

Interactive Technologies in Museum Exhibition Systems in the Era of Digital Transformation: Current Applications and Emerging Trends

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Abstract: *The ongoing wave of digital transformation is shifting museums from static display paradigms to multi-modal, interactive experience environments. Within this transition, interactive technologies have evolved from auxiliary presentation tools to structural mechanisms that shape exhibition systems. Drawing on international scholarship, this study analyzes how immersive media, touch-based interfaces, embodied interaction, and intelligent guidance systems influence the structural organization of exhibitions and reshape visitor experience. The paper further examines the functional logic of these technologies in cognitive processing, contextual construction, and narrative generation. Based on a synthesis of current applications, it identifies emerging trajectories in exhibition systems, including context-generation mechanisms, intelligent orchestration, and cross-platform narrative development. The findings suggest that interactive technologies are no longer peripheral additions but constitute the foundational operational logic of contemporary exhibition systems, offering critical insights into how museum experience is being reconfigured in the digital age.*

Keywords: Digital transformation; Museum exhibition systems; Interactive technologies; Immersive experience; Intelligent guidance.

1. INTRODUCTION

The rapid development of digital technologies has profoundly reshaped the structure of museum exhibition systems, their narrative modes, and the pathways through which visitors engage with content. Traditional linear communication models—primarily composed of display cases and textual labels—are gradually giving way to cross-platform, multi-media interactive experience systems. As noted in museum experience research, visitor experience is co-constructed by personal background, social context, and physical environment, and the integration of digital technologies significantly transforms the contextual layer, making experiences more immersive and participatory (Falk & Dierking, 2013). Digital transformation is therefore not merely a technological upgrade but a systemic reconfiguration of knowledge frameworks and cultural communication mechanisms (Parry, 2019).

Within this broader shift, immersive media, multi-touch interfaces, embodied interaction systems, and intelligent guidance technologies have become core components of exhibition systems. Existing studies indicate that immersive media enhance presence and emotional engagement (Slater, 2009), touch-based interfaces stimulate exploratory behaviors and active learning (Horn et al., 2012), embodied interaction integrates physical action with cognitive processes (Rogers, 2018), and intelligent guidance systems generate personalized pathways through user modeling. However, most international research focuses on the localized effects of single technologies, with comparatively limited attention to how different types of interactive technologies operate in conjunction within an integrated exhibition system. In addition, discussions concerning the systemic trends of future exhibition systems remain insufficiently developed.

Against this backdrop, this study examines the functional positioning and application logic of interactive technologies within museum exhibition systems from a systems perspective. It analyzes their influence on cognitive processing, emotional engagement, and behavioral experience, and further outlines the developmental trajectories of exhibition systems in the era of digital transformation. Rather than employing experimental analysis, the study synthesizes interdisciplinary theories and international literature to provide a structured analytical perspective for research on museum exhibition systems and for practical efforts in digital transformation.

2. LITERATURE REVIEW

As museums continue to restructure their knowledge organization models and exhibition strategies in the context of digital transformation, research on interactive technologies has gradually developed into a multidimensional and interdisciplinary body of scholarship. Existing studies generally concentrate on three main areas: the mechanisms of media transformation within exhibition systems, the role of interactive technologies in cultural heritage communication, and the impact of digital experiences on visitor cognition and behavior. Although these studies do not operate under a unified theoretical framework, collectively they trace the historical trajectory through which museum exhibition systems have expanded from traditional static dissemination structures into dynamic, participatory systems.

In the field of media transformation, scholars widely argue that exhibition systems have shifted from centralized structures dominated by “display cases and labels” toward distributed knowledge systems supported by digital media and interactive logic. With the rise of digital cultural platforms, museums have entered a “post-materiality” era in which digital content becomes a key medium for constructing cultural meaning, resulting in exhibition systems that exhibit both networked and contextualized characteristics (Navarrete, 2020).

Research on interactive technologies in cultural heritage primarily revolves around immersive media, multi-touch interfaces, embodied interaction, and intelligent guidance systems. Immersive media remain one of the most extensively discussed topics in museum studies. A systematic review of extended reality technologies indicates that AR, VR, and MR have evolved from tools for simple scene reconstruction into mechanisms for contextual storytelling, spatial interpretation, and knowledge construction (Bekele et al., 2018). The theory of presence proposed by Slater (2009) further demonstrates that immersion in virtual environments plays a structural role in shaping learning and emotional responses, a framework widely applied in analyzing how VR influences cognitive and affective engagement in museum settings. In addition, AR’s layered information structure has been shown to enhance visitor comprehension of complex content, giving it a distinctive advantage in exhibitions characterized by high information density (Javornik, 2016). Beyond immersive media, multi-touch interfaces and interactive visualization tools have also been identified as important instruments for increasing visitor participation.

Intelligent guidance systems, another key research topic in recent years, represent an early form of artificial intelligence application in museums. Through user modeling and real-time behavioral analysis, such systems can provide personalized and context-sensitive exhibition pathways, shifting museums away from uniform narrative structures toward more flexible, multi-path modes of storytelling (Kuflik et al., 2015). Yet scholars also note that technological intervention may lead to fragmented information structures or inconsistent visitor experiences. For this reason, exhibition systems must be designed to ensure that interactive technologies serve not only as functional tools but also as integral components of narrative construction.

In the domain of visitor studies, researchers have examined how digital experiences influence cognition, memory, emotion, and behavior. Interactive technologies have been shown to enhance learning effectiveness and experiential quality through greater sense of control, immediate feedback, and higher visual complexity (Pallud, 2017). Digital media are also understood to deepen emotional engagement, enabling affect to play an increasingly significant role in the process of meaning-making (Witcomb, 2015). Nevertheless, some studies caution that digital experiences may also increase cognitive load or cause distractions, suggesting the need to balance sensory stimulation with information density in exhibition design (Tost & Champion, 2019). Taken together, these studies indicate that interactive technologies can both enhance and complicate visitor experience, underscoring the importance of understanding their effects from a systems perspective rather than through isolated technical analysis.

3. CURRENT APPLICATIONS OF INTERACTIVE TECHNOLOGIES IN MUSEUM EXHIBITION SYSTEMS

In the context of digital transformation, the application of interactive technologies in museums has expanded from localized device updates to structural mechanisms embedded throughout the entire exhibition system. As technological categories, interaction modes, and narrative strategies diversify, exhibition systems increasingly take the form of a composite ecology that integrates immersive media, visual–interactive interfaces, embodied interaction, and intelligent recommendation mechanisms. Each type of interactive technology assumes distinct functions within the system, influencing information presentation, contextual construction, attention modulation,

and processes of meaning-making. Together, they contribute to a multilayered structural division of labor within the exhibition environment.

Immersive media have become a central component of contemporary exhibition systems. Through the spatial immersion of virtual reality, the informational overlays of augmented reality, and the contextual integration of mixed reality, these technologies create highly contextualized knowledge environments supported by visual, auditory, and sensorimotor feedback. Research indicates that immersive media in cultural heritage contexts are shifting from “virtual reconstruction” toward “narrative generation,” transforming the role of exhibition systems from static presenters of content to dynamic orchestrators of experiential contexts (Bekele et al., 2018). The spatial enclosure and perceptual isolation produced by virtual reality enable visitors to temporarily disengage from real-world disturbances, thereby heightening attentional focus and sensory engagement.

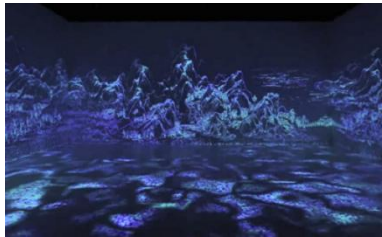
Touch interaction and visual–interactive interfaces represent a second major category of interactive technology within exhibition systems. Their primary function lies in enabling operable knowledge structures, allowing visitors to construct informational pathways through direct touch-based actions such as tapping, sliding, enlarging, and zooming. Multi-touch interfaces have been shown to stimulate exploratory behavior by lowering operational barriers and increasing the transparency of information structures (Horn et al., 2012). Within exhibition systems, touch-based technologies often support information aggregation, data visualization, and archival expansion, presenting hidden layers of information, structural relationships, and temporal trajectories. In contrast to immersive media—which emphasize “situated entry” into a narrative—touch interfaces emphasize “operational understanding,” making cognitive processes visible and promoting reflective engagement.

Embodied interaction plays an increasingly important role in contemporary exhibition systems by integrating bodily action, sensor-based feedback, and object manipulation. Based on theories of embodied cognition, physical actions serve not only as behavioral outputs but also as cognitive inputs, suggesting that bodily engagement enhances information processing and contextual memory (Rogers, 2018). In museum environments, embodied interaction is frequently used to recreate historical movements, simulate craft techniques, or structure exploratory tasks, allowing visitors to develop bodily grounded understandings of processual or skill-based knowledge.

Intelligent guidance systems and personalized recommendation mechanisms have introduced new structural logic into exhibition systems. Through user modeling, intelligent guidance can dynamically adjust exhibition content based on visitors’ interests, behavioral trajectories, and time constraints, shifting museums from single-path narrative structures toward multi-path, adaptive forms of storytelling (Kuflik et al., 2015). As artificial intelligence capabilities develop, such systems increasingly demonstrate learning and predictive abilities, generating personalized knowledge pathways based on behavioral analytics. However, these systems may also fragment the experience or disrupt narrative coherence, raising the challenge of balancing personalization with narrative integrity at the system level.

Within the overall structure of exhibition systems, these technologies rarely operate independently; instead, they form synergistic relationships through various modes of coupling. Immersive media may provide the contextual framework, touch interfaces may function as embedded knowledge-expansion tools, and embodied interaction may reinforce contextual understanding through action-based engagement. In advanced systems, intelligent guidance can selectively trigger immersive scenes or dynamically adjust knowledge depth based on predicted user needs, producing multi-technology, cross-context narrative structures.

Table 1: Structural Functions of Interactive Technologies in Museum Exhibition Systems

Type of Interactive Technology	System Functional Features	Typical System Roles	Effects on Visitor Experience	Image
Immersive Media	Context construction; spatial simulation; narrative integration	Builds immersive cognitive environments; strengthens contextual understanding	Enhances sense of presence; increases attentional focus; deepens emotional engagement	

Multi-touch Interaction and Interactive Visualization	Information access; data organization; structural presentation	Constructs operable knowledge structures; expands informational layers	Promotes exploratory behavior; improves information transparency	
Embodied Interaction (Gesture, Motion, Object-based Input)	Behavioral participation; skill simulation; bodily memory	Couples action with cognition; reenacts process-based knowledge	Increases participation motivation; enhances long-term, embodied memory	
Intelligent Guidance and Personalized Recommendation	User modeling; path generation; dynamic content scheduling	Creates diversified narrative paths; improves system adaptability	Enhances relevance and personalization; strengthens visitors' sense of autonomy	

4. EFFECTS OF INTERACTIVE TECHNOLOGIES ON USER EXPERIENCE AND SYSTEM STRUCTURE

The integration of interactive technologies into museum exhibition systems not only alters modes of information presentation but also profoundly shapes visitors' cognitive processing, emotional engagement, and behavioral patterns. Because an exhibition system constitutes a composite environment formed by informational structures, spatial configurations, and user experience, technological interventions tend to produce structural effects. Consequently, the outcomes of visitor experience cannot be explained solely by the properties of individual technologies; rather, they must be understood within the systemic logic through which these technologies collectively operate. Existing international studies demonstrate that immersive media, touch-based interfaces, embodied interaction, and intelligent systems influence visitor experience at different levels—yet more importantly, their effects frequently intersect, resulting in highly composite experiential outcomes.

Immersive media exert a significant impact on emotional engagement. As noted in presence theory, the “illusion of being there” generated by virtual environments constitutes the foundation of immersive experience and shapes both immediate emotional reactions and longer-term memory related to cultural meaning-making (Slater, 2009). The increasing use of immersive technologies in museums allows visitors to perceptually “enter” narrative contexts, fostering heightened attentional focus and emotional resonance. However, studies also caution that excessive sensory stimulation may increase cognitive load; therefore, immersive environments must be carefully calibrated against information density to avoid situations in which attention is consumed by the technology itself rather than by exhibition content.

Multi-touch interfaces primarily support cognitive processing through operational engagement. Research indicates that touch-based interaction encourages exploratory behavior and helps visitors actively construct knowledge structures rather than passively follow linear narratives (Horn et al., 2012). Embodied interaction enhances learning and contextual understanding through bodily engagement. In cultural heritage settings, embodied interaction is frequently used to simulate traditional craftsmanship, recreate historical motions, or design exploratory tasks, enabling visitors to engage in bodily participation as a means of knowledge construction. One of its key advantages is the formation of action-based memory, which is highly durable and context-dependent, making it particularly valuable for exhibits emphasizing processual, skill-based, or spatial content (Rogers, 2018).

Intelligent guidance systems reshape the narrative structure of exhibition systems through user modeling. Dynamic recommendations based on behavioral data enhance alignment between exhibition content and individual interests,

resulting in more adaptive and targeted experiences (Kuflik et al., 2015). As such systems evolve from static path optimization toward dynamic context generation, exhibition structures increasingly exhibit characteristics of “real-time narrative,” in which visitors co-construct their own experiential pathways. However, personalized recommendations may also fragment the knowledge structure, presenting a challenge for maintaining narrative coherence. Ensuring continuity between personalized content and the overarching interpretive framework thus becomes a critical concern.

To illustrate the structural effects of different interactive technologies, Table 2 summarizes their primary experiential outcomes, systemic influences, and potential risks.

Table 2: Experiential Effects and Systemic Implications of Interactive Technologies in Museum Exhibitions

Technology Type	Primary Experiential Effects	Systemic Implications	Potential Risks
Immersive Media	Enhances presence, emotional engagement, and attentional focus	Reconstructs narrative space and contextual frameworks	Sensory overload; attentional distraction
Touch-based Interfaces and Interactive Visualization	Promotes exploratory behavior; increases information transparency	Restructures information architecture and modes of knowledge organization	Fragmentation of interaction processes; information overload
Embodied Interaction	Strengthens action-based memory; increases participation	Introduces process-based experiences and embodied learning mechanisms	Device constraints affecting interaction fluidity
Intelligent Guidance and Personalized Recommendation	Enhances content relevance; strengthens sense of autonomy	Establishes dynamic narrative pathways; increases system adaptivity	Experience discontinuity; fragmentation of knowledge structures

5. FUTURE TRENDS AND SYSTEM EVOLUTION

As digital infrastructure continues to undergo rapid upgrades and artificial intelligence technologies steadily mature, museum exhibition systems are gradually shifting from an early developmental stage—one characterized primarily by the parallel coexistence of multiple interactive technologies—toward a future model defined by higher degrees of intelligence, ubiquitous connectivity, and integration across different spatial and functional domains. In this emerging framework, exhibition systems will no longer be centered around a single type of interactive medium or isolated device; instead, they will increasingly consist of immersive spatial environments, data-driven intelligent services, and cross-platform narrative networks that operate in concert. Through this transformation, exhibitions are evolving from one-off, spatially confined encounters into continuous experiential structures that extend across the pre-visit, on-site, and post-visit stages of cultural engagement.

Among the trends shaping this evolution, cross-media narrative development is expected to become a particularly important direction. As extended reality technologies, mobile media, and context-aware sensing devices continue to converge, exhibition systems will gradually transcend the traditional limitations imposed by physical space. This convergence will support the formation of narrative chains that link together online and offline environments, as well as museum interiors and broader urban contexts, thereby enabling cultural experiences to achieve greater continuity, wider social connectivity, and deeper integration into visitors’ everyday lives.

Artificial intelligence is anticipated to assume an even more structural and foundational role in future exhibition systems. With the ongoing advancement of user modeling, natural language processing, and multimodal recognition technologies, museums will become increasingly capable of perceiving visitors’ behavioral intentions and understanding their cognitive needs in real time. This will enable the generation of personalized narrative pathways that adapt dynamically to individual preferences. Such adaptive capabilities will not only elevate the relevance and precision of content delivery but also endow exhibition systems with new forms of interpretive agency and co-creative potential, allowing visitors and systems to jointly shape the meaning-making process. However, the expansion of highly individualized narratives also carries the risk of fragmenting the overall knowledge structure and weakening the coherence of overarching interpretive frameworks. Therefore, future exhibition systems must carefully balance the tension between maintaining narrative unity and offering

differentiated, personalized experiences, ensuring both the integrity of cultural knowledge and the stability of broader contextual meaning.

Overall, the evolution of museum exhibition systems is moving toward configurations that are more intelligent, more interconnected, and more capable of generating context-rich experiential environments. In this process, interactive technologies will no longer function merely as supporting tools but will increasingly serve as core structural elements that define how museum experiences are organized, interpreted, and sustained in the era of digital transformation.

6. CONCLUSION

Digital transformation is reshaping the structural logic of museum exhibition systems, positioning interactive technologies as critical mediators connecting cultural content, spatial context, and visitor experience. By synthesizing international research, this study has examined the mechanisms through which immersive media, touch-based interfaces, embodied interaction, and intelligent guidance systems operate within exhibition environments, revealing their combined influence on cognitive processing, emotional engagement, and behavioral participation. The findings indicate that exhibition systems are shifting from traditional, static narrative models toward adaptive, context-rich, and multi-path structures shaped by technological integration.

Looking ahead, exhibition systems will increasingly adopt intelligent content orchestration, cross-platform narrative networks, and context-generative experiential modes. Interactive technologies will thus move beyond their role as auxiliary tools to become fundamental components structuring the logic of museum experience in the digital era, offering new paradigms for cultural communication and knowledge construction.

REFERENCES

- [1] Falk, J. H., & Dierking, L. D. (2013). *The museum experience revisited*. Routledge.
- [2] Parry, R. (2019). *Museum technology: A critical history*. Routledge.
- [3] Slater, M. (2009). Place illusion and plausibility in virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1535), 3549–3557. <https://doi.org/10.1098/rstb.2009.0077>
- [4] Horn, M. S., Solovey, E. T., Crouser, R. J., & Jacob, R. J. (2012). Comparing tangible and graphical user interfaces for data exploration tasks. *IEEE Transactions on Visualization and Computer Graphics*, 18(12), 2779–2788. <https://doi.org/10.1109/TVCG.2012.220>
- [5] Rogers, Y. (2018). *Designing interactive systems: A comprehensive guide to HCI and interaction design* (3rd ed.). Wiley.
- [6] Kuflik, T., Wecker, A. J., Lanir, J., & Stock, O. (2015). An integrative model for museum visitors' guidance. *ACM Transactions on Interactive Intelligent Systems*, 5(3), 1–25. <https://doi.org/10.1145/2808232>
- [7] Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., & Gain, J. (2018). A survey of augmented, virtual, and mixed reality for cultural heritage. *Journal on Computing and Cultural Heritage*, 11(2), 1–36. <https://doi.org/10.1145/3145534>
- [8] Javornik, A. (2016). Augmented reality: Research agenda for studying the user experience. *Journal of Retailing and Consumer Services*, 30, 252–261. <https://doi.org/10.1016/j.jretconser.2016.02.004>
- [9] Pallud, J. (2017). Impact of interactive technologies on stimulating learning experiences in a museum. *Information & Management*, 54(4), 465–478. <https://doi.org/10.1016/j.im.2016.10.004>
- [10] Witcomb, A. (2015). Toward a pedagogy of feeling: Understanding how museums create affective experiences. In *Museums and the future of critical heritage studies* (pp. 285–299). Routledge.
- [11] Tost, L. P., & Champion, E. (2019). A critical approach to immersive media in cultural heritage. *Digital Scholarship in the Humanities*, 34(1), 155–176. <https://doi.org/10.1093/llc/fqy024>
- [12] Navarrete, T. (2020). Museums in the digital age: The rise of the digital cultural consumer. *Museum Management and Curatorship*, 35(5), 498–518. <https://doi.org/10.1080/09647775.2020.1733040>