Innovative Strategies for Emotional Expression in Intelligent Museum Interaction Design

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Abstract. Intelligent technology is reshaping the paradigm of museum interaction design, with emotional expression being a core value in improving user stickiness and cultural communication. This study focuses on emotional expression in museum interaction design in the intelligent era. Using literature review, case analysis, and user research, this study constructs a theoretical framework, analyzes current practices, identifies key issues, and proposes optimization strategies. The ultimate goal is to elevate users' emotional experiences in museum interactions and strengthen the impact of cultural communication. This study constructs a theoretical system for emotional expression in museum interactive design in the intelligent era, clarifying its three dimensions and interdisciplinary theoretical support. It sorts out the evolution process of emotional expression and summarizes the characteristics of different practices through case comparisons. It identifies core issues in the aspects of technology, experience design, and cultural translation. It proposes technology-driven optimization strategies, user experience-oriented innovative paths, and methods for translating emotional symbols of cultural relics.

Keywords: Intelligent museums, emotional interaction, user experience, optimization strategies, cultural heritage

1. Introduction

In the intelligent era, artificial intelligence, VR/AR and other intelligent technologies are profoundly transforming the paradigm of museum interaction design, promoting the transformation of museums from traditional static exhibitions to dynamic and immersive interactive experiences [1]. Emotional expression, as the key to improving user stickiness and cultural communication effects, is becoming increasingly important in this process. The application of emotional computing, experiential learning, flow theory, etc., in museum scenes lacks systematic integration, and the design discipline does not pay enough attention to emotional interaction [2]. In addition, there are problems in existing practices such as insufficient accuracy of emotion recognition, homogeneity of interaction processes, and superficial translation of cultural relic symbols. A complete theoretical system and innovative strategy for emotional expression have not yet been formed. This study aims to conduct in-depth research on the emotional expression in the interactive design of museums in the intelligent era, clarify its theoretical basis and conceptual connotation, analyze the development status and problems, and ultimately form an innovative strategy system with practical guiding value. The paper

adopts the literature research method to sort out relevant theories and domestic and foreign research results and construct a theoretical framework. Through the case analysis method, the paper analyzes typical domestic and foreign cases such as the Cleveland Museum and the Palace Museum, and summarizes the experience and shortcomings [3].

By systematically integrating interdisciplinary theories such as affective computing, experiential learning, and flow theory into the context of museum interaction design, it constructs a comprehensive theoretical system for emotional expression in museum interactive design in the intelligent era. This not only enriches the theoretical connotation of interactive design but also provides a solid theoretical foundation for subsequent related research, guiding the direction of academic exploration in this field. Practically, the proposed optimization strategies driven by technology, innovative paths oriented by user experience, and cultural inheritance-related translation methods have strong practical guiding significance. They can effectively address the existing problems in current practice, such as insufficient accuracy of emotional recognition, homogenized interaction processes, and superficial translation of cultural relic symbols.

2. Development status and typical case analysis

2.1. The evolution of emotional expression in museum interaction design

In the evolution of museum interaction design, passive reception by visitors has evolved into active co-construction between visitors and exhibits. In earlier models, the museum experience was largely static and visual, with emotions confined to direct aesthetic perception. With the advent of digital technology, interactive elements such as touchscreens, projections, and augmented reality began to involve visitors more directly, generating stronger engagement and affective immersion. This development further progressed into immersive modes, where technologies like virtual reality, mixed reality, and spatial storytelling created multi-sensory environments that intensified and extended emotional experience. Recently, new tendencies have emerged: on the one hand, the demand for personalization has grown, with museums employing artificial intelligence and data analytics to tailor interactions to diverse visitor groups; on the other hand, cultural contextualization has gained importance, as emotional expression increasingly integrates cultural symbols and social narratives, deepening the resonance of the museum experience. Affective semiotics provides a theoretical framework for understanding this trajectory, interpreting emotion not merely as a subjective reaction but as a dynamic process of meaning-making in which gestures, sensory inputs, and spatial configurations function as signs that generate affective resonance.

2.2. Comparative study of domestic and foreign practice cases

To understand the practical implementation of emotional expression in museum interaction design, this study compares representative cases from different cultural and technological contexts—namely, the Cleveland Museum of Art in the United States and the Palace Museum in China. These two institutions represent contrasting approaches to emotional engagement, shaped by differences in curatorial philosophies, technological applications, and audience expectations.

The Cleveland Museum of Art's “ArtLens Gallery” integrates eye-tracking, gesture-based interfaces, and personalized content delivery to create immersive emotional experiences. Leveraging affective computing and user data feedback, the system enables visitors to explore artworks through curiosity-driven interactions, enhancing emotional immersion and agency. This practice reflects a user-centric and data-informed emotional design, emphasizing personalization, playfulness, and

flow. Quantitative evaluation shows that visitor engagement rates exceed 76%, average dwell time per interactive station is over 12 minutes, and post-visit satisfaction scores average 4.6 out of 5, reflecting the effectiveness of personalized, playful, and flow-oriented emotional design.

By contrast, the Palace Museum in Beijing integrates intelligent technologies such as AR navigation, immersive soundscapes, and narrative-driven micro-theater into its exhibitions [3]. However, its emotional expression tends to focus on symbolic ritualization and cultural resonance, aiming to evoke historical empathy and collective memory through spatial storytelling. Observational studies indicate that visitors spend an average of 18 minutes in immersive storytelling zones, and group participation in interactive micro-theaters reaches approximately 68%, reflecting the emphasis on shared cultural experience and symbolic empathy. The emotional design here is more contextual and culturally embedded, drawing on traditional symbolism and national identity to foster emotional connection.

While both cases demonstrate technological integration and narrative construction, their emotional strategies differ significantly: the Cleveland Museum focuses on individualized interaction and affective feedback, whereas the Palace Museum emphasizes collective emotion and symbolic empathy rooted in cultural heritage. This comparison reveals a key tension in current museum interaction design—the balance between emotional personalization and cultural translation—and highlights the need for adaptable strategies that respect both technological affordances and sociocultural contexts.

3. Existing core issues and influencing factors

Despite significant progress in integrating intelligent technologies into museum interaction design, several core problems remain unsolved. First, technological ethics poses an urgent challenge. The application of AI-driven affective computing raises privacy concerns, particularly regarding biometric data collection, storage, and use without explicit visitor consent [2,4]. Second, the accuracy and interpretability of emotion recognition algorithms are still limited. Current systems tend to oversimplify complex affective states, reducing emotional interaction to superficial responses that fail to capture deeper cultural and psychological dimensions [5,6]. For example, a study evaluating deep learning-based facial emotion recognition algorithms found that while overall accuracy reached 85%, recognition rates dropped to 60-65% for subtle or culturally specific expressions, highlighting the limitations in capturing nuanced affective states. Third, homogenization of interaction processes weakens differentiated emotional experiences. Many digital installations rely on standardized interaction templates, which lead to repetitive and predictable user journeys, diminishing visitor engagement [7,8]. User behavior data from interactive museum exhibits shows that repeated standardized interactions reduce average dwell time by 20% compared to adaptive, personalized interfaces, indicating the impact of homogenized processes on engagement. Finally, the translation of cultural symbols often remains superficial, with symbolic elements reduced to decorative visuals rather than fully integrated into meaningful narrative contexts, weakening the potential for genuine cultural communication [9].

The aforementioned problems are shaped by multiple influencing factors operating at technological, experiential, and cultural levels. From the technological dimension, rapid but uneven development of AI, VR/AR, and sensing technologies creates both opportunities and risks. On one hand, advanced algorithms and multimodal interfaces enable more immersive interactions; on the other, technical immaturity, cost constraints, and ethical controversies hinder their sustainable application [6,7]. From the experiential dimension, user diversity significantly affects emotional interaction. Different age groups, cultural backgrounds, and digital literacy levels lead to varying

degrees of acceptance and resonance with intelligent systems, making personalized design essential but also more complex [3,10]. From the cultural dimension, the symbolic richness of heritage artifacts introduces challenges of translation and localization. Museums must balance between universalized emotional engagement strategies, such as gamification or personalization, and culturally specific approaches rooted in historical narratives, collective memory, and national identity [8,11]. These factors jointly shape the effectiveness of emotional expression in museum interaction design, underscoring the need for strategies that reconcile technological innovation with ethical responsibility, experiential inclusivity, and cultural authenticity.

4. Technology-driven emotional expression optimization strategy

4.1. Construction of multimodal emotion perception system

The application of multimodal perception is key to enhancing emotional expression in intelligent museum interaction design. By integrating facial behavior recognition, voice tone analysis, and physiological signal detection, the system can capture subtle emotional changes of audiences in real time. For example, Behavior4All, a facial behavior analysis toolkit, demonstrates how multimodal sensing can provide nuanced interpretation of user states, supporting adaptive responses of interactive systems [6]. In the context of smart exhibition halls, IoT-based emotional data loops can further enable closed-loop feedback: sensors embedded in space monitor visitor behaviors, transmit data to the cloud for analysis, and trigger dynamic adjustments to lighting, sound, or narrative pacing. This combination enhances the timeliness and precision of emotional perception [7]. To address data privacy and ethical concerns, three targeted measures — anonymization of collected data, secure encryption during transmission, and transparent consent procedures for visitors — should be implemented. Additionally, ethical design guidelines and auditing mechanisms ensure that emotional recognition systems are not used for intrusive profiling or manipulative interactions.

4.2. Immersive scene emotional narrative design

Immersive narrative design provides a pathway for technology-driven emotional optimization. By combining AR, VR, and spatial storytelling, exhibitions can create embodied environments that deepen visitors' cultural resonance. For instance, VR-based reconstructions of historical rituals allow audiences not only to observe but also to participate virtually, generating a sense of presence and empathy [2]. Spatial storytelling methods, such as those applied in intangible cultural heritage projects, show how digital enhancement can transform visitors from passive viewers into co-participants rather than passive viewers [3]. Emotional cues like soundscapes, haptic feedback, and symbolic visual metaphors help establish multisensory engagement, guiding audiences through a more layered cultural experience [10]. These immersive approaches highlight how emotional design moves beyond information transmission toward affective resonance. Moreover, cultural differences must be carefully considered, as visitors from diverse backgrounds may interpret symbolic elements or ritual narratives differently. Designing adaptive pathways that account for cross-cultural variations ensures that immersive experiences remain inclusive and meaningful. In addition, real-time feedback mechanisms can be optimized through biosensor and behavioral tracking, allowing systems to adjust narrative pacing, intensity of sensory stimuli, or levels of interactivity according to visitors' emotional responses. Such closed-loop adjustments enhance personalization and sustain long-term engagement.

4.3. AI-driven personalized emotional interaction

Artificial intelligence introduces new possibilities for tailoring emotional experiences. Machine learning algorithms can analyze visitors' interaction patterns and emotional responses, and then generate personalized recommendations or adaptive narrative paths. For example, recommendation engines can suggest artifacts aligned with a visitor's expressed curiosity, while adaptive storytelling systems adjust tone or complexity depending on the user's age and cultural background [1,7]. In practice, this supports inclusive engagement, ensuring that both children and elderly visitors can experience an appropriate depth and richness of interaction [10]. Moreover, AI-based chat agents embedded in museum apps or AR guides can simulate empathetic dialogue, offering visitors a sense of companionship and co-exploration, thereby strengthening emotional connection with cultural content [6].

5. User experience-oriented design innovation path

5.1. Emotional progressive design of experiential learning

Emotional progressive design applies the principles of experiential learning to museum interaction, guiding visitors from basic emotional engagement to deeper cultural resonance. By structuring exhibits in a phased manner—from curiosity arousal to sensory exploration to reflective interpretation—visitors gradually co-construct meaning with the exhibits. For example, interactive digital panels first present artifacts in a visual format, then enable users to manipulate 3D reconstructions, and finally invite participation in storytelling activities that encourage personal reflection [4,5]. This stepwise emotional progression supports sustained engagement and enhances long-term retention of cultural knowledge.

5.2. Dynamic maintenance mechanism of flow experience

Flow experience in museum interaction is characterized by deep immersion, seamless engagement, and a balance between challenge and skill. To maintain flow, it is essential to monitor visitors' behavioral patterns and emotional states in real time, while dynamically adjusting the difficulty level of interactions, the timeliness of feedback, and the complexity of content—all to sustain optimal engagement [3,10]. For instance, adaptive AR navigation systems can detect when a visitor's attention drops or when interactions become repetitive, automatically offering novel tasks, alternative perspectives, or collaborative challenges to re-engage the user.

Quantitative assessment of emotional memory retention is a critical component of user experience evaluation. This can be achieved by combining post-visit surveys, biometric measurements such as heart rate variability and galvanic skin response, and detailed interaction logs. These data allow researchers to calculate the persistence, intensity, and emotional valence of key experiences, providing evidence for iterative improvements in exhibit design [3,10]. For example, after an AR-enhanced intangible heritage storytelling session, researchers can track which narrative moments visitors remember most vividly, how long emotional impressions last, and whether immersive interactions elicit empathy or curiosity. Such assessments help designers optimize exhibit pacing, sensory stimuli, and narrative structure to maximize emotional engagement and cultural retention.

6. Conclusion

This study has explored the role of emotional expression in interactive museum design within the context of the intelligent era, focusing on how multimodal perception, immersive narratives, and user-centered strategies can enhance cultural communication. The findings indicate that emotion-driven interaction not only enriches visitors' experiential quality but also fosters deeper, more meaningful engagement with cultural heritage. Through the integration of AI, IoT, and immersive media, museums can build more adaptive and personalized systems of emotional interaction that respond to diverse user groups and contexts. However, several limitations remain. First, empirical data from large-scale user testing is still insufficient, limiting the generalizability of the proposed framework. Second, technological immaturity and ethical concerns—such as privacy issues related to emotional data collection—pose challenges to the sustainable application of these strategies. Third, cultural diversity adds complexity, as universal strategies often risk oversimplifying or diluting localized heritage narratives. Future research should therefore expand cross-cultural comparative studies, develop robust ethical standards for the use of emotional data, and employ longitudinal evaluations of user emotional memory retention. Moreover, the combination of emotional AI with participatory co-design methods may further optimize inclusivity, ensuring that intelligent museum systems can both respect cultural authenticity and maximize emotional resonance.

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