Paradigm Academic Press
Art and Society
ISSN 2709-9830
MAY. 2025 VOL.4, NO.4

Research on Multi-Dimensional Presentation and In-depth Experience of Cultural Heritage Driven by XR Technology

Zijing Lu[1]

[1] Johns Hopkins University, United States

Correspondence: Zijing Lu, Johns Hopkins University, United States.

doi:10.63593/AS.2709-9830.2025.05.002

Abstract

This paper takes extended reality (XR) technology as the core to explore its application logic and practical paths in the multi-dimensional presentation and in-depth experience of cultural heritage. Based on the immersive, interactive and multimodal fusion characteristics of XR technology, it is proposed to achieve digital translation of cultural heritage through spatial reconstruction, dynamic narrative and cross-media fusion, and to construct a deep experience paradigm through emotional resonance, educational dissemination and social collaboration. Based on the above theoretical analysis, combined with actual cases, an analysis of the reality of multi-dimensional presentation of cultural heritage is conducted. The case study shows that XR technology not only breaks through the temporal and spatial limitations of traditional display, but also activates the contemporary value of cultural heritage through the integration of virtual and real. In response to the shortcomings of existing research, it is pointed out that technology empowerment needs to balance the expression of cultural connotations and the boundaries of technological innovation. In the future, it is necessary to explore the collaborative application of artificial intelligence and the metaverse to promote the paradigm shift of cultural heritage from “preservation” to “activation”.

Keywords: XR technology, culture-driven, cultural heritage, multi-dimensional presentation, deep experience

1. Introduction

At present, many cultural heritage institutions around the world are attempting to integrate XR technology into their conservation and dissemination practices. For instance, the Palace Museum uses VR technology to recreate scenes of court life, and the Dunhuang Academy uses AR technology to analyze the details of mural art. These explorations have initially verified the feasibility of technology empowerment. However, most of the existing research focuses on the path of technology implementation, but lacks theoretical integration on how it can systematically serve the multi-dimensional presentation and in-depth experience of cultural heritage. In addition, issues such as the risk of cultural distortion in the application of technology, ethical boundaries of user experience, and sustainable operation models still need to be further explored.

2. The Importance of Applying XR Technology to the Protection and Inheritance of Cultural Heritage

Cultural heritage, as the core carrier of the collective memory and identity of human civilization, is facing unprecedented challenges in its protection and inheritance. Under the double impact of globalization and rapid urbanization, material cultural heritage is vanishing at an accelerated pace due to natural erosion, man-made destruction or developmental damage; Intangible cultural heritage is gradually losing its vitality due to intergenerational transmission breaks and changes in cultural ecology. According to a UNESCO report, about one-third of the world’s cultural heritage is in an endangered state, and traditional conservation methods, mainly physical restoration and static display, are limited by physical space, financial costs and technical bottlenecks, making it difficult to systematically address the fragmentation, isolation and vitality of cultural heritage. Under

this traditional approach to protection and inheritance, the public's perception of cultural heritage is generally at the level of "passive viewing", lacking deep participation and emotional resonance, resulting in a gap in the intergenerational transmission of cultural identity. Against this backdrop, exploring the digital protection and living inheritance paths of cultural heritage has become a major issue that needs to be addressed urgently in the global cultural field.

The rapid development of extended reality (XR) technologies — including virtual reality (VR), augmented reality (AR), and mixed reality (MR) — provides revolutionary tools for the creative transformation of cultural heritage. By constructing interactive Spaces that blend the virtual and the real, XR technology breaks through the temporal and spatial limitations of the physical world, allowing cultural heritage to be presented in multi-dimensional, dynamic and immersive forms. The potential of XR is reflected in three aspects: First, high-precision restoration and scene reconstruction, with 3D modeling, laser scanning and real-time rendering, can create millimeter-level digital twins of cultural heritage, restoring its historical appearance and details; Second, Multi-sensory interaction and narrative innovation, through haptic feedback, spatial audio and gesture recognition technologies, users can "touch" the texture of cultural relics, "listen" to the echoes of history and actively participate in the narrative. In recent years, the application of XR technology in the cultural field has shifted from experimental exploration to large-scale implementation. According to a survey by the International Council of Museums (ICOM), more than 60 percent of cultural institutions worldwide have incorporated XR technology into their digital transformation strategies, indicating that it will become a core driver for the protection and dissemination of cultural heritage.

3. Multi-Dimensional Presentation Strategies for Cultural Heritage Driven by XR Technology

The multi-dimensional presentation of cultural heritage is the core path for XR technology to empower cultural protection and dissemination, with the core goal of reconstructing the temporal and spatial attributes and narrative logic of cultural symbols through technology. This process needs to be carried out around three dimensions: spatial reconstruction and scene restoration, dynamic narrative and interaction design, cross-media content integration, to form an organic unity of technology, content and experience.

3.1 Spatial Reconstruction and Scene Restoration

3D modeling and digital twin technology is based on laser scanning, photogrammetry and algorithmic generation technology, through which cultural heritage can be transformed into digital models with centimeter-level precision, using real-time rendering engines to simulate dynamic light and shadow and physical properties. Cultural heritage elements such as the dougong structure of ancient buildings, the brushstrokes and textures of murals, and the material textures of cultural relics can all be restored through polygonal meshes and material mapping techniques to form interactive "digital twins". This process not only breaks the physical limitations of users' access to cultural heritage, but also gives life to historical scenes through parametric adjustment of seasonal changes and the alternation of day and night, allowing users to observe the morphological evolution of cultural heritage in different temporal and spatial dimensions.

XR technology embeds users in virtual scenes through spatial positioning and motion tracking technology to help users achieve a "body presence" roaming experience. In terms of narrative design, XR technology can use spatio-temporal anchors to associate historical events, character stories with spatial nodes, forming a narrative chain of "scene triggering - information unlocking". For instance, when a user walks through a digitally restored Song Dynasty market, they can trigger conversations with vendors, watch folk performances, or even participate in virtual festivals by touching virtual stalls. This gamified experience reduces the heaviness of cultural heritage presentation and instead allows the user to view it with a relaxed and pleasant mindset. It enables users to build a three-dimensional understanding of history and culture through time travel.

3.2 Dynamic Narrative and Interaction Design

The presentation of cultural heritage driven by XR technology should not be limited to linear statements, but should stimulate active participation and meaning construction through dynamic narrative and interaction design. XR can capture users' actions, language and decision-making behaviors and adjust the narrative path accordingly. For example, in a virtual archaeological scene, XR technology allows users to choose different excavation tools or exploration directions, which will trigger differentiated artifact discoveries and plot developments; In the experience of intangible cultural heritage skills, XR technology helps users improve the precision of operations, adjust the sequence of operations, and design the form of the finished product and the ending of the story based on their own choices. This branching narrative design breaks the passivity of traditional displays, making users co-creators of the meaning of cultural heritage. The presentation of cultural heritage by XR technology relies on the synergistic stimulation of multiple sensory channels. On the visual level, it restores the details of cultural scenes through high-resolution rendering and dynamic light and shadow technology; On the auditory level, spatial audio technology is used to locate sound sources and simulate

environmental sound effects, presenting sounds that touch the heart, such as the bells of ancient temples and the hustle and bustle of the city. At the tactile level, devices such as force feedback gloves and vibrating vests are used to simulate the tactile and physical interaction of materials, and to simulate more concrete elements such as the resistance of carved stone and the softness of textiles. This multi-sensory interactive presentation method not only enhances the user's sense of reality in the experience of cultural heritage, but also helps users to immerse themselves in the scene through the user's sensory compensation mechanism, which helps to attract new users, achieve the wide dissemination of cultural heritage, create explosive dissemination effects, and expand the audience boundaries of cultural heritage.

3.3 Cross-Media Convergence of Content

The application of XR technology helps the presentation of cultural heritage to break through the limitations of a single medium and achieve the expansion of information dimensions and the enhancement of narrative depth through cross-media content integration. XR scenes can serve as an integrated platform for multi-media content, transforming documents such as ancient texts and oral history records into interactive 3D annotation layers, embedding video materials such as documentaries and animations into specific perspectives of virtual scenes, and binding audio guides with spatial nodes to form an "what you see is what you hear" interpretation system. For example, in a digital museum, when a user clicks on a pattern on the surface of a bronze ware, it can simultaneously trigger expert explanations, casting process animations, and textual interpretations of inscriptions, enabling the immediate association of multi-dimensional knowledge and reorganizing it into an organic whole through a non-linear narrative structure. For example, using graph database technology to build a semantic network of cultural symbols, starting from an artifact or a legend, to help users associate and jump, and explore the knowledge graph; Or use gamification mechanisms such as puzzle tasks, achievement systems, etc., to guide users to independently piece together information fragments and form an overall understanding of cultural heritage in the process of exploration. This design respects the complexity of cultural knowledge while lowering the cognitive threshold through technical logic.

4. The Realization Path of the Deep Experience of Cultural Heritage

The deep experience of cultural heritage is the core goal of XR technology in empowering cultural dissemination. The core lies in the construction of immersive, interactive and social cultural fields through technology, enabling users to internalize and pass on cultural values through emotional resonance, knowledge construction and group participation. This process needs to be carried out around three paths: emotional resonance and cultural identity, educational function and knowledge dissemination, social attribute and group participation, forming an organic unity of technology empowerment, content innovation and group interaction.

4.1 Emotional Resonance and Cultural Identity

Emotional resonance is the foundation of cultural identity, and XR technology transforms abstract cultural values into perceptible emotional experiences through role-playing and situational simulation and symbolic meaning enhancement of cultural symbols. Through avatars and scene immersion technology, users engage in cultural narratives from a "first-person perspective". For example, in a virtual historical setting, users can play the roles of ancient artisans and literati, participate in the creation of cultural heritage by simulating the making of pottery, writing poetry, etc., and understand the emotional value embodied behind the work. Users can also participate in the decision-making process with the support formed by technology to understand the context of ancient productive forces and production relations. How individuals respond to natural disasters, handle social relations, and experience the survival wisdom and emotional world of cultural groups. The scenario simulations created by XR technology can also be combined with the impact of seasonal changes on farming, the competition for resources in war scenarios, etc., enabling users to understand the survival logic and collective memory behind cultural symbols in the process of solving virtual problems, thereby stimulating deep emotional resonance.

4.2 Enhancement of the Symbolic Meaning of Cultural Symbols in XR

XR technology can highlight the metaphorical and spiritual core of cultural symbols through deconstruction and recombination of symbols. For example, XR technology transforms traditional patterns into interactive 3D models, allowing users to observe the abstraction process from original totems to auspicious patterns through gesture manipulation and trigger associated mythological stories and philosophical ideas. Using spatial audio technology to recreate sound symbols such as chime bells and hymns in a virtual sacrificial scene, simulating the ritual of the sacred space through sound field positioning and frequency changes, and enhancing the awe and identification with cultural symbols. In addition, the XR can guide users to understand the social function and symbolic system of the symbols through the wearing rules of specific costumes in the ritual scene. Under this interactive experience, the user's understanding of cultural heritage goes beyond the physical level and becomes a profound emotional experience. The user is no longer a spectator or appreciator of cultural heritage, but has the opportunity to become a creator or witness of cultural heritage. This experience can bring a profound soul impact

to the user. It enables users to deeply understand the value of cultural heritage for the inheritance of human civilization and its reference significance for the current conflicts and contradictions in life, thereby integrating the thoughts and inspirations brought by cultural heritage into their own production and life, forming the recreation of cultural heritage and truly realizing the dissemination value of cultural heritage.

4.3 The Application of XR Technology in the Field of Educational Communication

Deep experiences need to balance the accuracy and fun of knowledge transmission. XR technology achieves innovative upgrades in educational functions through interactive learning modules and gamified design, explanations of historical context and scientific value. XR technology can break down cultural heritage knowledge into interactive "knowledge units" and promote active learning through gamification mechanisms. For example, in a virtual archaeological scenario, users need to operate virtual tools such as brushes, Luoyang shovels, etc. to complete the task of cleaning and classifying artifacts, and the system gives real-time feedback based on the user's operation accuracy and logical sequence; In the experience of intangible cultural heritage skills, the system designs a "challenge mode", such as completing the drawing of a specified pattern and meeting the craftsmanship standards, to unlock achievements and receive cultural MEDALS and background stories. In addition, the system can introduce an AI dialogue system that simulates historical figures or expert roles, allowing users to debate cultural issues and deepen their understanding through dynamic dialogue. XR technology can place cultural heritage in a macroscopic historical coordinate system through spatio-temporal visualization technology. For example, adding a timeline interface allows users to drag sliders to observe the entire process from the origin to the evolution of a certain cultural phenomenon, better understand the operation of cultural heritages with obvious temporal attributes such as the evolution of bronze vessel patterns and the inheritance of architectural styles, and simultaneously trigger explanations of related historical events; By using 3D anatomical models and data visualization technology, reveal the scientific value of cultural relics, and transform abstract scientific principles into intuitive visual demonstrations. This "macro narrative + micro analysis" design helps users build a systematic understanding of cultural heritage.

4.4 Social Attributes and Group Engagement

The in-depth experience of cultural heritage needs to rely on group interaction to achieve meaning sharing. XR technology builds a social network for cultural participation through the collaborative mechanism of multi-user collaborative experience and cultural discussions and secondary creation in virtual communities. Cultural presentation venues such as museums should leverage XR technology to enable multiple users to collaborate in real time in the same virtual space to jointly complete cultural tasks. For example, in virtual reconstruction projects, users can divide tasks such as measurement, transportation, and design, and work collaboratively through gesture recognition and voice communication to restore historical buildings or artifacts; In virtual festival events, users can form teams to participate in folk activities such as dragon dance and opera, and use motion capture technology to synchronize and coordinate group movements. The collaboration mechanism can also introduce team points, time-limited challenges, etc., to stimulate users' enthusiasm for participation and sense of collective honor. The XR platform can serve as a social venue for cultural discussions, allowing users to gather in digital museum halls, historical scene restoration areas, etc. through avatars to engage in real-time discussions about cultural heritage or hold online lectures; The platform also provides secondary creation tools such as 3D modeling software and animation production interfaces, encourages users to create virtual clothing and digital artworks based on cultural materials, and uses NFT technology for rights confirmation and trading. For example, users can apply their own designed traditional patterns to virtual clothing or shoot creative short films in historical scenes, forming a closed-loop ecosystem of "experience – creation – share". In addition, communities can establish user-generated content (UGC) incentive mechanisms, select quality works through expert reviews and public voting, and promote the continuous output of cultural innovation.

5. Conclusions

The dissemination of cultural heritage based on XR technology presents new challenges and opportunities. Driven by technology dissemination and innovation, XR technology has facilitated a transformation in the way culture is disseminated by creating interactive scenarios, reinforcing cultural symbols, and enhancing spatio-temporal visualization. With the support of technology, the linear narrative of cultural dissemination breaks through static limitations and enhances interactivity, allowing users to gain a deeper understanding of the logic of cultural symbols, deepen their understanding of cultural heritage, and internalize cultural heritage as their own emotional cognition. This way of communication can further inspire users' empathy for cultural groups, facilitate the formation of emotional connections among users, help users explore more diverse cultural heritage content in the cognitive and social dimensions, and form more effective cultural heritage communication strategies.

References

Jiao Chaoyue, (2024). Exploring the innovative practice of XR immersive Fusion News short drama: A Case Study of "Shu Dao Cui Yun: Two Thousand Years of Seeing a Tree as a Face". *Home Theater Technology*, (20), 80-82.

Li Yunlong & Liu Yuancheng, (2025). Application of XR virtual-reality fusion technology in ultra-high-definition evening party production. *Broadcasting and Television Technology*, *52*(01), 29-33.

Lin Zhiyu, (2025). Design of Smart Exhibition Hall System Based on 5G Cloud XR technology. *Electronic Products World*, *32*(03), 49-52.

Liu Xiulan, (2024). Innovation and Practice of XR Scene Generation based on AI technology. *Radio and Television Networks*, *31*(07), 38-40.

Liu Zheng, Zhang Jiesen, (2024). Immersive Communication and poetic Narrative: Digital Performance empowered by XR technology. *Science Communication*, *16*(20), 11-15.

Peng Yuyuan, Wang Xinyu, Xu Lin, (2025). Research on Festival Experience Design Strategies under Metaverse Technology: A Case Study of the Ziyuan River Lantern Festival. *Science and Technology & Innovation*, (06), 172-175.

Qiao Zhengxin, Si Xiaoxia, (2024). Virtual City imagery construction: Embodied Cognition and Aesthetic consciousness of New Quality Productivity XR Technology. *New Media Research*, *10*(17), 23-27+36.

Wang Songheng, (2025). From the Aesthetic Interpretation of the Chinese Nation to the Narrative of Film and Television - Technical Application and Narrative Design of XR Virtual Production. *Da Guan (Forum)*, (03), 63-65.

Wu Jiangbo, (2024). Research on the Design of media installations in Nixing Pottery Museum Based on XR technology. *Ceramic Science and Art*, *58*(06), 92-94.

Ye Xiaxian, (2024). Technology, Embodiment and Fusion: On China's First XR Digital Drama Macbeth. *Journal of Xinjiang Arts Institute*, *22*(04), 47-53.