Design and evaluation system construction of VR cultural heritage products from the perspective of user experience

Yuyuan Liu

School of Arts, Qingdao Agricultural University, Shandong, China

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Abstract: In the digital age, virtual reality (VR) technology offers innovative avenues for cultural heritage preservation, but its development still faces a disconnect between user experience and the transmission of cultural values. This paper systematically constructs a design and evaluation system for VR cultural heritage products from a user experience perspective. First, by analyzing the connotations and types of VR cultural heritage products and integrating user experience theory with cultural communication theory, a design framework is proposed with the core goal of "integrating cultural value transmission with deep user experience." This multi-layered design strategy encompasses strategic, content, interaction, and sensory layers. Second, a comprehensive evaluation model is established encompassing four dimensions: system usability, experience quality, emotion and cognition, and behavioral intention. This model integrates subjective and objective evaluation methods to form a closed-loop optimization mechanism. Finally, implementation recommendations are proposed for typical application scenarios such as museum guided tours, intangible cultural heritage teaching, and historical restoration. This study aims to provide theoretical guidance and practical tools for the development of VR cultural heritage products, promoting their transformation from a technology-oriented to a user-value-oriented approach.

Keywords: User experience (UX); Virtual reality; Cultural heritage; Design framework; Evaluation model

1 INTRODUCTION

Under the dual waves of globalization and digitalization, the protection and inheritance of cultural heritage are facing unprecedented opportunities and challenges. The survival of traditional culture requires not only static recording and preservation, but also a way of dissemination and experience that can transcend time and space and be vivid and tangible. VR technology, with its unique immersiveness, interactivity and imagination, provides a new technical path and practice field for cultural inheritance. It can break physical limitations, reshape historical scenes, and transform abstract cultural connotations into perceptible and participatory embodied experiences, greatly expanding the depth and breadth of cultural expression [1]. However, technology itself is not the goal. How to make technology truly serve the effective transmission of cultural values and be accepted by people has become the current core issue. In this context, from the perspective of user experience, systematically thinking about the design methods and evaluation standards of VR cultural products not only has important theoretical innovation value, but also has urgent practical significance for guiding

industrial practice and promoting its sustainable development.

At present, many exploratory practices have been carried out in the field of combining VR with cultural inheritance at home and abroad. From the virtual palace roaming project launched by the Palace Museum to the cave restoration and art exhibition carried out by the Dunhuang Academy using VR, a series of projects have fully demonstrated the huge potential of this application direction [2]. At the same time, user experience design theory has formed a relatively mature methodological system in the field of Internet and mobile products, but its application in the emerging medium of VR, especially in the special context of cultural heritage, is still in its early stages. Existing practices mostly focus on technical implementation and visual presentation and often have a tendency of "focusing on technology but not experience" and "having form but no charm", lacking in-depth consideration of user cognitive laws, emotional resonance and cultural identity formation mechanisms [3]. Most products have failed to build a set of user-centered methodological guidance and effect evaluation mechanisms that run through the entire design and development process, which directly leads to the fragmentation of user experience and the discount of cultural communication effect. Therefore, this study aims to address this gap and try to build a design and evaluation system that has both theoretical support and practical guidance.

Based on the above background and current situation, this study will follow the logical thinking of "problem raising-theoretical construction-application guidance". The core content of the research focuses on two major areas: first, to build a multi-level design framework centered on user experience and oriented towards VR cultural heritage products, clarifying its strategic goals, core principles and specific design strategies; then, to design a corresponding multi-dimensional dynamic evaluation model, establish key evaluation dimension indicators and method sets, and scientifically measure the product's experience quality and cultural communication effectiveness [4]. In terms of research methods, a comprehensive application of literature research, case analysis, system design and model construction will be used. The technical route will be gradually advanced along the steps of "theoretical foundation sorting - critical analysis of existing cases-system framework construction-application path interpretation", aiming to eventually form a set of application-oriented theoretical results that can provide practical guidance for the planning, development and iterative optimization of related products.

2 RELEVANT THEORIES AND CONCEPTUAL FOUNDATIONS

As an emerging form of cultural digitalization, VR cultural heritage products are essentially about building a digital experience environment that carries specific cultural connotations through virtual reality technology. Such products not only need to have immersion and interactivity at the technical level, but more importantly, they need to become a medium for transmitting cultural values, achieving the sublimation from "technical presentation" to "cultural experience". Its typical characteristics are manifested in three aspects: digital translation of cultural content, immersive participation in user experience, and functional attributes of educational communication [5]. From the perspective of product form, they can be mainly divided into immersive virtual tours, interactive cultural narratives, traditional skills simulation training, and cultural scene restoration experience. Each type has its own different focus in terms of technical implementation and user experience design.

User experience theory provides important methodological guidance for the design of VR cultural heritage products. Classic user experience theory believes that user experience includes multiple levels of elements such as functionality, usability, emotion, and meaning. These elements present new connotations and expressions in the VR environment [6]. In view of the particularity of VR experience, the theory of presence, the flow experience model, and the technology acceptance model have all been proven to have important guiding value. These theories collectively point out that an excellent VR user experience not only needs to focus on the usability of interface operations but also needs to pay attention to the user's psychological feelings and emotional investment in the virtual environment, so that users can naturally and comfortably integrate into the virtual cultural scene and gain in-depth cultural cognition [7].

Cultural communication and learning theory provide a theoretical basis for the evaluation of the effectiveness of VR cultural heritage products. Experience learning theory emphasizes the internalization of knowledge through four steps: concrete experience, reflective observation, abstract generalization, and active practice. This process is highly consistent with the immersive experience environment provided by VR technology [8]. Narrative transmission theory reveals how the plot influences the audience's attitudes and behaviors by attracting their attention and stimulating emotional resonance, which provides theoretical support for designing an infectious cultural narrative experience. These theories show that the value of VR cultural heritage products lies not only in the technical presentation, but also in whether they can achieve the effective transmission of cultural knowledge and the deep resonance of cultural emotions through a carefully designed experience process.

3 VR CULTURAL HERITAGE PRODUCT DESIGN FRAMEWORK FOR USER EXPERIENCE

The first task in designing VR cultural heritage products is to establish clear design goals and core principles. Its core goal is to achieve an organic integration of accurate transmission of cultural values and deep user experience, ensuring both the authenticity and integrity of cultural content and the ability of technical means to provide users with an immersive, comfortable and meaningful participation experience [9]. To achieve this goal, five leading design principles need to be followed: the cultural authenticity principle requires accurate restoration and appropriate translation of cultural elements; the immersion principle focuses on creating an immersive sense of presence through multi-sensory channels; the narrative principle emphasizes the use of storytelling to build emotional connections; the usability principle ensures that the interaction method is intuitive and easy to use; and the comfort principle focuses on the balance between physical comfort and psychological pleasure. These principles together constitute the basic basis and value scale for design decisions.

Based on the above goals and principles, we have constructed a four-level design framework. At the strategic level, it is necessary to clarify the core positioning of the product, balance user needs and cultural goals, and define the target user groups and the types of cultural experiences they expect to obtain. The content layer is responsible for selecting, transforming, and reconstructing cultural content. It needs to transform abstract cultural connotations into experiential digital forms and use narrative techniques to build meaningful emotional connections [10]. The interaction layer focuses on the interaction between users and the virtual environment. It requires the design of natural interaction mechanisms that conform to human instinctive cognition, the planning of smooth experience processes, and the establishment of timely and effective feedback systems. As the most direct user contact point,

the sensory layer needs to create an environmental atmosphere and emotional tone with cultural characteristics through the collaborative design of multiple modalities such as vision, hearing, and touch.

At the technical implementation level, modern three-dimensional reconstruction and rendering technology provides a solid foundation for the digital restoration of cultural scenes. From photogrammetry to laser scanning, from real-time lighting to physical rendering, the choice of each technology directly affects the authenticity and artistic appeal of cultural presentation. The selection of interactive technology needs to comprehensively consider the technical maturity, user adaptability, and the matching degree of cultural scenes. From handle interaction to gesture recognition, from positioning tracking to eye movement control, different interaction methods shape different cultural participation modes [11]. At the same time, performance optimization and comfort assurance technologies are crucial, including frame rate stabilization, delay control, motion comfort processing, etc. These technical details are directly related to the smoothness and comfort of the user experience and are an important guarantee to avoid technology interfering with cultural experience.

4 USER EXPERIENCE EVALUATION MODEL FOR VR CULTURAL HERITAGE PRODUCTS

Building a scientific user experience evaluation model is crucial for ensuring the quality of VR cultural heritage products. This model aims to establish a systematic evaluation mechanism. Its core objective is to comprehensively measure a product's overall performance in terms of functional effectiveness, user satisfaction, and cultural communication effectiveness through multi-dimensional measurement. The evaluation model requires a systematic perspective, focusing not only on technical performance indicators but also on users' subjective psychological experiences and, more importantly, the transmission of cultural values. This creates a three-dimensional evaluation framework that provides a comprehensive and accurate basis for product iterative optimization.

Based on this approach, the evaluation model establishes four key dimensions. The system usability dimension primarily examines the product's basic performance, including the smoothness of interactive operations, the understandability of interface elements, and the efficiency of task completion. The experience quality dimension focuses on assessing the user's subjective experience in the virtual environment, encompassing key indicators such as the intensity of presence, the depth of immersion, and physical comfort. The emotional and cognitive dimension delves deeper into the user's psychological state, encompassing key elements such as the strength of emotional resonance, the accuracy of cultural understanding, and the effectiveness of knowledge acquisition. The behavioral intention dimension focuses on the long-term impact of the experience, primarily measuring users' degree of cultural identification and willingness to actively spread the word. These indicators directly reflect the actual effectiveness of cultural communication.

To accurately obtain evaluation data for each dimension, a multifaceted approach combining subjective and objective methods is required. Subjective evaluation methods include quantitative measurement using validated standardized scales, qualitative insights gained through in-depth interviews, and immediate feedback collected through user self-reports.

Objective evaluation methods track user action paths and interaction patterns through behavioral log analysis, record system operational data using performance monitoring tools, and capture user attention allocation using devices such as eye tracking. Comprehensive evaluation should follow a process of "pre-experience baseline measurement-in-experience data collection-post-experience comprehensive evaluation." The evaluation results should be translated into specific design improvement recommendations, forming a complete closed-loop optimization mechanism.

5 APPLICATION PROSPECTS AND IMPLEMENTATION RECOMMENDATIONS FOR THE DESIGN FRAMEWORK AND EVALUATION MODEL

The design framework and evaluation model constructed in this article must be implemented in specific projects to realize their value. During project development, the design framework serves as a systematic guiding tool, providing comprehensive methodological support for teams from strategic positioning to detailed design. Development teams should integrate the framework's four layers into every stage of product development, ensuring that every design decision addresses both cultural value and user experience. The evaluation model should be implemented throughout the product development lifecycle, conducting formative evaluations during the prototype phase to identify issues, iterative testing during development to validate the design, and summative evaluations after launch to measure the final impact, thus forming a virtuous cycle of "design-evaluation-optimization."

The application of the framework and model requires adjustments and specific emphases for different types of VR cultural heritage projects. For museum VR guided tours, the sensory and content layers of the design framework should be prioritized, enhancing the visitor experience through high-precision reproduction and vivid storytelling. Evaluations should also focus on metrics such as knowledge transfer efficiency and visual immersion. In VR teaching of intangible cultural heritage skills, the design of the interaction layer is particularly critical, requiring precise simulation of the realism of skill manipulation. Evaluation should focus on skill acquisition outcomes and operational usability. For VR restoration projects of historical scenes, defining cultural objectives at the strategic level and historical accuracy at the content level are crucial. Evaluations should pay particular attention to dimensions such as cultural authenticity and emotional resonance.

To ensure the effective implementation of the framework and model, several practical recommendations are provided for development teams and organizational structures. Regarding team composition, it is recommended to establish a multidisciplinary collaborative team that, in addition to technical personnel, should also include cultural experts, user experience designers, and educational communication specialists to ensure the integration of diverse expertise. An iterative development model is recommended, with a mechanism for cultural experts to participate in the review process throughout the entire process, emphasizing early and frequent user testing. Care should be taken to avoid excessive pursuit of technical brilliance at the expense of cultural expression. Hardware compatibility and comfort adjustments should also be prioritized to ensure the final product possesses both cultural depth and a comfortable and enjoyable user experience.

6 SUMMARY AND OUTLOOK

Through systematic theoretical exploration and practical analysis, this study constructed a comprehensive design and evaluation system for VR cultural heritage products. On a theoretical level, it proposed a multi-level design framework centered on user experience, clarifying the full-process design strategy from strategic positioning to sensory realization. On a practical level, it established a multi-dimensional evaluation model encompassing comprehensive measurement indicators from system usability to behavioral intention. The value of this system lies in its integration of discrete design elements and evaluation criteria into a cohesive whole. This provides a methodological tool for the VR cultural heritage field that combines theoretical sophistication with practical guidance. This will help address current issues such as "emphasis on technology over culture" and "emphasis on presentation over experience," and promote the industry's shift from a technology-oriented to a user-value-oriented approach.

It should be noted that this study still has certain limitations. First, the constructed framework and model are primarily based on theoretical derivation and existing case studies. Their universality and effectiveness require further verification in a wider range of real-world projects. Second, the study primarily focuses on design methods and evaluation criteria, with relatively limited discussion of specific technical implementation details. Furthermore, due to differences in VR hardware performance and cost, the implementation of some of the experience criteria proposed in this study may vary across different device platforms. These limitations also leave room for further research and exploration.

Looking ahead, the development of VR cultural heritage products will demonstrate a trend of diversification and integration. Technically, with the maturity of technologies such as artificial intelligence, cloud computing, and haptic feedback, VR cultural experiences will become more intelligent, personalized, and immersive. Content-wise, they will evolve from single-scene restoration to cross-temporal and spatial narratives, creating a deeper cultural experience. Application scenarios will also expand from specialized venues such as museums and historical sites to broader areas such as family education and distance learning. It is recommended that subsequent research focus on user experience differences across cultures, long-term usage evaluation, and the development of standardized evaluation tools. This will promote the establishment of more comprehensive industry standards and practices, ensuring that VR technology truly becomes a powerful vehicle for cultural heritage innovation.

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