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Value Reconstruction and Framework Construction of AI Curation Technology in the Digitalization Process of Museums Driven by Design Studies

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ABSTRACT
The deep integration of museum digitalization and artificial intelligence (AI) technology is driving a paradigm shift in curation models, with the perspective of design studies providing a crucial theoretical framework and methodological support. Based on design theory, this research explores the value reconstruction and implementation paths of AI curation technology in museum digitalization through literature review, case analysis, and framework construction. From a design studies perspective, it discusses the theoretical framework and practical paths of AI curation, proposing a four-layer technical framework of "data collection-intelligent analysis-exhibition design-feedback iteration" to clarify human-machine collaboration. It introduces design control tools like the "cultural weight matrix" to balance algorithmic output with cultural accuracy and establishes evaluation dimensions covering data ethics and cultural fairness. The study offers practical pathways for intelligent transformation in museums. Future work should explore metaverse-distributed curation and lightweight solutions.

KEYWORDS
Design studies; Museum digitalization; AI curation; Audience experience; Spatial narrative; Interaction design

1 Introduction

1.1 Research background and industry trends

With rapid digital technology development, museums, as core venues for cultural heritage and knowledge dissemination, are undergoing major digital transformation. AI technology has evolved from an auxiliary tool to a creative partner in curation, revolutionizing practices and shifting exhibitions from static displays to dynamic interaction and personalized experiences. According to the International Council of Museums (ICOM) 2024 report, over 78% of museums worldwide have incorporated AI into development plans, focusing on digitalization of cultural resources, intelligent guide systems, and audience behavior analysis. In China, this trend is growing, reflecting active deployment in cultural digitization. Applications include digital management of cultural relics (e. g., Yungang Grottoes mural restoration), audience experience upgrades (e. g., Shandong Museum's Dunhuang immersive field via VR), and curation process optimization (e. g., Wuhan Science and Technology Museum's computer vision recommendation system). However, a "technology first, design lag" issue exists: AI theme generation relies overly on historical data, leading to fragmented narratives (e. g., Mawangdui Han Tomb exhibition weakening cultural identity); algorithmic bias causes cultural misinterpretation (e.g., 34% error rate in non-Western art recognition); and absent human-machine collaboration reduces designers to parameter adjusters (e. g., KAIST virtual curation system). These highlight the lack of a design studies framework in technology integration.

1.2 Research status and theoretical gap

A review of domestic and international achievements (Table 1) reveals that the absence of a design studies perspective is the core bottleneck in AI curation:

Existing research shows three fractures: narrative logic rupture (e. g., British Museum's mummy CT scanning overpowering context), humanistic imbalance (e.g., Dunhuang AIGC mural re-creation debates), and lack of collaboration

Table 1 Current status of ai curation research and design studies intervention space

Research Dimension	Representative Case/Theory	Main Contribution	Design Studies Perspective Missing
Technical Layer	Yungang Grottoes AI Mural Restoration	Preserves artifact information beyond physical limits	No visual norms for cultural symbol translation
Audience Experience	Shandong Museum VR Dunhuang Narrative	Builds multi-sensory immersive field	Spatial emotion not linked to cognitive psychology
Cultural Communication	Mawangdui "Three-Culture Integration" Path	Develops methodology for cultural IP	No cultural weight matrix for content regulation
Ethical Governance	EU Horizon 2020 Federated Learning Framework	Protects data privacy	Ethical design not translated to user experience

mechanisms (e.g., designers unable to intervene in AI decisions). This stems from the systemic absence of design studies across technology, narrative, and ethics, requiring interdisciplinary integration to reconstruct human-machine relationships.

1.3 Theoretical innovation of design studies intervention

Design studies, researching interactions between people, objects, environments, and systems, provides theoretical and methodological support for museum digitalization. It emphasizes spatial narrative reconstruction centered on audience experience, information delivery optimization, and cultural value transmission. This study proposes reshaping AI curation with design thinking, constructing a "technology-narrative-ethics" framework. Theoretically, it uses Wu Hongliang's "empathic field" theory to foster emotional resonance and cultural identity through narrative methods, spatial design, and interactive experiences, transforming exhibitions into emotional narrative spaces where AI serves audience meaning construction (e.g., Beijing Art Academy's open title design). Methodologically, it employs case analysis (e.g., Shandong Museum, Dunyang Academy) and framework construction. Innovations include a four-dimensional technical framework with a design control layer (cultural weight matrix) and ethical feedback layer (federated learning); defining designers as "AI training guides" setting cultural parameters and innovation constraints; and integrating SLAM positioning and space syntax for an action-symbol-emotion loop. This generates triple value: establishing a design studies-oriented AI curation evaluation system; providing lightweight solutions for small museums (e.g., "Curation Assistant Cloud"); and promoting design-driven transformation in line with national "Cultural Digitalization" strategy.

2 Core value of museum digitalization from a design studies perspective

2.1 Expanding cultural narrative dimensions

Digital technology enables multi-dimensional narratives beyond physical space limitations. Zhejiang University's Research Center for Archaeology and Art 3D-printed Yungang Grottoes' Cave 12, replicating large-scale relics for exhibition. Dunhuang Academy's "Digital Library Cave" uses virtual reproduction and AIGC to reconstruct Buddhist rituals, allowing audience choice in exploration paths, shifting from "viewing" to "participating." This non-linear narrative reflects design studies' "user-centered concept," enhancing participation and immersion. Mawangdui Han Tomb's digital practice uses immersive LED screens, parametric rendering, and digital restoration to display "cosmic operation - life sublimation," interpreting tomb structure and cultural concepts. The fragmented recombination aligns with cognitive "script theory," using multimodal interaction to make Han Dynasty culture perceptible.

2.2 Deepening audience-centered design

AI curation enables personalized experiences through data drive. Wuhan Science and Technology Museum's AI guide uses computer vision and NLP to capture dwell time, expressions, and behaviors, adjusting content dynamically. It switches to cartoon commentary and AR games for young audiences, and provides academic resources for researchers, meeting diverse needs through adaptive design.

Table 2 Layered design model for museum audience experience

Audience Type	Cognitive Characteristics	AI Response Strategy	Design Value
General Visitors	Superficial cognition/Entertainment	Storytelling + AR interaction	Reduce cognitive load
Student Groups	Knowledge construction needs	Contextualized learning tasks	Promote meaning construction
Professional Researchers	Deep analysis needs	Academic databases and tools	Support exploration
Special Groups	Accessibility needs	Voice navigation/Tactile feedback	Achieve inclusive design

In accessibility, AI enhances inclusivity. Hangzhou's "Grotto Art Immersive Exhibition" developed a tactile-auditory system for visually impaired audiences, and AI sign language for hearing-impaired, aligning with "universal design principle."

2.3 Reconstructing spatial experience and interaction

ICOM (2019) advocates museums as cultural "contact zones" for inclusive, democratic dialogue. Digital technology application has increased focus on cultural content media and user experience. AI with XR creates blended virtual-real spaces: Emperor Qinshihuang's Mausoleum AR reveals original Terracotta colors; British Museum's "Egyptian Mummies" uses CT data for virtual dissection. These demonstrate spatial transparency—digital layers revealing historical information. KAIST's virtual curation uses genetic algorithms to optimize artwork layout based on characteristics and visitor flow, allowing curators to adjust weights (e.g., era contrast or style evolution), reflecting human-machine collaboration—AI provides data, designers control narrative.

Table 3 Comparison of ai-empowered museum space reconstruction models

Reconstruction Model	Technical Support	Design Innovation Point	Application Case
Physical Space Extension	SLAM + AR positioning	Virtual-real scene matching	Digital Terracotta color restoration
Emotional Space Creation	Affective computing + Spatial audio	Dynamic environment adjustment	Met Museum "HEAR WE ARE"
Interactive Space Creation	Motion capture + Haptic feedback	Multi-modal sensory synergy	Mawangdui somatic ritual operation
Virtual Space Generation	Cloud rendering + Metaverse	Multi-user collaborative creation	Dunhuang Metaverse Cave Plan

Viewing paradigms shift from "objects in cases" to "living cultural entities." Metropolitan Museum's "HEAR WE ARE" lets exhibits "narrate" stories; Yingxian Wooden Pagoda VR allows "participation" in construction. This echoes behavioral "field theory"—audiences as participants, not observers, transforming cognitive experience.

3 Integration of design studies into the ai curation technology framework

3.1 Data layer: structuring cultural semantics

Data collection builds a multi-dimensional cultural gene bank. Dunhuang Academy's "multimodal knowledge graph" decomposes murals into visual symbols, craft characteristics, and cultural semantics, mining pattern-period relationships, embodying information architecture design. Technological innovation diversifies methods: Tsinghua University used robot dogs with 3D scanning for Yingxian Wooden Pagoda data, plus environmental sensors for spatiotemporal database. Ethical design is crucial: Wuhan Science and Technology Museum conducts security and privacy testing for personal data.

Table 4 Multimodal data collection types and design value in ai curation framework

Data Type	Collection Method	Design Transformation Direction	Ethical Consideration
Artifact Ontology Data	3D scanning/Spectral analysis	Digital twin construction	Copyright protection & replication limits
Audience Behavior Data	Computer vision/Positioning beacons	Visit flow optimization	Anonymization principle
Environmental Parameter Data	IoT sensor network	Display condition warning	Equipment concealment design
Cultural Context Data	Literature mining/Knowledge graph	Narrative logic generation	Cultural authority verification
Emotional Feedback Data	Micro-expression recognition/Voice analysis	Experience upgrade	Informed consent mechanism

3.2 Analysis layer: algorithmic translation of design intent

Intelligent analysis translates design goals into algorithmic parameters. In theme generation, NLP assists conceptual divergence. For Mawangdui, AI analyzed historical materials like "Book of Han," extracting themes ("Dai Hou Family," "Han Dynasty Health Preservation") combined with social hotspots, generating directions like "Han Dynasty Nobility's Eternal Life Pursuit." Designers set cultural weights (e.g., historical importance ⩾0.7, public awareness ⩾0.5) to align AI output with academic positioning. Audience profiling goes beyond demographics: Harvard Art Museum's "Surprise Machines" uses CNN to analyze micro-expressions, dwell time, and interaction frequency, building emotional response maps for personalized recommendations, embodying user modeling. KAIST's spatial adaptability model cost function includes cluster cohesion, separation, visual continuity, and flow smoothness. Designers balance academic rigor and aesthetic appeal by adjusting weights.

3.3 Design layer: human-machine collaborative creative generation

Exhibition design is where design studies intervenes, with AI as "creative catalyst." Digital curation retains professional teams while enabling public participation. In spatial narrative, Dunyang's "Conquering Demons" picturebook had AI generate storyboards: linear, thematic, spatial. Designers chose spatial narrative for circular gallery, creating samsara sense, showing human-machine complementarity. Intelligent layout tools revolutionize curation: British Museum's AI system generated layout schemes ("Chronicle," "Social Hierarchy," "View of Life and Death") for Ancient Egypt exhibition; curators chose the third and optimized showcase orientation, saving 80% time. Generative AI excels in visual style translation: Sanxingdui input bronze patterns into StyleGAN, generating new patterns blending ancient Shu and modern minimalism for products, controlling variables for cultural recognizability.

Table 5 Comparison of AI-driven optimization algorithms for exhibition space layout

Algorithm Type	Core Mechanism	Design Adaptation Scenario	Representative Case
Genetic Algorithm	Selection-Crossover-Mutation iteration	Large-scale exhibit cluster layout	KAIST Virtual Museum
Particle Swarm Optimization	Position-Velocity collaborative update	Streamlined gallery flow design	British Museum Egypt Exhibition
Reinforcement Learning	Environmental feedback reward	Adaptive layout adjustment	NY MoMA Experimental Gallery
Graph Neural Network	Node relationship modeling	Thematic relevance spatial expression	Palace Museum Context Topology Exhibition
Constraint Programming	Condition satisfaction priority	Special display condition constraints	Louvre Fragile Artifacts Exhibition

3.4 Feedback layer: dynamic optimization of the experience loop

Real-time feedback optimizes exhibitions. Multi-modal data collection (behavior tracking, emotion recognition, eye tracking) records user behavior, emotions, and attention. Quantitative analysis optimizes communication content. Wuhan Science and Technology Museum's sensing system captures trajectories, voice feedback, and interaction frequency; low dwell time triggers warnings, building a PDCA cycle. Affective computing deepens feedback: Boston Museum of Fine Arts' "Empathy Canvas" uses facial recognition and galvanic skin response for emotional heat maps; finding Renoir's "Strolling in the Rain" caused teen confusion, prompting AR analysis on Impressionist techniques, adhering to "minimum necessity" principle. Long-term data reveals cognitive patterns: Palace Museum found a 40% drop-off between "Ceramics-Furniture" areas due to visual fatigue; inserting a neutral transition zone increased dwell time by 27%, confirming environmental arousal theory.

4 Design studies-driven implementation paths and challenges

4.1 Ethical governance framework construction

AI curation faces algorithmic bias and cultural misinterpretation. Museums must ensure fair, objective information. Microsoft Research 2024 reported 34% error rate for non-Western art (e.g., Ukiyo-e classified as "cartoons"). Algorithmic recommendations may reduce exploration autonomy; digital replicas may challenge historical authenticity. Solutions include multicultural datasets, anthropologist review, and explainable AI interfaces. Data privacy requires layered protection: EU "Horizon 2020" proposed federated learning (raw data local, share parameters), differential privacy (add noise), and data trust (third-party management). Design must translate privacy to experience, e.g., Chicago Art Museum letting audiences set "data visibility." Museums should cooperate with legal and technical providers for solutions. Cultural authority balance is key: Dunhuang AIGC mural re-creation sparked authenticity debates; dual-track output—academic mode (archaeological evidence) and creative mode (marked fictional parts)—respects rigor and creativity.

4.2 Designer role transformation

Designers must shift from executors to strategy guides. Digital technology must enhance, not overshadow, content. In Helsinki Art Museum's "AI Curator," designers defined cultural weight matrix (e.g., "Finnish nationality" indicators), set innovation constraints (e.g., 30% original brushstroke retention), and guided human-machine co-creation workshops, requiring data literacy and cultural insight. Interdisciplinary collaboration is crucial: Mawangdui project used T-shaped teams—archaeologists and programmers for depth, designers as "glue" for integration. Designers need "technology translation" skills, e.g., transforming Han Dynasty cosmology into VR navigation logic.

4.3 Curation process re-engineering

Traditional linear process (theme-research-selection-layout) evolves into agile co-creation. Palace Museum's "Digital Patron" used SCRUM: sprint planning (e.g., two-week AI pattern generation), daily stand-ups (designer feedback), sprint reviews (scholar evaluation), iterative optimization (adjusting keywords). This reduces risks. Audience co-creation is trending: British Museum invited voting on AI-generated Egyptian exhibition plans; the "Comparative Narrative of Pharaohs and Commoners" was chosen. Designers developed visual decision-making tools, translating professional concerns (safety, logic) into popular options ("impressive" vs. "intimate"), enabling public participation without affecting professionalism, strengthening museum public attribute.

5 Conclusion and outlook

This study deconstructs AI curation's technical framework and paths from a design studies perspective. Design thinking provides value orientation and experience standards, enabling technology to serve cultural dissemination; the four-layer framework (data-analysis-design-feedback) builds a human-machine collaboration loop, with design ensuring cultural accuracy and innovation; ethical governance and process re-engineering are key for sustainability. Future research should deepen: metaverse platforms for AI curation (e.g., Dunhuang's "Grotto Universe" for multi-user creation); theoretical evaluation system for digital heritage ("fidelity-innovativeness-communication power"); lightweight solutions for small museums (e. g., "Curation Assistant Cloud" with transfer learning). AI is reshaping curation and cultural communication; designers must uphold critical thinking and cultural mission, guiding AI as a partner in civilizational inheritance. By building human-machine symbiosis, virtual-real integration, and past-present dialogue spaces, museums will thrive digitally, connecting past and future, individual and civilization.

References

[1] Wang Xiaoyi. AI Empowerment and Humanistic Warmth: The Innovation Path of Museums in the New Technology Era[J]. Cultural Relics World, 2025, (05): 8-9.

[2] Wu Hongliang. Empathic Field and Sustainable Development——New Thoughts on the Operation of Museums and Art Galleries[J]. Art Observation, 2025(5): 7-11.

[3] Hou Yahan. The Application of Digital 3D Technology in Museum Curation Practice[J]. Collection and Investment, 2021, 12(12): 75-77.

[4] Hunan Provincial Museum. Technology Assists Exhibition: "Mawangdui" Han Dynasty Culture Revitalized - The Curation Practice of Hunan Provincial Museum's "Life Art - Mawangdui Han Dynasty Culture Immersive Digital Exhibition"[N]. China Cultural Relics News, 2024-12-13 (06).

[5] Yan Ting. Research and Application of AI-Based Interactive Exhibits at Wuhan Science and Technology Museum[J]. Technology Innovation and Brand, 2024, (06): 76-80.

[6] CLIFFORD J. Museums as contact zones[M]. Routes: travel and translation in the late twentieth century, 1997: 188-219.

[7] Hou Yumeng. Accessibility, Expression, Resonance: Challenges and Methods of Digital Collection Curation[J]. Digital Humanities Research, 2021, 1(04): 77-91.

[8] Lee H, Park G, Suh J, et al. Infinitehip: Extending language model context up to 3 million tokens on a single gpu[J]. arXiv preprint arXiv: 2502.08910, 2025.

[9] Mao Ruohan, Xia Zihe. Museum Digital Curation: Connotation, Context, and Characteristics[J]. Palace Museum Journal, 2025, (05): 30-43+146-147.

[10] Lu Yiping. Context Organization, Theme Refinement, and Immersive Experience Design of Archival Materials in Museum Digital Curation[J]. Shanxi Archives, 2025(1): 113-115.

[11] Dong Hengshuo, Luan Haoyu, Guo Sujia, et al. Analysis of the Development Status and Prospects of VR Exhibitions[J]. Journal of Capital Normal University (Natural Science Edition), 2024, 45(06): 74-80.

[12] Zhou Ying, Shen Yue. Research on the Application of Generative AI Technology in Museum Narrative[J]. Packaging Engineering, 2024, 45(20): 513-517.

[13] Wang Xiaoyi. AI Empowerment and Humanistic Warmth: The Innovation Path of Museums in the New Technology Era[J]. Cultural Relics World, 2025, (05): 8-9.

[14] Bai Fang. The Application of Digitalization and Accessibility Innovation in Curation Practice——Taking the Exhibition "Focus: The Adaptation of Chinese and Western Visual Arts in the 18th-19th Centuries" as an Example[J]. Art and Folk Custom, 2023, (01): 4-11.