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Research on the Application of Generative AI in Digital Art Design for Intangible Cultural Heritage

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Abstract: With its unique interactivity, communicative power, and innovativeness, digital art design offers a new pathway for the dissemination of intangible cultural heritage (ICH). As a cutting-edge technology in the field of artificial intelligence, generative AI leverages machine learning algorithms and big data analytics to automatically generate multimodal content such as text, images, audio, and video, thereby greatly enhancing design efficiency. This study examines the characteristics and challenges of digital art design related to ICH, elucidates the fundamental principles and technical features of generative AI, and discusses its application logic and potential scenarios in ICH-focused digital art design. It also identifies the current limitations of generative AI and proposes corresponding solutions, aiming to provide new approaches and methods for ICH transmission and preservation, advance the integration of digital art design with AI technologies, and promote innovative development in the cultural and creative industries related to ICH.

Keywords: generative AI, intangible cultural heritage, digital art design, cultural creativity

1. Introduction

With the rapid development of information technology and the advent of the digital era, the transmission and protection of intangible cultural heritage (hereinafter referred to as “ICH”) are facing unprecedented opportunities and challenges. As a treasure of human civilization, ICH carries rich historical memories and cultural genes, playing an irreplaceable role in promoting cultural diversity and reinforcing national identity and cultural confidence. However, the traditional means of disseminating ICH are restricted by geography, language barriers, and the limited number of inheritors, leading to a narrow scope and limited impact of ICH transmission.

Digital art design, with its unique interactivity, communicability, and innovativeness, opens up new avenues for ICH transmission and development. Generative AI, as a cutting-edge technology in the field of artificial intelligence, has already demonstrated tremendous potential and value across various domains. Through machine learning algorithms and big data analysis, it can automatically generate multimodal content such as text, images, audio, and video. When applied to digital art design, generative AI greatly enhances design efficiency and can intelligently generate personalized works that align with user needs (Yang & Zhuo, 2020).

The practical significance of applying generative AI to ICH-oriented digital art design is considerable. On the one hand, by analyzing the features and elements of ICH, generative AI can automatically create design works that adhere to the stylistic attributes of ICH, thus enabling innovative interpretation and expression of ICH culture. On the other hand, thanks to the interactivity and communicability of digital art design, ICH culture can be presented in a more vivid and intuitive manner, improving audience awareness and interest, expanding its reach, and enhancing its social impact.

This paper analyzes the characteristics and challenges of digital art design for ICH, as well as the basic principles and technical features of generative AI. By exploring in depth the application logic and scenarios of generative AI in ICH-oriented digital art design, we reveal its positive influences on the transmission and development of ICH culture, and further propose its limitations and corresponding

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suggestions.

2. Features and Challenges of Digital Art Design for Intangible Cultural Heritage

2.1. Features of digital art design for intangible cultural heritage

2.1.1 Profound cultural connotations

Unlike standard digital art design, digital art design for intangible cultural heritage (ICH) calls for a deep understanding and distillation of core cultural elements — such as traditional craftsmanship, folk tales, and totemic symbols — followed by their artistic reinterpretation through digital technology. This process breathes new life and a contemporary spirit into ICH, yet still needs to convey its rich cultural resonance. By doing so, ICH can be presented to modern audiences in a more vivid and diverse manner, retaining its time-honored essence while embracing innovative forms of expression.

2.1.2 Integration of technology and art

Digital art design for intangible cultural heritage (ICH) represents a profound convergence of technology and art. On one hand, it relies on cutting-edge digital tools — such as 3D modeling, virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) — to achieve digitized presentations and interactive experiences of ICH. On the other hand, it underscores the uniqueness and aesthetic value of artistic creation: through the creativity and craftsmanship of designers, traditional ICH elements are reimagined in tandem with contemporary design concepts, resulting in works that retain a traditional allure yet embrace modern sensibilities. This fusion not only enhances the dissemination of ICH but also broadens the range and depth of expression in digital art design (Liu et al., 2022).

2.1.3 Interactivity and participation

With the support of digital platforms, works of digital art rooted in ICH can transform audiences from passive viewers into engaged participants. For instance, by employing virtual reality (VR) technology, viewers are able to immerse themselves in a simulated ICH environment and personally observe, or even attempt, the crafting processes behind traditional techniques. Meanwhile, artificial intelligence (AI) makes it possible to "converse" with ICH elements, granting users individualized insights and experiences. This focus on interactivity and participation not only enriches the appeal and intrigue of ICH, but also facilitates broader dissemination and exchange — ensuring that the cultural legacy endures and flourishes in a modern context.

2.2 Challenges in digital art design for intangible cultural heritage

2.2.1 Balancing cultural authenticity and innovation

A central challenge in the realm of digital art design for intangible cultural heritage (ICH) involves preserving the authenticity of these traditions while engaging in thoughtful, contemporary innovation. On the one hand, designers must explore ICH in depth, ensuring that the resulting works faithfully capture its essence and unique cultural value. On the other hand, they must bring forward artistic novelty and creative expression, so that ICH can resonate with modern audiences. Achieving this balance calls for respecting tradition while courageously experimenting with new ideas, thereby identifying a middle ground between safeguarding time-honored practices and embracing forward-looking design (Ye & Xu, 2023).

2.2.2 Audience acceptance and market positioning

The audience for digital art designs rooted in ICH is both diverse and complex. People of different ages, cultural backgrounds, and aesthetic preferences bring varying levels of awareness and enthusiasm for ICH, which poses a considerable challenge for designers. Striking the right balance between faithfully representing the subtle distinctions of ICH and achieving broad market appeal requires deep insight into audience needs. Equally pressing is the question of how to position such works in the marketplace. In seeking to preserve cultural value while ensuring economic viability, designers and stakeholders alike must explore how best to integrate heritage and commerce.

2.2.3 Balancing cultural preservation and intellectual property rights

Digital art designs rooted in intangible cultural heritage can promote the continuity of traditional knowledge yet must also address challenges involving intellectual property protection. On one side, widespread access to digital tools makes it simpler to reproduce and share cultural artifacts, extending their reach to broader audiences. On the other side, these same technologies raise the likelihood of unauthorized copying and piracy, potentially threatening the legitimate interests of cultural practitioners and designers. Determining how to safeguard intellectual property while still encouraging open cultural sharing is a crucial legal and ethical concern in this field.

3. The Application Logic of Generative AI in Digital Art Design for Intangible Cultural Heritage

3.1 Fundamental principles and technical characteristics of generative AI

Generative AI refers to a class of intelligent algorithms adept at autonomously producing novel data or content, setting it apart from discriminative AI, which largely addresses tasks such as classification and prediction based on existing data samples. By creating outputs not previously encountered, generative AI demonstrates significant potential in areas like artistic innovation and design exploration. Commonly used frameworks include Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), and diffusion models. These systems employ mechanisms such as adversarial training and probabilistic encoding to uncover deep-seated patterns within datasets, enabling the synthesis of new and distinctive outputs. For instance, GANs encompass a generator and a discriminator that engage in iterative competition: the generator refines its ability to produce increasingly lifelike samples, while the discriminator sharpens its skill in discerning authentic data from artificially generated content. Through this process, both components steadily enhance their performance.

Several technical advantages stand out. First, generative AI fosters originality, creating entirely new material that can fuel fresh ideas for design or art. Second, tweaking model parameters or input conditions makes it possible to yield multiple styles or configurations, meeting diverse user demands. Third, in comparison to manual methods or rule-based approaches, generative AI can rapidly provide a large number of viable solutions, significantly boosting efficiency. Finally, by assimilating new datasets or user feedback over time, these models continuously refine their outputs and evolve in quality, supporting ongoing improvements to the creative process (Li et al., 2023).

3.2 Feasibility of applying generative AI in digital art design for intangible cultural heritage

Digital art design for intangible cultural heritage aims to merge age-old cultural expressions with contemporary digital techniques, resulting in works that retain traditional appeal while meeting modern aesthetic standards. Generative AI provides a powerful technical pathway to achieve these goals (Yi, 2020). Its creative and versatile nature directly aligns with the core requirements of heritage-based designs. Although intangible cultural heritage offers rich artistic components, designers often struggle to present such elements in genuinely novel ways. Through generative AI, it becomes possible to generate multiple design proposals distinguished by diverse styles, enlarging the scope of creative exploration and revealing deeper cultural significance.

Generative AI also improves efficiency. Conventional methods typically require extensive time and effort, for instance, in hand-drawing or modeling each element. By contrast, generative AI can produce numerous design concepts in a relatively short timeframe, trimming production cycles and boosting overall productivity. This capability proves essential for projects that must adapt quickly to shifting market conditions or frequent design iterations.

Furthermore, the self-improving capacity of generative AI underpins continuous refinement in

heritage-based digital art projects. As audience responses and market expectations evolve, designers can recalibrate model settings or integrate fresh datasets, ensuring that newly generated outputs reflect up-to-date preferences. Sustaining this adaptive approach is critical for preserving both the vitality and competitiveness of digital art design for intangible cultural heritage.

3.3 Principles for applying generative AI in digital art design for intangible cultural heritage

3.3.1 Data collection and preprocessing

Before integrating generative AI into heritage-focused digital art, it is essential to gather a wide range of cultural data, encompassing images, text, audio, and video. These materials form the foundation for model training and creative generation. However, raw datasets often contain noise, missing elements, or inconsistencies. To address these concerns, steps such as cleaning, normalization, and structured enhancements are needed, ensuring higher data quality and greater ease of use.

In keeping with the specific goals of intangible cultural heritage (ICH) digital art design, it is necessary to choose and train an appropriate generative AI framework. For instance, image generation tasks often benefit from models like Generative Adversarial Networks (GANs) or diffusion approaches. GANs rely on a generator–discriminator setup, producing a wide range of high-quality images and offering considerable flexibility for crafting visually distinct cultural works. Diffusion models, on the other hand, employ an iterative denoising process, allowing more precise control over details—a valuable feature when designing intricate ICH motifs (Tang & Feng, 2024).

3.3.2 Model selection and training

In keeping with the specific goals of intangible cultural heritage (ICH) digital art design, it is necessary to choose and train an appropriate generative AI framework. For instance, image generation tasks often benefit from models like Generative Adversarial Networks (GANs) or diffusion approaches. GANs rely on a generator–discriminator setup, producing a wide range of high-fidelity images and offering considerable flexibility for crafting visually distinct cultural works. Diffusion models, on the other hand, employ an iterative denoising process, allowing more precise control over details—a valuable feature when designing intricate ICH motifs (Tang & Feng, 2024).

During model training, prompt instructions and large-scale general AI models can be integrated where appropriate, coupled with well-chosen loss functions and optimization strategies. This arrangement helps the model internalize the core attributes and stylistic traits of ICH, ensuring that the generated output aligns with both artistic and cultural requirements.

3.3.3 Design generation and optimization

With the aid of an AIGC-based intelligent design platform, a trained generative AI model can produce digital art concepts for ICH in response to specified inputs and constraints, such as combinations of cultural motifs, stylistic directions, or preferred color schemes. Designers then review and refine these model outputs, selecting those that align with project requirements for further enhancement. User feedback and market dynamics can also guide the optimization process: by adjusting model parameters or incorporating new data, designers ensure that the system evolves in step with shifting demands.

3.3.4 Interactive experience and feedback loop

Immersion and user engagement lie at the heart of digital art design inspired by ICH. When combined with other digital media—such as VR and AR — generative AI offers more varied and immersive interactions. At the same time, audience responses are vital for ongoing refinement. By collecting and analyzing user feedback, designers gain insights into preferences and needs, then adjust their design strategies and fine-tune AI models accordingly.

As shown in Figure 1, generative AI does not operate in isolation; instead, it participates in a closely woven cycle alongside designers, users, and the ICH itself. Designers make use of AI-generated ideas and outputs to drive creation, while user

interaction produces valuable feedback. Throughout this process, heritage elements remain a constant source of inspiration and form the cultural foundation. Such a feedback loop not only aids in preserving and renewing traditional heritage but also propels the evolution and enhancement of digital art design focused on cultural legacies.

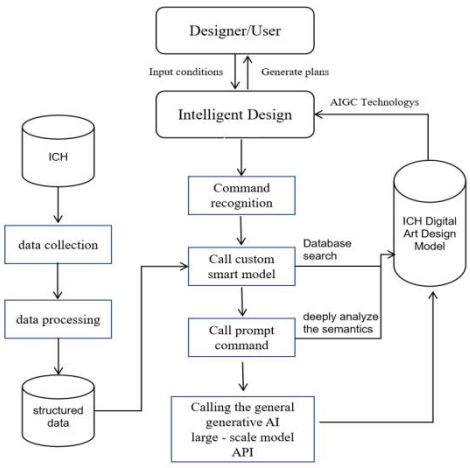

Figure1 The Application Principles of Generative AI in Digital Art Design for ICH

4.1 Generating Digital Art Designs for Intangible Cultural Heritage

4.1.1 Automatic generation of patterns and textures

Design patterns and surface textures hold a special significance within intangible cultural heritage, exemplified by art forms such as embroidery, papercutting, and ceramics. Generative AI can analyze extensive datasets containing heritage motifs—capturing layout techniques, color schemes, and textural features — and subsequently produce fresh designs that retain traditional qualities. These AI-driven outputs reflect the cultural spirit of the originals while harnessing algorithmic creativity to deliver new aesthetic effects (Zhong et al., 2021).

For instance, a generative AI system can create embroidered motifs reflective of the Shu embroidery style. Figure 2 illustrates two digital collectibles emphasizing lotus as the primary visual element, generated using the prompt "Produce a Shu embroidery digital collectible centered on lotus blossoms" through the Wenxin Yiyan platform. The resulting images incorporate the compositional balance, colors, and texture details characteristic of classic Shu embroidery, yet also introduce novel combinations that significantly enhance the efficiency of digital art design.

Figure2 Two digital collections of Shu embroidery generated by AI

4.1.2 Intelligent generation of forms and structures

In the context of digital art design for intangible cultural heritage, creating forms and structures involves a complex process of analyzing and rearranging traditional artistic elements. By studying the underlying logic and compositional rules present in cultural artifacts, a generative AI system can intelligently produce new shapes that reflect heritage aesthetics. For instance, when applied to three-dimensional modeling, this approach allows deep learning models and chain-of-thought methods to absorb spatial and structural traits rooted in traditional culture and then generate 3D objects displaying distinct heritage features. Such outputs can be integrated into virtual reality and augmented reality scenarios, providing users with a more immersive cultural experience.

4.1.3 Creation of dynamic artistic effects

Generative AI techniques also enable the production of dynamic effects within heritage-based digital artworks. Through algorithmic simulation and analysis of shifting cultural motifs, these methods yield art pieces with rich, animated features. As illustrated in Figure 3 (captured from an animation), a face-changing scene in Sichuan Opera can be reimagined through AI-assisted modeling of the

traditional performance process. By capturing the movement details and refining them algorithmically, it becomes feasible to create animation segments that authentically represent the face-changing style. Such dynamic effects not only strengthen the expressive power of ICH but also deliver a vivid visual encounter for viewers.

Figure3 Screenshot of an animated video of Sichuan Opera Face-changing

4.2 Reconstructing Digital Experience Scenarios for ICH

4.2.1 Virtual museums and exhibition halls: cultural presentation beyond physical boundaries

As key vehicles for digitizing intangible cultural heritage, virtual museums and exhibition halls aim to faithfully represent historical artifacts while transcending spatial constraints. By analyzing distinctive features of a heritage project, generative AI can create convincing architectural environments and realistic atmospheres, further fine-tuning layout and lighting through intelligent algorithms. Figure 4 shows a digital presentation of the Sanxingdui Museum, in which the system draws on existing documentation and material evidence to establish a virtual showcase. In this immersive space, not only are textures, colors, and surface details of the relics reproduced with high fidelity, but dynamic lighting also highlights each artifact's nuanced beauty (Liu, 2021). Meanwhile, AI-based voice guidance, powered by natural language processing and deep learning, offers personalized and multilingual explanations that delve into the archaeological background, stylistic traits, and cultural significance of the objects. Such an immersive platform transcends geographical and time limitations, bringing the distinctive allure of intangible heritage to audiences around the globe. Moreover, As illustrated in Figure 5，the museum has fully utilized the interactive potential of generative AI by developing a digital art creation platform that allows visitors to participate directly. On this platform, visitors can freely select cultural motifs, patterns, and color elements from the artifacts, after which the system instantly generates personalized digital artworks that can also be converted into cultural creative products. Such interactive design significantly enhances visitor engagement and strengthens their emotional connection to Sanxingdui culture, thereby promoting cultural dissemination and revitalization. This practical exploration not only expands the social influence of Sanxingdui culture but also provides valuable insights and examples for the digital transformation of traditional museum exhibition approaches.

Figure4 The Sanxingdui Digital Museum generated by artificial intelligence

Figure5 Concept Art for the Virtual Museum

4.2.2 Developing interactive experiences: From observation to participation

Passing on intangible cultural heritage is not merely a matter of static display; it also calls for hands-on involvement, encouraging a deeper personal connection. Generative AI excels in creating engaging settings where participants transition from passive observers to active contributors. Taking digital papercutting as an example, the system constructs a virtual workshop that allows anyone to design and craft patterns through straightforward gestures or touchscreen input. Based on real-time tracking of user movements, the AI instantly generates papercut effects and offers immediate tips alongside cultural insights, making traditional techniques more accessible than ever. This participatory approach, blending heritage and technology, expands the appeal of age-old art forms while promoting interactive and enjoyable learning.

4.2.3 Story-Focused narratives: Vivid expressions of cultural heritage

What truly enriches intangible heritage is not only its aesthetic and technical achievements but also the layered history, myths, and folklore that underpin it. Generative AI can integrate these narrative elements to form coherent, emotionally resonant story worlds that vividly present cultural origins and values. For instance, in projects based on folk tales, the system interprets the underlying legends to generate virtual environments and character designs. Through animation, audio effects, and interactive storytelling, these traditional narratives come to life, conveying their dramatic essence in a direct and engaging manner. While accurately depicting plotlines and details, the AI also fine-tunes pacing and visual composition, creating immersive scenes that draw in viewers. By emphasizing storytelling, this method enriches the expressive range of heritage while strengthening cultural ties and emotional investment, revealing the historic depth and artistry contained in these traditions.

4.3 Personalized Digital Art Design for ICH

4.3.1 User-Involved personalized design: Tailored cultural creations

The rise of personal expression has led to greater demand for one-of-a-kind cultural experiences, and generative AI offers users an opportunity to co-design artwork inspired by heritage. By entering preferred themes, motifs, or color palettes, individuals collaborate with the system to produce creations that blend tradition with fresh perspectives. This joint process satisfies the desire for novelty while weaving cultural heritage into everyday life. In digital embroidery applications, for example, users specify patterns, hues, and overall style, and the AI responds by generating pieces that suit these choices. Such outputs can become collectible digital assets or find practical applications in fashion and interior decoration, thus integrating intangible heritage into modern living. This user-guided customization keeps heritage vital, merging long-standing practices with innovative design.

4.3.2 Customized heritage derivative products: Market relevance and cultural innovation

Derivative products serve as a bridge between cultural heritage and wider audiences, contributing to both the preservation and commercial viability of tradition. Generative AI helps adapt these products to contemporary demands, offering tailored designs in line with specific market niches. Shadow puppetry is a representative example: by drawing on different stylistic preferences, the system can produce either sleek, minimalist versions for younger consumers or more traditional formats for collectors. Beyond

quickly suggesting product concepts, the AI also refines the details to ensure each item demonstrates the distinctive aesthetic value and craftsmanship of intangible heritage. This market-sensitive approach enriches heritage product lines, combining cultural renewal with current consumer trends to forge new pathways for industry growth. In the process, intangible heritage reaches broader audiences, fostering enhanced appreciation and recognition of its enduring significance.

5. Summary

Generative AI holds significant promise for the future of ICH digital art, offering ever more varied and sophisticated creative possibilities as technology continues to evolve. Even so, its current application remains constrained by several critical factors. The first involves data dependence and potential bias, given that the performance of an AI design platform is profoundly shaped by the comprehensiveness, diversity, and reliability of its training inputs (Xu, 2021). For ICH — which is inherently complex—skewed or incomplete data can result in generated works that fail to reflect key cultural attributes and stylistic nuances.

Another limitation lies in the inherent scope of AI-driven creativity. When dealing with designs bearing deep cultural significance, algorithms may struggle to match the innovative thinking and emotional sensitivity typical of human artists, and may also lack moral judgment (Mei & Zheng, 2020). Opacity in AI decision-making constitutes a further challenge, since insufficient transparency can erode mutual trust among designers and users. In addition, legal and ethical pitfalls — including copyright disputes, intellectual property infringement, and data privacy breaches—cannot be overlooked.

Several strategies are essential to address these issues. Strengthening data collection and preprocessing is vital to ensure that training material remains both comprehensive and unbiased, and advanced methods can bolster data integration as well. Emphasizing the primary role of human ingenuity throughout the design workflow is equally important, with generative AI positioned as an auxiliary resource to enhance efficiency without supplanting the irreplaceable depth that human artists bring (Liu & Liu, 2020). Heightening interpretability and transparency also remains crucial: developers should explore visualization tools and algorithmic refinements to enhance designers' and users' understanding of how decisions are made. Lastly, active involvement by governments and professional bodies is necessary to develop legal guidelines and ethical protocols, clarifying copyright rules, privacy safeguards, and regulatory oversight. By combining these measures, it becomes possible to harness generative AI's potential while simultaneously preserving and renewing heritage in the digital era, ensuring high-quality cultural expression and ongoing innovation.This study thoroughly investigates the practical application and innovative scenarios of generative AI in digital art design for intangible cultural heritage, highlighting its significant potential in cultural dissemination and interactive experiences. Due to objective constraints, this study has not conducted field research or user interviews. Nonetheless, existing research and publicly available information from museums suggest that interactive platforms utilizing generative AI likely enhance user participation and increase their cultural interest and sense of identity. However, potential issues may remain in practical usage, including operational challenges and insufficient emotional resonance. These aspects of user experience and feedback require further empirical verification and refinement in future research.

Conflict of Interest

The author declares that she has no conflicts of interest to this work.

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