3.2 The Louvre VR Experience: Innovation in the Immersive Exhibition of the Mona Lisa

To commemorate the 500th anniversary of Leonardo da Vinci’s death, the Louvre Museum partnered with HTC VIVE Arts to launch its first virtual reality art project, Mona Lisa: Beyond the Glass. Utilizing VR technology, the project allows visitors to engage with the world-famous painting in an immersive manner, enabling close-up observation of the canvas texture, pigment layers, and the three-dimensional

reconstruction of the background. By constructing a virtual environment, the experience removes the physical barriers of the display case, and provides access to the painting's historical context, compositional structure, and the artist's creative intentions, resulting in a deeper visual and cognitive interaction with the artwork (Bakre & Doulatramani, 2017). It is evident that this VR initiative marks a significant innovation in traditional modes of art presentation. The involvement of virtual reality liberates artworks from the constraints of display cases, shifting toward more interactive and immersive forms of digital communication. This empowers visitors to gain deeper insights into the painting, free from spatial limitations, and to appreciate it in a fully immersive manner.

### **3.3 VR Experience in the Palace Museum: Digital Restoration Exploration of Traditional Culture**

In recent years, the Palace Museum has actively explored the application of digital technologies in the preservation and dissemination of cultural heritage. In 2019, the museum partnered with Tencent to launch a project based on artificial intelligence and cloud computing, aiming to advance the digital acquisition and virtual reconstruction of artifacts. According to official data, more than 100,000 cultural relics in the museum's collection have been digitally modeled with high precision, and visualized in three dimensions on virtual reality platforms. With the aid of VR devices, users can take immersive tours through iconic architectural complexes such as the Hall of Supreme Harmony (Taihe Dian). This enables a more intuitive understanding of the artifacts' structural characteristics and their underlying historical and cultural significance. This initiative not only broadens the digital dissemination channels for traditional culture, but also strengthens public engagement and cultural identity (Pine & Gilmore, 1998).

## **4 TECHNICAL CHARACTERISTICS AND USER EXPERIENCE OF IMMERSIVE VR MUSEUM**

### **4.1 Interaction Modes**

Virtual tours are a form of digital presentation that recreates real-world spaces using 360-degree

panoramic images or videos. These visuals are either captured using 360-degree cameras or composed by stitching together multiple real-world photographs from various angles. This approach enables users to gain an immersive perception of a physical site without leaving their home (Sparacino, 2002). This interactive mode allows users to virtually visit museums from home, and the emergence of 360-degree navigation has effectively removed temporal and geographical constraints. It also offers more flexible ways for audiences to engage with exhibitions. By reconstructing realistic scenes, this technology provides an immersive and contactless remote access experience for users, thereby extending the methods of cultural space presentation and dissemination.

### **4.2 Immersion and Engagement: How to Improve User Experience**

Immersion is a critical factor that bridges aesthetic experience and escapism, and it often forms an inseparable part of the overall experience in both real and virtual environments (Cheng & Pan, 2024). Therefore, enhancing immersion is essential for improving user experience, allowing users to feel fully present within the environment. When users perceive a VR art exhibition as closely resembling a real-life visit, their perceived usefulness and immersive quality of the experience—particularly in terms of aesthetic enjoyment and escapism—are significantly heightened (Sparacino, 2002). The most effective way to enhance user experience is to simulate reality as closely as possible. By maximizing realism, users can achieve a fully immersive museum exploration experience.

### **4.3 The Educational Function of VR Museum: How to Enhance Learning Effect**

This wearable museum device consists of a lightweight processor housed in a portable shoulder-mounted backpack, and is equipped with a monocular, VGA-resolution color display attached to a pair of headphones. After a brief period of adaptation, the user's brain naturally merges the real-world image seen by the uncovered eye with the virtual image projected to the other eye, resulting in a fused augmented reality (AR) overlay. Additionally, the device includes a custom-designed long-range infrared positioning sensor system which tracks the visitor's location and duration of stay within the exhibition space. To overcome limitations of

commercial infrared systems such as short range and narrow angle the research team developed a dedicated tracking solution tailored to museum spatial environments (Li & Lv,2024). Using sensor-enabled wearable devices, museums can monitor visitors' movement paths and dwell times in real time, enabling the delivery of more personalized and context-aware tour content. This technological approach not only enhances the immersive experience, but also facilitates a higher degree of interactivity and precision in cultural communication. In the context of virtual museums, visitors shift from passive recipients to active explorers. Through interactive operations and immersive visual environments, they engage more deeply in the learning process, thereby stimulating their curiosity and desire for knowledge.

#### **4.4 User Acceptance: Factors Affecting the Long-Term Use of VR Museums**

Studies have shown that users' acceptance of virtual reality (VR) museum technologies is primarily influenced by experiential factors such as interactivity, immersion, and presence. These experiences not only strengthen users' understanding and trust in the technology, but also positively affect perceived ease of use, enjoyment, and usefulness, thereby increasing users' willingness to use the technology and their intention to revisit. Immersion, in particular, has been empirically shown to have a significant positive correlation with the perceived usefulness of the technology. Meanwhile, smooth system navigation and operational stability are also considered critical conditions, as they directly affect the reduction of cognitive load and the optimization of the overall experience (Hazarika & Rahmati,2023). Whether users are willing to engage with VR museums in the long term often depends on their overall perception of immersion, interactivity, and system fluidity. These key factors jointly influence users' enthusiasm and their intention for continued use. From the perspective of technology acceptance models, experiential factors such as immersion and interactivity, are central variables affecting users' willingness to engage with VR museums. These factors typically work by enhancing users' perceptions of system usefulness and enjoyment, thus indirectly promoting their adoption and continued use of the technology.

## **5 CURRENT CHALLENGES: LIMITATIONS OF VR MUSEUMS AND DIRECTIONS FOR IMPROVEMENT**

### **5.1 Technology and Hardware Threshold**

These issues are exacerbated by the limitations of current hardware devices, such as VR headsets, which are often bulky and uncomfortable to wear, and prolonged use can cause fatigue (Kumar & Devi,2023). The limitations of hardware are unlikely to be resolved in the short overcoming them remains a significant challenge. To address fatigue and discomfort from extended wear, miniaturization of hardware is essential. The high cost of VR equipment also impacts user participation, as many potential visitors may not be able to afford such devices, thereby limiting the audience reach of VR experiences. Therefore, reducing hardware costs and improving accessibility, as well as developing VR content suitable for low-end devices, have become urgent issues for the VR museum sector (Kim,2023). The relatively high price of VR devices and the lack of widespread technological adoption are major obstacles to the implementation of VR technologies in museums, and they significantly hinder deeper user engagement. In response to the current challenges of high cost and technical barriers, lowering hardware costs and creating VR content compatible with mid-to-low-end systems have become critical strategies for promoting the broader adoption of virtual museums.

### **5.2 Lack of Interactivity**

Although online museum tours offer a high degree of visual realism, they still lack behavioral authenticity. Researchers have emphasized the need to enhance interactivity, which is likely tied to qualitative improvements in the sense of presence. Enhancing interactivity in VR exhibitions can significantly increase users' sense of presence and satisfaction, thereby boosting their overall engagement (Brusaporci,2021). In the experience of visiting virtual museums, interactive features serve as a crucial link between visual presentation and user behavioral response. They play a central role in constructing a sense of realism and enhancing participation. Although current visual simulation technologies have reached a high level, the lack of sufficient interactive design remains a major barrier

to immersive experiences. Therefore, improving the quality of interaction between users and virtual systems has become a critical direction for optimizing the overall user experience. Relevant studies also indicate that user engagement often depends on the richness of interactive content and the flexibility of response mechanisms, both of which directly affect user satisfaction and intention for continued use.

### 5.3 Cultural Authenticity and the Ethical Issues of Digital Restoration

In the process of digitally reconstructing cultural heritage, overreliance on technological means to create a “pseudo-reality” should be avoided. Without sufficient historical evidence, reconstructed content may mislead audiences regarding historical facts, thereby affecting the public’s accurate understanding of cultural memory (Ciolfi & Petrelli, 2023). During the digital restoration of cultural heritage, finding a balance between technological presentation and historical authenticity has become a major ethical challenge for virtual museum exhibitions. The widespread application of virtual technologies in artifact restoration has indeed improved visual presentation, but without rigorous historical documentation, such presentations risk deviating from the original cultural context, potentially misleading viewers and contributing to the spread of inaccurate historical impressions.

## 6 FUTURE TRENDS

### 6.1 Integration of AI and VR: Intelligent Navigation and Personalized Recommendation

In the context of virtual reality (VR) museums, personalized visit experiences have emerged as a key strategy to enhance user engagement and satisfaction. Relevant studies suggest that combining artificial intelligence (AI) with Internet of Things (IoT) technologies, such as implementing voice-based navigation systems like “Vocal Museum” in conjunction with indoor positioning features, can provide location-based, personalized commentary for visitors, while also better responding to individual user needs and preferences. At the content design level, voice interaction systems should balance the richness of information with alignment to user expectations, thereby creating a more immersive cultural experience. Overall, the integration of AI and

VR is driving a structural transformation in museum guide systems, offering new pathways for intelligent cultural heritage dissemination (Fernandez-Palacios & Remondino, 2021). In the construction of future digital museums, AI-driven personalized tour systems will play a critical role in enhancing immersion and engagement, and serve as a vital technological approach for the precise dissemination of cultural heritage.

### 6.2 Web VR and Lightweight Applications: Improving Accessibility and Popularity

Many virtual reality (VR) cultural heritage projects still heavily rely on high-performance hardware, such as head-mounted displays and motion tracking systems, which limits widespread use among the general public, especially among institutions with limited educational resources, older adults, and users with physical disabilities. To expand audience reach, system design should support compatibility with multiple device types, including smartphones, tablets, and standard personal computers. Research also highlights the importance of integrating accessibility features at the early stages of system development, such as voice navigation, screen readers, simplified interfaces, adjustable fonts, and low-motion or anti-dizziness modes, to improve overall accessibility and user-friendliness, thereby making virtual cultural experiences more inclusive and sustainable. To expand the application of VR in cultural heritage dissemination, the primary task is to reduce reliance on high-end equipment and simplify operational procedures, while ensuring compatibility across various devices. At present, for such technology to function on a broader societal level, it must be tailored to different user groups such as students and teachers, elderly users, and people with physical disabilities, by providing lightweight, cross-platform, and inclusive experience solutions. Only in this way can VR evolve from a specialized tool into a public-oriented cultural medium, achieving comprehensive progress in both accessibility and dissemination.

## 7 CONCLUSIONS

Virtual reality (VR) technology, as a vital form of contemporary digital media, has demonstrated significant value in the dissemination and exhibition of cultural heritage. Through a systematic review of the development, typologies, and core technological

paths of immersive VR museums, this study summarizes several key findings as follows: First, virtual museums utilize 3D modeling and digital reconstruction technologies to transcend the spatial and temporal limitations of traditional exhibitions, thereby offering a more immersive audiovisual environment for the presentation and interpretation of artifacts. Second, case studies from the British Museum, the Louvre, and the Palace Museum indicate that VR not only enhances sensory engagement, but also stimulates learning motivation and cultural participation. Third, from the perspective of user experience, immersion, interactivity, and content personalization are key determinants of user satisfaction and continued engagement. Finally, although VR museum technologies have grown increasingly sophisticated, challenges persist, such as high hardware thresholds, difficulties in ensuring historical authenticity in reconstructions, and insufficient accessibility design. These issues call for a balanced approach between technological optimization and ethical regulation. To promote the deep integration of virtual reality (VR) technology in the field of cultural heritage, and to ensure its sustainable development within the public cultural service system, this paper proposes the following recommendations based on current practices and identified challenges: First, it is recommended to reduce reliance on high-end hardware at the system design level, and to promote the development of WebVR and lightweight mobile applications, in order to enhance accessibility for general users. This approach will not only expand audience coverage, but also ease the technical burden on small and medium-sized museums. Second, on the content level, user interaction and engagement mechanisms should be strengthened, by introducing features such as multi-user collaboration, real-time feedback, and task-oriented exploration, to enhance immersion and participation among visitors. Third, AI technologies should be incorporated to enable intelligent content recommendations and adaptive responses based on user behavior, allowing users of diverse backgrounds, ages, and interests to receive personalized information services, and thereby enriching individual learning experiences. Fourth, cultural authenticity should serve as the fundamental baseline for virtual reconstruction, and it is advisable to establish interdisciplinary collaboration mechanisms to ensure historical context and cultural meaning are accurately represented during modeling and display processes, thus avoiding “pseudo-realism” that may distort public understanding. Finally, to address the needs of special user groups, accessibility design

should be embedded at the early stages of system development, including features such as simplified interfaces, voice assistance, and anti-dizziness modes, thereby fostering a more inclusive environment for cultural communication.

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