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Protection and immersive experience of cultural heritage in the digital age: Technological empowerment, spatial reproduction, and future risks

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Abstract

Cultural heritage serves as a vital foundation for preserving collective memory and shaping social identity, as it embodies the shared history, values, and traditions of a community. Technologies, such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) are more often used in heritage preservation and tourism in the digital era, thus changing how people engage with and perceive the past. This paper uses the theory of space production to examine how immersive experiences across three interconnected dimensions – physical space, mental space, and social space – reproduce cultural heritage. Drawing on chosen case studies, the study shows that digital technology can enhance the sensory and emotional involvement of visitors, encourage participatory cultural expression, and assist the revival of local culture and urban memory. By connecting historical stories with modern audiences, immersive technologies produce dynamic exchanges between tradition and innovation. The article also discusses the issues facing digital reproduction as well, such as worries about authenticity, cultural uniformity, and possible marginalization of local voices. This paper offers an integrated framework connecting technology mediation, spatial transformation, and cultural sustainability to balance invention with cultural integrity. The framework provides an understanding of how immersive digital practices could be tools for social empowerment and heritage interpretation. In the end, this article underlines the need of striking a balance between technological progress and the preservation of cultural diversity and authenticity by stressing the role of digital media in transforming cultural settings. It also adds to the ongoing discourse on this topic.

Keywords: Cultural heritage; Space production; Immersive experience; Digital technology; Cultural reproduction

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1. Introduction

Cultural heritage protection has gained significant traction among citizens in China. Cultural heritage, as defined by the UNESCO (2003), encompasses "the legacy of physical artifacts and intangible attributes inherited from the past, maintained in the

present, and bestowed for future generations."[1] Cultural heritage generally encompasses monuments, traditions, and practices that embody collective memory and identity. With the growing enthusiasm among the Chinese people in tourism activities, these factors promote the deep integration of digital technology and physical industries in the Internet era. Using technological innovation to enhance the digital tourism experience of cultural heritage has become a new trend in the cultural and tourism industries. In 2024, the Ministry of Culture and Tourism, along with four other central departments, issued the "Smart Tourism Innovation Development Action Plan." This plan emphasizes supporting cultural and tourism institutions in adopting human-machine collaboration models. It encourages the use of cutting-edge technologies, such as artificial intelligence-generated content (AIGC) to improve the efficiency and effectiveness of tourism marketing.[2] In this context, immersive cultural tourism projects become a bridge connecting digital technology and cultural heritage. Traditional cultural heritage faces the challenge of "going out" and "staying" in the era of information explosion and global cultural exchange. Young people prefer new cultural tourism methods that are interactive, entertaining, and social, but the traditional static exhibition modes cannot meet their high participation needs. Multi-sensory participation and immersive interaction can enhance emotional engagement and stimulate imagination, creating profound and memorable experiences.

The immersive experience was proposed by American psychologist Mihaly Csikszentmihalyi in 1975. It originates from the flow experience in psychology, also known as Flow Theory. This theory suggests that immersion is a highly focused, enjoyable, and time-forgetting psychological state experienced when people are fully engaged in an activity. Researchers divide immersive experiences into two dimensions: Broad and narrow. The broad dimension refers to the psychological aspect, while the narrow dimension refers to the technical aspect. Immersive cultural tourism experience spaces refer to the use of virtual reality (VR), augmented reality (AR), and other interactive devices in cultural heritage spaces through physical space design and digital technology to enhance visitors' experience, interaction, and participation, providing them with an immersive experience.

"The development of technology in the digital age infuses digital media and methods, such as mixed reality applications into cultural heritage, revitalizing and innovating tourism destinations." The organic combination of digital technology and the digitalization and intelligence of production spaces brings new development momentum to cultural tourism development and heritage protection. Academic research on the application of VR in tourism began in the 1990s, but its basic principles started forming in the 1930s – 1980s.[3] With the advancement of digital technology, VR and AR have become important means of immersive cultural heritage display. These technologies allow for deeper participant engagement and interaction with cultural heritage beyond traditional static displays. The protection of cultural heritage requires the organic integration of culture and technology to expand new spaces for cultural heritage development.[4] It is important to use digital technology to protect cultural heritage and strengthen the digital development of cultural heritage.[5] AIGC technology empowering cultural heritage has been an important trend in empowering the preservation of cultural heritage in recent years. It allows tourists to deeply understand cultural heritage content without affecting the original cultural heritage.[6]

The theory of space production provides a theoretical framework for understanding how cultural heritage is continuously reproduced in social practice. Lefebvre proposed that space is a product of social relations.[7] It is not only a physical existence but also a collection of cultural meanings and social relations. As a unique type of space, cultural heritage carries historical memory and social value. The application of Lefebvre's triad of space started late in China but is now widely used in many fields.[8] Researchers believe that the combination of information technology and the experience economy promotes immersive cultural tourism as a new trend. Technology is not an independent display but is closely integrated with theatrical arts and cultural heritage, jointly constructing the core of immersive experiences.[9] He *et al.*[10] emphasize culture-oriented space production to promote value production, such as economic, cultural, social, and ecological values. Ye *et al.*[11] explore the positive impact of digital scene-driven open innovation from the perspective of Lefebvre's Triad of Space. Lefebvre's theory provides an important reference value for immersive cultural heritage experiences due to its historical background, critical spirit, starting point from daily life, and theoretical model and research framework. Foreign researchers frequently conducted quantitative studies on the impact of immersive cultural tourism experiences on decision-making and satisfaction. At present, local cultural heritage elements remain underexplored, and existing world cultural heritage resources are not being effectively utilized to foster local tourism development. The integration of new digital technologies, such as artificial intelligence (AI), with the cultural tourism industry represents a growing trend and an important direction for the industry's development, though the present research still has limitations.

The vulnerability and non-renewability of cultural heritage make it inherently susceptible to degradation

from natural erosion and human factors. Thus, exploring how to effectively excavate and showcase its intrinsic value while ensuring proper preservation has become a core issue that must be addressed. Through literature analysis, researchers have shown that cultural heritage protection and sustainable development are not mutually exclusive.[12] Cultural heritage listed on the World Heritage List can stimulate local tourism development. Static protection and rigid displays of cultural heritage are ineffective methods of safeguarding it.[13] The present imbalance in regional development and disparities in cultural heritage resources has led to a dual mechanism for protecting and developing both tangible and intangible cultural heritage in China.[14] Therefore, it is essential to develop and utilize cultural heritage responsibly, ensuring scientific protection, sustainable inheritance, and maximizing its value in contemporary society. Existing research seldom explores the relationship between immersive AI experiences and virtual-real spaces from a systematic spatial analysis perspective. This paper aims to integrate Lefebvre's theory of space production – perceived, conceived, and lived spaces – to develop a comprehensive framework for immersive experiences and explore how technologies such as extended reality (XR), AI, internet of things (IoT), and brain-computer interfaces can enhance the expression, identity, and value of cultural heritage in specific applications.

2. Multidimensional reproduction and cultural co-creation of cultural heritage under the theory of space production

Henri Lefebvre, a French Marxist philosopher and sociologist, developed his theory of "The Production of Space" (1991) against the backdrop of post-war urbanization, capitalist expansion, and social upheaval. His political commitment to critiquing capitalist modernity and advocating for social justice deeply influenced his spatial theories. Lefebvre argued that space is not a neutral container but a social product shaped by power relations, ideologies, and human practices. His work emerged as a critique of the capitalist commodification of space and aimed to reclaim space for emancipatory social practices.

The theory of space production emphasizes the social and multidimensional attributes of space, providing a new perspective for the study of cultural heritage. In his book "The Production of Space,"[15] Lefebvre proposed the theory of space production, which led to the "spatial turn" in social theory and geography. Lefebvre's concept of "spatial triad" includes spatial practice, representations of space, and representational spaces, which are the core ideas of his theory of space production.

Spatial practice refers to the production and reproduction of space, including the specific locations and spatial characteristics of each social formation. Representations of space refer to the abstract construction of symbolic space, associated with production relations and the "order" imposed by these relations, thus linked to knowledge, symbols, codes, and "positive" relations. Representational spaces refer to spaces directly experienced through associated images and symbols, emphasizing how residents and users interact within this space and how it is understood. The spatial triad theory provides theoretical support for major issues such as improper institutional management and low social space presence in some cultural heritage sites.

The coupling relationship between social, mental, and physical spaces with people, behavior, and the environment can be understood as a complex dynamic system where various factors influence and interact with each other. People, as the core subjects, live, work, and socialize in physical, mental, and social spaces. These spaces intertwine and collectively influence people's behavior and experiences. Behavior is the manifestation of people's interactions in different spaces, constrained by the physical environment, guided by mental space, and regulated by social space. The environment includes physical, mental, and social types, which together form a complex ecosystem that influences and shapes people's lifestyles and social structures.

Cultural heritage is not static historical relics but a dynamic process that is continuously redefined and reproduced in the flow of space and time. Heritage conveys established historical values and cultural meanings while also creating new experiences and cognitions through modern technology and social practices. Through the multiple interactions of physical, mental, and social spaces, historical culture is innovatively expressed in the contemporary context, gaining new vitality and social significance in modern society. The spatial triad theory divides space into three interrelated parts: physical space, mental space, and social space. These spaces have their own boundaries but are interconnected, interpenetrating, and synergistic. The concept of the "living museum" proposed by Catherine Grenier and André Malraux emphasizes that museums should be organic entities that continuously adapt to social needs. Through new exhibition relationships, the displayed artifacts and artworks become spiritual places for dialogue. Based on the spatial triad theory, a theoretical model for analyzing the activation of cultural heritage, space design, and community development is constructed (Figure 1). The integration of the spatial triad theory and the living museum theory forms a theoretical model of the triadic co-production of immersive cultural

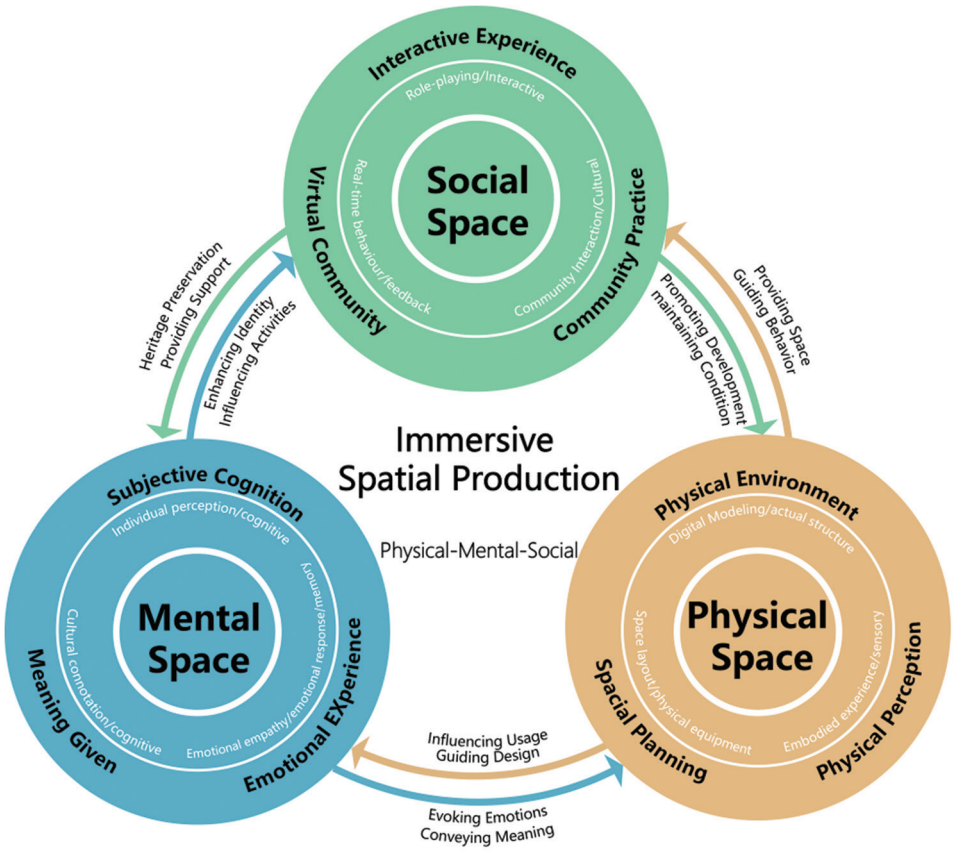

Figure 1. Immersive space production model. Image created by authors.

heritage experiences from the perspective of "physical-mental-social" isomorphism. This model aims to more comprehensively understand how to activate and protect cultural heritage in different spatial dimensions while promoting the development of cultural heritage and enhancing people's cultural identity.

2.1. Spatial reconstruction: Reconstruction of physical space and historical reproduction

Physical space, or the physical space of perception, refers to the physical environment directly experienced through the senses, including the actual structure, layout, and physical presence of buildings. At this level, the living museum theory focuses on how to transform actual locations in cities into places for displaying and experiencing cultural heritage. The physical space of perception is the foundation of experience. As a physical space of perception, it involves the personal experience of participants and the acceptance by society as a whole, that is, the role mechanism of space in social reproduction. It collectively presents new spatial characteristics such as on-site experience, sensory immersion, and decentralized spatial forms. Traditional architectural cultural heritage, as a living museum, uses its physical space to display local history and culture. Visitors personally experience it, increasing their sense of interaction and evoking collective memory.

In immersive cultural heritage experiences, the human body, as the basis of perception, is the existence of physical space and the carrier of identity. Through embodied sensory experiences, the body is brought into the scene. In the digital age, the use of immersive technologies such as XR expands the experiential scenes of cultural heritage as a physical space. The integration of multi-sensory immersion and technology allows each participant to gain a unique experience in a space that combines virtual and real elements. Through the application of digital technology, traditional physical spaces are deconstructed and reproduced, promoting the transformation of cultural heritage display forms. For example, Notre-Dame Cathedral uses immersive digital technology to achieve sustainable protection of cultural heritage in its reconstruction project after the 2019 fire. Gaël Hamon and his team at Art Graphique and Patrimoine used advanced technologies such as laser scanning and photogrammetry to create a detailed digital model of the cathedral. This 3D model, constructed from billions of data points, forms the

basis of the digital reconstruction work. The digital model leaves a permanent digital archive for digital cultural tourism development. At the design level, the digital production of physical space involves the integration of multi-sensory stimuli and interactive methods. 3D modeling, interactive design, and user experience optimization are key. Designers need to consider how to realistically restore physical characteristics in virtual space and enhance audience participation through interaction.

The "Vanished Pharaohs" project uses 1:1 high-precision reconstruction to restore the interior and surrounding environment of the Egyptian Pyramid of Khufu. Visitors can explore the core area of the pyramid, climb to the top to enjoy the panoramic view of the Giza Plateau, and "participate" in the mummy-making process by wearing VR devices and freely walking around. This meticulous restoration not only enhances the authenticity of cultural heritage but also makes history more vivid through virtual interaction.

"Entering Tang Dynasty in a Dream" virtually recreates the grandeur of the Tang Dynasty through digital technology. Participants, as "observers," follow virtual tour guides to visit classic scenes such as the underground palace of Zhaoling Mausoleum, the landscape of Qinling Mountains, and Taiji Palace, experiencing the culture of the Tang Dynasty across time and space. The highlight of this project lies in the grand construction and detailed restoration of the scenes, making the immersion more profound. These large-scale VR projects reconstruct physical spaces through digital technology, breaking the limitations of physical space and enabling cultural heritage to be presented more vividly.

Space is a product of social practice, and the reproduction of physical space is the foundation of immersive cultural heritage experiences. The space of historical heritage is not a closed, fixed existence. With the support of VR, AR, and other technologies, physical space is reactivated as a platform for social and cultural interaction. This "reproduction" gives historical heritage new value dimensions, allowing it to connect with contemporary cultural needs and social practices. This process of "revitalizing" history transforms the "past tense" into a space that generates new meanings through interaction with contemporary audiences. Therefore, the physical space of heritage becomes a field for continuously shaping and updating cultural cognition in modern society.

2.2. Emotional resonance: Deep experience and emotional stimulation of mental space

Mental space, or "conceived space" as proposed by Lefebvre, refers to the process of imbuing physical space with meaning through subjective cognition and emotional experience. Based on AIGC immersive experiences, mental space achieves a logical transformation from passive acceptance to active participation, from static display to dynamic interaction, and from single-dimensional to multi-dimensional integration. Traditional historical education's mental space construction involves one-way transmission of information, fixed historical information and scenes, and education relying on text and images, with audiences lacking participation and multi-sensory experiences.

In the "Anne Frank" VR experience, space reproduction focuses on reconstructing historical memory, emotional experience, and cultural significance. This allows the audience to feel Anne Frank and her family's psychological state and inner world while hiding from the Nazis in the virtual space. They can "walk through" historical street scenes and physical realities, transitioning to dynamic displays that combine virtual and real elements. This effectively brings the audience back to Amsterdam during World War II. The reproduction of mental space allows the audience to gradually explore and understand the deeper meanings behind the immersive experience story in an undisturbed virtual environment. The virtually reconstructed room retains the family's furniture and personal belongings from 1942 to 1944, fully recreating their living environment. This allows the audience to see their living conditions directly and, through reconstructed details such as furniture placement and daily items, relive the psychological pressure and inner world endured by Anne's family in a small space. This experience surpasses traditional visiting modes, allowing people to understand and feel individual memories of a significant historical period in a deeper and more intimate way.

The inheritance and innovation of mental space are the core of immersive cultural heritage experiences. The re-"experience" of cultural heritage in the mental cultural world blurs the boundaries between history and the present. Across technological intervention and emotional resonance, it becomes a "living" existence. In this process, the construction of mental space involves cultural reconstruction and emotional interaction and identity construction between individuals and space through immersive experiences. By entering the audience's perceptual and emotional dimensions, it helps them interactively perceive the emotional significance behind historical events, reshaping the connection between history and the present. "Space is a product of social relations" is reconstructed and recreated through the intertwining of new social needs, cultural cognition, and emotional experiences.

2.3. Interactive empowerment: Reproduction and interactive collaboration of social space

Social space emphasizes the use and interaction of space by people in their daily lives. It involves how cultural heritage influences and is influenced by the social practices of community members. Living museums encourage visitors to interact with community groups, promoting cultural exchange and forming a shared collective memory and social cohesion. The production of social space is continuous and multidimensional. Virtual community platforms can dynamically adjust interactive tasks and scenarios based on participants' real-time behavior and feedback, making the experience space constantly change and adapt.

First, through AIGC technology and immersive experience technology, a virtual community platform is constructed, allowing users to engage in role-playing and interactive tasks in a virtual space. Second, it transforms the experience space, breaking the traditional user tourism model. Users actively participate in historical contexts through interactive tasks and role-playing, becoming part of the story.

In the "ALAB Shanhai Space" project, the A-Station team cleverly integrates the real geographical space of Beijing's 798 and 751 squares with the virtual world, redefining visitors' experiences at this Beijing cultural and artistic landmark. Across Vision Pro devices, visitors exist as observers and become part of the story through interaction. For example, visitors can interact with mythical creatures from the "Classic of Mountains and Seas" in VR. This design makes each visitor's experience unique and social. Each interaction triggers different plot developments, allowing visitors to share and discuss their discoveries, forming a new social bond. In addition, the project has designed a walking area of over 2000 m^2. When a group of visitors enters a specific area, the system generates specific virtual scenes based on their behavior. Other visitors can also form a special collective experience through active observation or participation, transforming the traditional passive visiting mode into a new social space.

To enhance interactivity, the project also includes photo-taking and social media sharing functions, extending visitors' experiences to a broader social network. Visitors can take photos in virtual scenes and share them on social platforms, forming a collective social interaction. For different age groups, A-Station has designed content meticulously. Young users are attracted by fantasy and novelty elements, while older users focus on the depth of cultural background and historical stories. By customizing content for different user groups, the project enhances the participation of various users. In addition, visitors can share their discoveries through digital tags or mark points of interest in virtual space, adding a new dimension to social interaction.

In terms of technology and management, the team developed a backend management system to monitor the location of each device in real-time, prevent device loss, and optimize battery management, ensuring a smooth visitor experience and the stability of the virtual social space. Through these design and technological innovations, "ALAB Shanhai Space" effectively realizes the reproduction of social space, enhances the attractiveness of the 798 Art District, and provides a new paradigm for the application of spatial computing in the cultural tourism industry.

The continuation and co-construction of social space is the reproduction process of cultural heritage immersive experiences in the social dimension. In Lefebvre's theory, social space is not an extension of physical space but a field constituted by human social behavior, interaction, and identity. The social space reproduction of cultural heritage reflects how cultural heritage establishes relationships with social members, communities, and collective memory in contemporary society. Across the empowerment of digital technology, these social relationships are continued, strengthened, and recreated.

However, this technological mediation calls important issues regarding authenticity into doubt. According to the UNESCO, authenticity is the "truthful transfer of cultural values" through material, shape, and function. Although digital technologies increase social involvement, they run the danger of replacing the actual and physical ties that support the genuineness of legacy. For example, AI-reconstructed historical conversations can give emotional involvement top priority above factual correctness, hence altering group memory. Lefebvre's dialectical perspective therefore reminds us that the lived social actions anchoring legacy in material and intangible traditions should be complemented, not replaced, by technological replication.

3. Future-oriented innovation in immersive cultural heritage experiences: Reconstructing the production and perception of space

In future immersive cultural heritage experiences, emerging digital technologies will transform cultural heritage into a dynamic, multi-dimensional interactive process that transcends time and space. By re-examining Lefebvre's theory of space production, a more innovative and in-depth theoretical framework can be provided for immersive cultural heritage experiences. Immersive cultural heritage

experiences are not merely the reproduction of physical space; they are a "spatial practice" interwoven with history, emotion, society, and culture.

3.1. Reconstruction of physical space: Beyond static reproduction to embodied perception

Traditional cultural heritage displays often rely on the restoration and static presentation of physical space. Modern technology, however, allows the physical space of cultural heritage to transcend the limitations of time and space, enabling virtual and dynamic reconstruction. Technologies such as laser scanning and photogrammetry can create digital models, ensuring the sustainable preservation and "perpetual" presentation of historical buildings and artifacts. At the same time, wearable devices can simulate tactile feedback, allowing visitors to touch virtual historical relics or artifacts through vibrations and temperature changes, creating a sense of "presence" through the fusion of virtual and real elements. Visitors can even experience the "craftsmanship spirit" of history by simulating ancient handicraft processes. In addition, olfactory simulation technology can recreate the smells of historical sites in virtual environments, creating a more comprehensive immersive experience. The synergy of multiple senses deeply stimulates visitors' embodied perception of spatial practice. XR technology can further break the limitations of time and space, enabling immersive "roaming."

3.2. Reproduction of mental space: Emotional and cognitive historical experience

Lefebvre's concept of mental space emphasizes the cognition and experience of history, culture, and emotions. With the development of AI and affective computing, immersive experiences can adjust and optimize display content in real-time based on visitors' emotional responses, historical knowledge, and interests. By combining natural language processing, brain-computer interfaces, and affective computing, these experiences can create deep immersion. The content can be adjusted in real-time according to visitors' knowledge levels and interests, and even generate dynamic historical plots based on their emotional changes. AI can enable visitors to converse with virtual historical figures, feel their emotional decisions, and resonate with historical figures or events on a deeper level. This interaction blends "scenery" and "story," creating a unique "mental experience" for users.

3.3. Dynamic generation of social space: Cross-temporal interaction and cultural co-creation

Lefebvre's theory of social space emphasizes the interaction between people, and between people and objects, within space. Future immersive experiences will not only involve one-way interaction between individuals and heritage but also create a cross-cultural, cross-temporal social co-creation space. Future 6G low-latency networks will effectively support collaborative experiences, allowing visitors from different cultural backgrounds worldwide to become part of the immersive experience. In virtual environments, visitors can communicate, share, and co-create, participating in the virtual reconstruction of historical sites, and discussing and creating new narratives for historical events. Consequently, cultural heritage becomes a dynamic cultural space co-created and shaped by multiple subjects, promoting equal dialogue and mutual learning among diverse cultures and fostering the co-construction and sharing of decolonized narratives.

4. Future-oriented immersive cultural heritage experiences: Innovation and risks

With the advancement of technological innovation, immersive cultural heritage experiences have raised several issues regarding cultural diversity, ethical responsibility, and technological sustainability. Future research and practice need to address these issues while promoting technological innovation to ensure the sustainable development of immersive cultural heritage experiences. Table 1 presents the innovation directions, technological applications, risks, and prospects for future immersive cultural heritage experiences.

4.1. Balancing historical authenticity and entertainment

The application of emerging technologies in cultural heritage protection and dissemination injects new vitality into cultural experiences. However, there needs to be a balance between historical authenticity and entertainment. Immersive technology can restore historical scenes with high presence through AIGC combined with VR technology, but over-reliance on AI may lead to the "entertainmentization" of historical content, even deviating from historical authenticity. For example, virtual reconstruction projects may introduce subjective creation in detail restoration, and this "dramatization" weakens its academic and educational value. It requires the collaboration of interdisciplinary expert teams from archaeology, history, and technology to jointly formulate content production standards to ensure the accurate expression of historical details. Introducing independent social review institutions, and integrating public feedback and professional opinions, can reduce the bias toward entertainment. Technology should not be a commercial gimmick; content review and historical verification are crucial. The authenticity of historical scenes should be reconstructed using multi-dimensional

Table 1. Future immersive cultural heritage experiences

Research direction	Innovation content	Technological application	Risks and prospects	Sources
Decolonization and diversified narratives of digital heritage	Achieving "decolonization" and "co-creation" of historical heritage through global cultural sharing and integration of diverse perspectives	AI, big data, VR	Balancing different cultural perspectives, avoiding cultural hegemony and single narratives	UNESCO 2021 Report on *Ethics of Digital Heritage*; ICOMOS Charter on Virtual Archaeology[16]
Ethical risks and social responsibility in immersive experiences	Ensuring that the display of historical heritage meets ethical requirements, avoiding misinterpretation of history and commercialization of culture	Ethical design frameworks, review mechanisms, user emotion analysis	Balancing entertainment with cultural respect, avoiding the virtualization and commercialization of history	IEEE Global Initiative on *Ethically Aligned Design*[17]; EU Project TIME MACHINE[18]
Intelligent immersive experiences and personalized historical cognition	AI emotional computing technology provides personalized, emotion-based historical experience pathways, adjusting content in real-time	AI, affective computing, behavior analysis	Complexity in designing personalized historical experiences and technical implementation challenges	MIT Media Lab's *Affective Computing* Research[19]; Google Arts & Culture Lab Case Studies[20]
Application of quantum computing and big data in immersive cultural heritage	Leveraging quantum computing and big data for the precise digital reconstruction of historical sites, thereby enhancing the authenticity and detail of historical scenes	Quantum computing, big data analysis	Complexity and resource consumption of technical implementation, ensuring historical authenticity	IBM Quantum & Cultural Heritage White Paper[21]; EU's VERITAS Project on 3D Reconstruction[22]
Virtual anthropology and immersive cultural heritage education	Virtual identities participate in historical events, experiencing the dynamic evolution of historical culture, enhancing the immersion of cultural education	VR, AR, simulation technology	Overcoming the gap between virtual historical education and real perception.	British Museum's *Virtual Reality Tours*[23]; Stanford University's *Virtual Human Interaction Lab*[24]
Decentralization and blockchain protection of digital heritage	Blockchain technology ensures the authenticity and immutability of digital cultural heritage content, providing digital heritage certificates	Blockchain, decentralized storage, smart contracts	Legal and ethical issues of technology adoption and application, data security, and privacy protection	World Monuments Fund & Arweave Blockchain Partnership[25]; UNESCO's *Charter on Digital Preservation*[15]

Note: The content is derived from the summary and analysis of recent academic and industrial trends prepared by the author's team.
Abbreviations: AI: Artificial intelligence; AR: Augmented reality; VR: Virtual reality.

scanning technology to ensure the authenticity of cultural relics, requiring long-term verification and review.

4.2. Technological barriers and digital divide

Although digital technology enhances participation in cultural experiences, the high cost of equipment and technological barriers hinder its popularization in developing countries and remote areas. Specifically, VR/AR headsets and brain-computer interface devices are expensive and difficult to popularize among all social groups. Remote areas with insufficient network bandwidth find it challenging to achieve equal immersive experiences with central cities.

An effective mechanism for regional development and resource allocation needs to be established. It is recommended that governments and enterprises jointly promote the construction and pilot of "immersive cultural" infrastructure, such as building "public digital cultural spaces" or mobile experience devices, to provide low-cost immersive experiences for underdeveloped areas. Developing low-tech, more compatible immersive technologies can also help achieve cultural equity by targeting underdeveloped areas and niche cultural heritage, avoiding new cultural inequalities.

4.3. Data security and privacy protection

The core of immersive technology is the real-time tracking and recording of user behavior and physiological data. If these sensitive data are leaked or misused without regulation, they may be commercially exploited or hacked, posing threats to personal privacy and security.

Some researchers propose using blockchain to trace and confirm the rights of digital heritage data, ensuring data immutability and traceability, and establishing a reliable mechanism for the digital protection of cultural heritage. However, in practice, legal and regulatory support and industry standards need to be established to clarify the boundaries and uses of data collection, limiting the abuse of rights from legal and ethical perspectives.

4.4. Sustainable and interdisciplinary future

Future immersive cultural experiences require not only technological breakthroughs but also multidisciplinary

collaboration and participation from all sectors of society. By constructing a collaborative network of "technology-academia-society" with multiple stakeholders, and establishing long-term cooperation mechanisms and funding support channels, all parties can jointly promote the scientific and sustainable development of digital cultural heritage protection. While ensuring respect for the cultural heritage itself, it is necessary to pursue technological breakthroughs and artistic creativity continuously, maintaining reverence and rigorous research for the cultural core, enabling cultural heritage to achieve true "activation" in the digital age.

5. Discussion

A monument to the social and historical developments handed down through the years, the cultural heritage reflects substantial riches deserving of continuous protection and worldwide respect. Particularly among younger generations, immersive experiences have grown in popularity and provide great chances to reawaken the public with cultural heritage through creative, interactive approaches. Using Lefebvre's theory of space production, this study investigates the multidimensional reproduction process of immersive cultural heritage events by providing a reconstruction framework including physical, mental, and social spheres. This framework helps one to see cultural heritage reproduction as both a historical reenactment and a continuous process through which modern technical developments and social activities create new cultural meanings and social values.

The study offers various rational impacts for developers of digital heritage, museum professionals, and legislators. Policymakers can apply the knowledge offered to create sensible plans for the preservation of legacy that combine modern technologies with harmony between authenticity and entertaining. Immersion technologies including XR, AI, and IoT allow museum workers and digital heritage creators to provide enhanced cultural experiences, increase audience participation, and raise public involvement.

However, the incorporation of new technology presents serious ethical and practical difficulties, most notably with relation to historical accuracy, data security, and fair access. Future studies should methodically investigate the effects of using AIGC in digital heritage presentations, therefore answering important issues on authenticity, accuracy, and content interpretation. Moreover, ethical guidelines controlling digital heritage projects must be developed, especially with regard to problems of historical authenticity, cultural sensitivity, and economic exploitation of historical resources.

Comparative studies assessing immersive experiences across many cultural settings, user long-term engagement with digitally mediated legacy, and how changing technologies – such as quantum computing, blockchain, and brain-computer interfaces – might reshape the terrain of heritage protection and interpretation could also be part of future research directions. Dealing with technological, ethical, and cultural issues will ultimately call for multidisciplinary cooperation among specialists in history studies, computer science, ethics, and sociology to guarantee that digital legacy preservation stays both responsible and creative.

6. Conclusion

The involvement of digital technology offers cultural preservation thus far unprecedented opportunities for creative reinterpretation and extensive distribution. Still, continuing critical study of these advances is essential. Future immersive cultural heritage experiences can better satisfy the various requirements of modern society as well as heritage preservation by aggressively tackling issues in ethics, authenticity, technological accessibility, and cooperative governance.

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Availability of data

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