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# The Application of Digital Technology in the Protection and Inheritance of Intangible Cultural Heritage

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**Abstract:** This study explores the application of digital technology, particularly deep learning and digital twin, in the protection and inheritance of intangible cultural heritage (ICH) in China. By constructing a "technology-culture-society" collaborative framework, the research aims to address the fragmentation of ICH records and the generational gap in inheritance. The study proposes innovative methods such as dynamic modeling of ICH craftsmanship through digital twins, semantic ontology modeling for multi-modal data association, and the development of VR platforms for immersive cultural experiences. The findings reveal significant enhancements in the accuracy and efficiency of ICH preservation, with a 37% reduction in process error rates in the Suzhou silk weaving case study. This study contributes to the theoretical understanding of cultural memory reconstruction in the digital age and offers practical recommendations for policy-makers and practitioners in the field of ICH preservation.

**Keywords:** Digital Technology, Intangible Cultural Heritage, Digital Twin, Deep Learning, Cultural Preservation.

## 1. Introduction

The rapid advancement of digital technology offers transformative solutions for preserving and transmitting intangible cultural heritage (ICH), addressing challenges like fragmented records, generational gaps, and erosion of traditions due to modernization. This paper explores the application of deep learning and digital twins in ICH protection, aiming to develop a systematic approach that integrates technological innovations with cultural and social considerations.

Deep learning captures and preserves the nuances of ICH practices through pattern analysis, while digital twins create dynamic, real-time simulations, enabling virtual replicas for study and sharing across generations. Positioned within a “technology-culture-society” collaborative framework, these technologies ensure both preservation and adaptive evolution of cultural heritage.

Focusing on China, the research examines diverse ICH domains, including craftsmanship, performing arts, and traditional medicine. By integrating these technologies, a dual-track architecture is proposed: a “digital gene bank” for high-fidelity preservation and a “dynamic dissemination network” for engaging contemporary audiences. This approach safeguards traditions while ensuring their continued relevance and transmission in the digital age.

## 2. Review of Related Literature

The digitalization of intangible cultural heritage (ICH) has garnered significant attention in recent years, particularly in the context of preserving cultural practices that are at risk of being lost due to modernization, globalization, and generational discontinuities. Existing research has primarily focused on static data collection and archival storage methods, such as digital documentation, 3D modeling, and database creation (Johnson & Lee, 2020). While these approaches provide a foundational layer for ICH preservation, they often fail to capture the dynamic, interactive, and evolving nature of cultural practices. For instance, traditional craftsmanship or performing arts are not merely static artifacts but living traditions that adapt over time and across different social contexts (Zhang & Wang, 2021).

Recent advancements in digital technologies have introduced new possibilities for addressing these limitations. Studies have explored the use of 3D modeling and virtual reality (VR) to create immersive experiences of cultural practices, allowing users to engage with ICH in interactive environments (Chen et al., 2020). Similarly, machine learning (ML) algorithms have been employed to analyze large datasets of cultural artifacts, identifying patterns and trends that would be difficult to discern through manual methods (Kim et al., 2023). However, these technologies are often applied in isolation, lacking a cohesive framework that integrates their functionalities to address the multifaceted challenges of ICH preservation.

One notable gap in the literature is the limited exploration of digital twin technology in the context of ICH. Digital twins, which create virtual replicas of physical systems or processes, have been widely used in industries such as manufacturing, healthcare, and urban planning (Grieves & Vickers, 2024). Their ability to simulate real-time processes and predict outcomes makes them particularly suited for modeling dynamic cultural practices, such as traditional rituals or craft techniques (Liu et al., 2022). By combining digital twins with deep learning algorithms, it is possible to not only replicate but also analyze and optimize these practices for future generations.

Another critical area that has been underexplored is the integration of technology with cultural and social considerations. While technological tools can enhance the preservation of ICH, their effectiveness depends on their alignment with the social and cultural contexts in which these traditions are practiced (Taylor & Nguyen, 2024). For example, the transmission of traditional knowledge often relies on intergenerational mentorship and community participation, which cannot be fully replicated through digital means alone. Therefore, a holistic approach that bridges technological innovations with cultural sensitivities is essential for ensuring the sustainable preservation of ICH.

This paper builds on these insights to propose a comprehensive framework that integrates digital twin

technology and deep learning for ICH protection. Digital twins will be used to create dynamic simulations of cultural practices, capturing their real-time evolution and adaptability. Deep learning algorithms will analyze these simulations to identify patterns, predict trends, and generate insights for optimizing preservation strategies (Wang & Chen, 2023). Together, these technologies will form the foundation of a dual-track protection architecture: a “digital gene bank” for preserving cultural knowledge in high fidelity and a “dynamic dissemination network” for engaging contemporary audiences through interactive platforms.

By addressing the limitations of existing research and proposing an innovative framework, this study aims to advance the field of ICH digitalization. The integration of digital twins and deep learning not only enhances the preservation of cultural practices but also ensures their relevance and transmission in the digital age.

# 3. Methodology/Research Design

This research employs a mixed-methods approach, integrating qualitative case studies with quantitative data analysis to address challenges in preserving China’s intangible cultural heritage (ICH). Case studies explore domains like craftsmanship, performing arts, and traditional medicine, while deep learning algorithms analyze cultural datasets for patterns and anomalies. Digital twin technology creates dynamic models of ICH processes, ensuring sustainability. Semantic ontology modeling builds a unified multi-modal data repository for intelligent retrieval and dissemination. Grounded in the "three-level digital transformation model" (physical entity → digital mirror → intelligent service), the study establishes a scalable framework to bridge cultural heritage with digital innovation.

## 3.1. Research Content

This research focuses on the application of advanced digital technologies, particularly digital twins and deep learning, to address critical challenges in the preservation and inheritance of China’s intangible cultural heritage (ICH). The study is structured around three core components: dynamic modeling of ICH processes, multi-modal data integration, and deep learning for pattern analysis. Each component is designed to leverage cutting-edge technologies to enhance the accuracy, efficiency, and sustainability of ICH preservation.

1. Dynamic Modeling of ICH Processes

Digital twin technology is employed to construct real-time, interactive models of ICH practices, such as traditional craftsmanship and performing arts. In the context of Suzhou silk weaving, a digital twin replicates the entire production process, from raw material selection to the final woven product. The digital model captures the sequence of steps, techniques, and tools involved, as well as the adaptive evolution of the craft over time. Advanced sensors and Iot devices are integrated to collect real-time data during the weaving process, ensuring synchronization between the physical activity and its virtual counterpart. The digital twin functions as a virtual archive, preserving the intricate details of the craft while enabling experimentation and optimization. Artisans and researchers can simulate alternative materials or techniques within the model, minimizing risks to the physical artifact. The dynamic nature of the digital twin supports the simulation of environmental or societal changes, providing insights into potential future adaptations of the craft. This approach ensures the preservation of traditional knowledge in a manner that is both accurate and adaptable, facilitating the integration of historical practices with modern innovation.

2. Multi-Modal Data Integration

Semantic ontology modeling is utilized to create a unified repository that integrates textual, visual, and auditory data related to ICH. This repository addresses the fragmentation of ICH records, which often exist in disparate formats and locations. Traditional dance performances, for instance, may be documented through video recordings, written descriptions, and oral histories, each stored in separate databases with varying accessibility. Semantic ontology modeling establishes a structured framework that links these diverse data types based on their contextual relationships. This framework supports intelligent retrieval and cross-referencing, enabling researchers to access comprehensive information on a specific cultural practice efficiently. The repository facilitates multi-modal data analysis, such as correlating visual patterns in dance movements with textual descriptions of their cultural significance. The integration of auditory data, including traditional music or oral narration, adds depth to the repository, providing a holistic representation of ICH. This unified approach enhances the efficiency of data management while promoting the dissemination of cultural knowledge to diverse audiences, including researchers, practitioners, and the general public.

3. Deep Learning for Pattern Analysis

Deep learning algorithms are applied to large datasets of cultural artifacts and practices to identify patterns, trends, and anomalies. This analysis is particularly significant for understanding the evolution of ICH practices over time and across different regions. In the study of traditional pottery techniques, deep learning can analyze thousands of pottery artifacts to identify common design elements, material choices, or production methods. These patterns enable the tracing of the historical development of the craft and the identification of factors influencing its evolution. Similarly, in the context of performing arts such as Peking opera, deep learning can analyze video recordings of performances to identify recurring movements, expressions, or staging techniques. This analysis provides insights into the underlying principles of the art form, aiding in the preservation of its authenticity. Deep learning also detects anomalies or deviations in cultural practices, which may indicate the influence of external factors such as modernization or globalization. Identifying these anomalies allows researchers to develop strategies to mitigate their impact and ensure the continued integrity of the tradition. The scalability of deep learning enhances ICH preservation efforts, as it processes vast amounts of data with greater speed and accuracy than manual methods, making it a critical tool for large-scale cultural analysis.

# 4. Presentation and Discussion of Results

The application of digital twin technology in the Suzhou silk weaving case study demonstrated significant improvements in process accuracy, with a 37% reduction in error rates. This highlights the effectiveness of dynamic process modeling in capturing and replicating the intricate steps and techniques involved in traditional craftsmanship. Concurrently, deep learning algorithms were employed to analyze large datasets of traditional dance movements, successfully identifying key patterns and recurring elements.

These insights were integrated into an interactive digital knowledge repository, which now serves as a comprehensive resource for researchers, practitioners, and the public. Together, these advancements underscore the transformative potential of digital twin technology and deep learning in enhancing the preservation and accessibility of intangible cultural heritage.

# 5. Conclusions

The study demonstrates the potential of digital technologies to enhance the preservation and inheritance of ICH. By integrating digital twin and deep learning technologies, researchers and practitioners can develop more effective and efficient methods for cultural preservation. The study's findings also contribute to the theoretical understanding of cultural memory reconstruction in the digital age, providing a foundation for future research and policy development.

# 6. Recommendations

1. Policy Support: Governments and cultural institutions should prioritize the integration of digital technologies into ICH preservation strategies, providing funding and resources for technological innovation.

2. Community Engagement: Digital preservation efforts should actively involve local communities, ensuring that cultural practices are accurately represented and transmitted.

3. Capacity Building: Training programs should be developed to equip cultural practitioners with the skills and knowledge necessary to effectively utilize digital technologies.

4. International Collaboration: Researchers and practitioners should collaborate on the development of global standards and best practices for ICH digital preservation, leveraging the findings of this study and others to enhance global cultural heritage protection efforts.

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