

Digitalization of Intangible Cultural Heritage: Evolution and Innovation of Technical Platforms and Tools in the Chinese Context (2000-2025)

Yan Xian^{1*}, Jiahui Yao¹

¹ Shanghai University of Engineering Science, Shanghai, China

Email Address

Xianyan@sues.edu.cn (Yan Xian)

*Correspondence: Xianyan@sues.edu.cn

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Abstract:

This paper examines the evolutionary logic of digital platforms and tools for intangible cultural heritage preservation in China from 2000 to 2025. Centered on a three-dimensional framework of technology, demand, and culture, the evolution is divided into three phases: 2010–2020: Interactive Experience Phase (VR/AR+motion capture, adapting to skill transmission); 2020–2025: Intelligent Convergence Phase (AI+metaverse+digital twins, supporting living innovation). The study identifies issues such as cultural distortion, subject absence, and resource silos in technology application, proposing interdisciplinary collaboration and policy-ethical regulation pathways. Conclusions indicate that technology must dynamically adapt to the living needs of intangible cultural heritage. This research provides a phased approach for digital preservation practices and contributes to refining the theoretical framework.

Keywords:

ICH Digitization, Technological Platforms and Tools, Chinese Context, Cultural Authenticity, Intelligent Integration

1. Introduction

In the modernization process, commercialized social production and diversified lifestyles profoundly alter the ecological environment of intangible cultural heritage. Sun Zuo (2025) points out that ICH faces core challenges such as corrosion of transmission chains and the trap of commercial standardization. For instance, craft-based ICH like gold smithing and brocade weaving risks losing its artisanal spirit and technical semantics due to the absence of living transmission carriers [1]. Concurrently, the General Office of the CPC Central Committee and the General Office of the State Council (2022) issued the “Opinions on Promoting the Implementation of the National Cultural Digitization Strategy,” explicitly advocating for the transformation of intangible cultural heritage from static archiving to living transmission. This provides policy guidance for the innovative application of technological platforms and tools [2]. However, current research exhibits limitations.

Yang Jiayi et al. (2025) conducted a Cite Space-based visualization analysis revealing that 72% of ICH digitization literature focused on technological applications, while only 9% addressed user experience and cultural adaptation, highlighting a research bias dominated by technology and lacking cultural consideration [3]. Although Zhao Yue et al. (2023) outlined four phases of ICH digitization—concept introduction, project exploration, engineering advancement, and integrated development—they failed to connect these phases with the differentiated needs of ICH rescue preservation, skill transmission, and living innovation [4]. Therefore, this study focuses on three core questions: First, how did digital platforms and tools for intangible cultural heritage evolve from static documentation to dynamic empowerment between 2000 and 2025? What were the defining characteristics and technological logic of each phase? Second, how do technological tools adapt to the preservation and transmission needs of different types of intangible cultural heritage, such as craftsmanship and performance-based forms, across these stages? What are the adaptation gaps and correction pathways? Third, how can the tension between cultural authenticity and technological innovation be balanced during technological evolution? How should regulatory mechanisms at the policy and ethical levels be constructed?

This study defines its timeframe as 2000–2025, based on the fact that academic literature on ICH digitization in CNKI core journals began in 2000. This timeline aligns closely with the systematic application of domestic digital technologies—such as relational databases and 2D image scanning—in emergency preservation practices for ICH. By constructing a three-dimensional evolutionary framework encompassing technology, demand, and culture, this study addresses existing research limitations that prioritize technology over adaptation, thereby enriching the theoretical framework for ICH digitization. Practically, it offers phased technical solutions for digitizing craft-based ICH, providing technical references for ICH digitization initiatives to advance the coordinated development of ICH preservation, dissemination, education, and policy.

2. Literature Review and Theoretical Foundation

Yang Jiayi et al. (2025) conducted a visualization analysis using Cite Space based on literature from CNKI and Web of Science (2008-2024) in the field of intangible cultural heritage (ICH) digital preservation. The analysis examined dimensions such as annual publication volume and keyword co-occurrence. They found that although domestic and international research began around the same time, their core focuses differed: domestic research emphasized the integration of ICH preservation and transmission with digital technologies, while international research leaned toward the relationship between technology application and user behavior [5]. Chen Juan et al. (2025) noted in their research on brocade intangible cultural heritage that while digital technologies have been integrated into brocade design, production, and exhibition—such as AI-generated pattern creation, 3D printing for workflow optimization, and AR innovations in display formats—existing applications predominantly concentrate on visual presentation and efficiency enhancement. They insufficiently explore core weaving parameters—such as silk thread tension, pattern precision, and craft semantics like the cultural connotations of traditional motifs—and some digital outputs merely achieve process visualization without enabling skill transmission. This hinders the profound transformation of brocade intangible cultural heritage from formal dissemination to skill inheritance [6]. Thus, the core challenges in technological application converge on three fronts: First, cultural distortion. Gao

Yang et al. (2020) noted that 3D modeling in Qinghai embroidery digitization overly prioritized visual precision, sacrificing the symbolic meaning of patterns and the emotional expression of stitches, thereby reducing intangible cultural heritage from a living tradition to static data [7]. Second, subject absence. Wu Lifang et al. (2025) found that 85% of digitization projects were led by technical teams, with inheritors only participating in skill demonstrations and excluded from technical design, resulting in tools disconnected from craft practices. Third, resource silos. Liu Chunhui (2025) noted that the brocade intangible cultural heritage databases in Jiangsu and Guizhou cannot achieve cross-provincial resource sharing due to inconsistent standards [8]. Regarding innovation directions, Gu Zuo et al. (2025) constructed an intelligent decision-making system integrating data foundations, smart analytics, and intelligence services, addressing resource fragmentation through multi-source data fusion [9]. Li Xu et al. (2025) proposed an AIGC multimodal narrative method to achieve multidimensional conversion of Nuo opera intangible cultural heritage into textual, visual, and interactive formats [10], revealing a collaborative gap between technological innovation and cultural inheritance. The phased evolution of ICH digitization technologies inherently suffers from a dominance of technical dimensions while neglecting cultural needs: it neither fully addresses the entire chain of requirements from salvage preservation to living innovation nor recognizes the core value of cultural semantic transmission and the central role of practitioners in technology adaptation. Consequently, technical tools struggle to genuinely serve the essential goal of living ICH transmission.

Interdisciplinary approaches exhibit insufficient integration. Embodied cognition theory provides theoretical support for sensory-interactive design in craft-based intangible cultural heritage, proposing a dual-cycle model of perception, action, reflection, and creation. However, it has not formed a closed-loop with the development of technical tools like VR, motion capture, and AI feedback systems. The TOE theory (Cao, et al., 2025) offers a systematic analytical perspective on technology, organization, and environment for empowering intangible cultural heritage with digital technology, effectively explaining the collaborative governance logic among entities like governments and enterprises. However, this framework has limited consideration for the living attributes of intangible cultural heritage: Regarding specific issues highlighted in the original text—such as “heritors must deeply engage in digital practices to prevent cultural distortion” and “insufficient digital literacy among grassroots heriters constrains technology implementation”—its existing analytical dimensions fail to adequately cover these concerns, making it difficult to provide targeted theoretical explanations and solutions [11]. Semiotic theory (Chen Xiang et al., 2024) applied to the digital translation of Huishan clay figurines extracts form, theme, color, and symbols through the CTS method. However, it fails to link these findings to technical parameters for 3D modeling, rendering the theoretical outcomes difficult to implement [12]. Quan Xi (2024) attempted to integrate empowerment theory with digital technology to analyze the action logic of young ICH practitioners [13]. However, this work failed to establish systematic connections between theoretical frameworks, technical tools, and cultural demands, thereby limiting the full realization of interdisciplinary value. The current integration of interdisciplinary methods in ICH digitization fundamentally suffers from limitations: theories such as embodied cognition, TOE, and semiotics each focus on singular dimensions without forming theoretical synergy around the core needs of living ICH transmission. The integration of theory and technology remains confined to conceptual associations, failing to form a closed-loop system where theoretical

frameworks guide technical parameter design and technological tools embody theoretical cultural significance. This fragmented interdisciplinary approach not only fails to leverage the synergistic value of different disciplines but may also lead to technological tools deviating from the cultural essence of ICH preservation due to scattered theoretical orientations. Ultimately, this hinders the profound leap from technological application to cultural empowerment in ICH digitization.

3. Evolutionary Analysis of Technical Platforms and Tools (2000–2025)

3.1. 2000–2010: Foundational Digitization Phase Centered on Emergency Preservation

During this phase, technology platforms primarily integrated relational databases with basic scanning tools, with the core objective of addressing the risk of ICH resource extinction. Representative technologies included 2D image capture, laser scanning, and text databases. Yue Wei et al. (2023) used Anhui Huagu Deng intangible cultural heritage as a case study, recording inheritors' movement trajectories through 2D imaging and constructing a foundational database with textual annotations to achieve the primary goal of preventing endangered techniques from disappearing [14]. The China Intangible Cultural Heritage Database, spearheaded by the National Library of China, integrated textual descriptions of national intangible cultural heritage projects, information on representative inheritors, and images of representative works, forming early digital achievements.

This stage of technology faces issues of cultural information loss and semantic gaps in craftsmanship. Liu Chunhui (2025) points out that constructing domain knowledge graphs and semantic networks enables knowledge-based intelligent retrieval and discovery, enhancing the professionalism of archival retrieval and utilization [15]. Zhang Xiaojuan (2018) observed in the digitization of Qinghai embroidery that certain needle techniques have vanished due to lost cultural contexts, while others remain critically endangered [16]. The symbolic meanings of cultural symbols were also not conveyed through annotation, reducing the digitization outcomes to a collection of images devoid of context. Solutions focused on supplementing cultural semantics. You Lisi (2025) proposed a five-tier semantic annotation system. In the 3D scanning of Mongolian saddles, simultaneous annotation of production techniques, folk functions, and symbolic meanings laid the foundation for cultural adaptation in subsequent technical phases [17]. Despite prioritizing salvage preservation in the foundational digitization phase, this stage—which uses databases and scanning tools to preserve the physical existence of intangible cultural heritage—has established a resource foundation for subsequent digital work. However, it remains constrained by a cognitive limitation where technical operations take precedence over cultural transmission.

3.2. 2010–2020: Interactive Experience Phase Centered on Skill Transmission

Technological platforms evolved to VR/AR + motion capture + 3D modeling, with the core objective of overcoming the temporal and spatial constraints of traditional transmission to achieve immersive skill transfer. Zhang Chongyang et al. (2025) applied VR in teaching Hebei paper-cutting ICH, recreating the complete process of folding, cutting, and unfolding. Combined with motion capture technology to record the force trajectories of the inheritor's hands, users could simulate operations via

motion-sensing devices, addressing the inefficiency of manual instruction. Chen Juan et al. (2025) applied augmented reality (AR) in brocade weaving ICH. Users scanning finished brocades could visualize the dynamic process of warp thread lifting and weft thread interlacing, intuitively grasping the core technique of “through warp, break weft.” This phase faced challenges of sensory disconnect and insufficient group adaptability. For instance, while VR tools simulate weaving scenarios in intangible cultural heritage brocade instruction, they cannot replicate warp tension feedback. Users struggle to perceive differences in weaving outcomes across silk thread materials, deviating from the perceptual-action loop emphasized by embodied cognition theory. Digital products in this phase achieved only 15% adoption among Gen Z users, as interaction designs overlooked youth socialization needs—omitting features like skill-sharing competitions—resulting in a mismatch between technological tools and target audience requirements. Regarding optimization pathways focused on sensory enhancement and group adaptation: Chen Chen et al. (2024) developed a traditional craftsmanship app that uses pressure sensors to simulate embroidery needle force, combined with user profiling to customize interaction logic, increasing youth usage to 42% [18]; Wang Ming et al. (2025) integrated VR environments with narrative storytelling in the documentary *Guardians of Intangible Cultural Heritage*. Employing dual-track narratives combining inheritor interviews and skill demonstrations, they enhanced user emotional resonance [19].

While this phase of VR/AR and motion capture technology marked the first critical leap from static observation to dynamic simulation of intangible cultural heritage skills, breaking the temporal and spatial constraints of traditional inheritance, the disconnect in physical sensation and the neglect of Gen Z's social needs collectively revealed that the technological design remained at the superficial level of tool functionality. It had yet to address the deeper requirements of implicit knowledge perception and cultural emotional resonance in the transmission of intangible cultural heritage skills, laying crucial groundwork for subsequent collaborative efforts in the intelligent integration phase.

3.3. 2020–2025: The Intelligent Integration Phase Centered on Living Innovation

Technology platforms exhibit integrated features of AI + metaverse + digital twins, with the core objective of propelling intangible cultural heritage from passive preservation toward active innovation. Li Xu et al. (2025) developed digital creative products for Guizhou Nuo Opera based on AIGC multimodal narrative. After designers set themes like mountain deity blessings, AIGC automatically generates Nuo Opera mask patterns → dance movements → interactive plots. Users can further refine these outputs, enabling human-machine co-creation [20]. Liu Zhonghua et al. (2023) constructed a Beijing lacquer carving metaverse exhibition hall where users participate via virtual identities in pattern design, craft process simulation, and finished product transactions. Virtual designs can be materialized as physical cultural products through 3D printing, forming a closed loop of virtual innovation and real-world transformation [21]. Cai Wei et al. (2024) applied digital twin technology to Jingdezhen ceramic intangible cultural heritage, real-time mapping the parameter relationships between wheel-turning speed, clay viscosity, and glaze thickness to provide data support for craft innovation [22].

While the integration of AI, metaverse, and digital twins in this phase achieves a paradigm shift from passive preservation to active co-creation of intangible cultural heritage, significantly expanding innovation boundaries, vigilance against

technological alienation risks is essential. Xue Ke et al. (2025) noted that AI-generated Miao silver ornament patterns suffer from algorithmic homogenization, blurring distinctive features across different sub-branches and eroding cultural diversity [23]; Zhou Yulan (2025) mentions that applying digital twin technology to brocade weaving ICH, by over-relying on data parameters while neglecting inheritors' experiential judgments, resulted in technical outcomes lacking the soul of handcrafted artistry [24]. Balancing approaches include: First, establishing cultural calibration mechanisms. Fei Anling et al. (2023) propose that AI-generated content must undergo inheritor review to ensure cultural symbol accuracy [25]; Second, constructing an equitable rights framework. Chen Haiyu et al. (2021) leverage consortium blockchain technology to define rights distribution among inheritors, technical teams, and users, enabling innovation revenue sharing through smart contracts [26]. Third, strengthening human-centered design. Huang Yonglin et al. (2022) emphasize that technical tools must retain interfaces for manual intervention—such as digital twin systems allowing inheritors to adjust parameter thresholds—to balance technological efficiency with artisanal expertise [27].

The perspectives of the aforementioned scholars fundamentally reveal the deep-seated risk of instrumental rationality overriding value rationality in technological applications. The ultimate goal of intangible cultural heritage digitization is not technological innovation itself, but rather using technology as a medium to ensure AI generation remains rooted in cultural DNA and virtual co-creation stays true to the essence of craftsmanship, ultimately achieving a dynamic unity between technological empowerment and cultural authenticity.

4. Unique Perspective and Academic Value

4.1. Interdisciplinary Integration: Three-Dimensional Synergy of Technology, Culture, and Policy

Existing research is largely confined to single disciplines: the computer science field focuses on technological development like AIGC and digital twins, the cultural sector emphasizes the authentic preservation of intangible cultural heritage, and the policy domain prioritizes institutional design—all lacking systematic coordination. This study proposes a three-dimensional intersectional framework: the technological dimension must adapt to the semantic transmission requirements of the cultural dimension while complying with the regulatory demands of the policy dimension.

It also adheres to the data tiered storage requirements outlined in the “Opinions on Promoting the Implementation of the National Cultural Digitization Strategy,” preventing technological development from becoming detached from cultural contexts or violating policy norms. This framework overcomes the limitations of existing interdisciplinary research, which often involves merely layering theories. It provides a systematic solution for ICH digitization that is technologically feasible, culturally adaptable, and policy-compliant.

4.2. Policy and Ethics: From Technical Standards to Value Leadership

At the policy level, Fan Lirong (2025) advocates for the construction of a national intangible cultural heritage archive service portal, which requires supplementary mechanisms for dynamic updates and regional coordination: Referencing the end-to-end AIGC design proposed by Liu Zhiming et al. (2024), the portal should establish an update system featuring periodic rescan of endangered techniques and real-time

supplementation of living techniques [28]; Drawing from Chen Haiyu et al.'s (2021) consortium chain model, provincial data silos should be dismantled to enable multi-regional sharing of locally collected data [29]. Ethically, core conflicts center on copyright ownership and technological ethics. For instance, digital ICH outputs must distinguish creators' property rights from inheritors' cultural rights, while AI-generated content revenues should be proportionally distributed to inheritor communities.

4.3. Future Trends: From Tool Empowerment to Ecosystem Building

Future ICH digitization will exhibit three major trends: First, deepening dynamic co-creation within the metaverse. Liu Zhonghua et al. (2023) predict that metaverse-based ICH communities will integrate cross-regional skill exchanges, virtual research programs, and cultural trade. For instance, the Dong Grand Song ICH could enable multi-clan choir rehearsals through digital virtual worlds. Second, AI-driven intelligent inheritance upgrades will extend beyond content generation to include skill diagnostics. For instance, motion capture technology could identify and correct needlework deviations in embroidery learners in real time. Third, digital ecosystem collaboration requires integrating resources from governments, enterprises, universities, and inheritors to build a full-chain ecosystem encompassing data collection, technology development, educational transmission, and industrial transformation. While advancing technological tools, vigilance is needed against potential risks: the metaverse may replace real-world transmission with virtual experiences, and AI may diminish inheritors' agency. Policy guidance and ethical review are essential to ensure technology consistently serves the fundamental goal of living intangible cultural heritage transmission.

5. Conclusion and Outlook

The evolution of digital platforms and tools for intangible cultural heritage from 2000 to 2025 follows a three-stage progression: The foundational digitization phase (2000-2010) addressed urgent preservation needs through databases and basic scanning, but faced core limitations in cultural information gaps. The interactive experience phase (2010-2020) adapted to skill transmission demands using VR/AR + motion capture, though it encountered issues like sensory disconnect and insufficient group adaptability. The 2020-2025 intelligent integration phase leverages AI, metaverse, and digital twins to support living innovation, requiring a balance between technological advancement and cultural authenticity. The core logic of this three-stage evolution is the transformation of technology from a tool to a partner, while ICH needs to shift from preservation to skill transmission and innovation. The dynamic alignment between these two dimensions is pivotal to technological evolution.

Limitations of this study include a concentration of case studies on national-level ICH, with insufficient research on technology adaptation for local-level ICH; and a lack of in-depth analysis on the relationship between technological costs and regional disparities. Future research may focus on three directions: First, lightweight technical solutions for local-level ICH. Second, interdisciplinary collaboration mechanisms to foster deep cooperation between computer science, cultural anthropology, and education, developing composite technical tools tailored for ICH. Third, policy optimization by incorporating cultural adaptability metrics—such as “participation rate of inheritors”—into the evaluation criteria for ICH digitization policies.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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