

AIGC-DRIVEN INTANGIBLE CULTURAL HERITAGE: INNOVATIVE DESIGN OF BIAN EMBROIDERY PATTERNS BASED ON DIFFUSION MODELS

YIBO, L.^{1*} – UGAP, C. A.¹

¹ *Faculty of Art, Sustainability and Creative Industry, Universiti Pendidikan Sultan Idris, Perak, Malaysia.*

**Corresponding author
e-mail: P20241000498[at]siswa.upsi.edu.my*

(Received 21st April 2026; revised 15th June 2026; accepted 25th June 2026)

Abstract. This paper presents a theoretical and experimental exploration of how artificial intelligence generated content diffusion model technology can be applied to the preservation of Bian embroidery, an Intangible Cultural Heritage. The study first analyses the artistic characteristics of Bian embroidery, focusing primarily on colour and patterns. Subsequently, a database of colour and pattern elements was constructed and translated into prompts, whilst standardizing prompt variables. Using three AI diffusion model software programmes: ChatGPT, Gemini and Midjourney; innovative Bian embroidery patterns were generated. The experimental results indicate that all three models are capable of reproducing the visual elements of Bian embroidery. However, differences exist between the models: ChatGPT's output more closely resembles traditional styles; Gemini tends to modify new pattern elements; whilst Midjourney generates patterns with greater visual expressiveness. This demonstrates that artificial intelligence generated content technology can facilitate the preservation and innovation of intangible cultural heritage, offering a practical method for integrating traditional embroidery with generative technology, and providing new insights and references for developing innovative media applications within the field of intangible cultural heritage.

Keywords: *artificial intelligence generated content, Bian embroidery, intangible cultural heritage, artistic characteristics*

Introduction

Intangible cultural heritage(ICH) is not only the crystallisation of the wisdom and spirit of the world's peoples, but also an integral part of their traditional culture. It embodies the profound historical memory and cultural values of various nations and regions, and serves as a vital source for sustaining cultural identity and creativity (Li et al., 2023). ICH currently faces a severe existential crisis in modern society; factors such as the ageing of practitioners, waning interest among the younger generation, and the severe impact of mass-produced industrial goods have created a real dilemma for the protection of ICH (Deshmukh et al., 2024). Against this backdrop, the current state of traditional Chinese intangible cultural heritage crafts, exemplified by Bian embroidery, is particularly telling. Bian embroidery originated during China's Northern Song Dynasty (960–1127 AD). Renowned for its meticulous and delicate stitching, its simple yet elegant colour palette, and its artistic style deeply rooted in Song Dynasty painting, it was listed by the Chinese government as part of the second batch of National Intangible Cultural Heritage in 2008. As a significant part of China's ICH, Bian embroidery is not only a treasure of Chinese embroidery art but also embodies the pinnacle of Song Dynasty craftsmanship and the refined elegance of the literati, possessing immense artistic value and serving as a distinctive cultural emblem (Ruiting, 2023). Since 1992, Bian embroidery artisans have created portraits of leaders from

Brunei and Malaysia, works that hold immense value as art collectibles. However, with the rise of digital technology and the influence of fast-paced modern aesthetic trends, numerous traditional intangible cultural heritage craft techniques - of which Bian embroidery is a prime example - are facing severe challenges, despite their exceptional artistic value. How to transcend the limitations of traditional craftsmanship, whilst preserving its core cultural essence, and chart a sustainable path that integrates with contemporary design and market demands has become a pressing issue in the field of cultural heritage preservation.

Since 2020, the rapid development of artificial intelligence generated content (AIGC) technology has offered potential solutions to the challenges of safeguarding intangible cultural heritage. Against this backdrop, diffusion models-as an advanced deep generative technology-have demonstrated significant advantages in the field of computer vision thanks to their powerful capabilities in generating visual content. Moreover, they have opened up new technological opportunities for the digital preservation and innovation of Bian embroidery, emerging as the driving force behind this wave of technological transformation (Po et al., 2023). The generative capabilities of diffusion models give them remarkable potential for cross-disciplinary applications. In the field of art and design, they can assist creators in generating visual works in a wide variety of styles (Epstein et al., 2023); In the field of dance, research has proposed an AI-based framework for the preservation and innovation of Reba dance from the perspective of media convergence. By integrating motion capture technology, AI modelling and immersive performance practices, scholars have provided a data-driven approach to the sustainable preservation of intangible cultural heritage dances (Yang and Ismail, 2026). In the entertainment industry, it can be used to generate special effects for films and television, as well as virtual world environments (Liu and Pan, 2022). A wide range of flagship generative AI applications have now been released: text-to-image models such as Midjourney and Stable Diffusion enable creators to generate visual works in a myriad of styles.

Literature review

New technologies bring about new perspectives for research, there has been a growing body of research into the use of diffusion models to generate patterns of intangible cultural heritage. Yu et al. (2025) proposed a method for generating and applying Miao embroidery patterns based on stable diffusion and low-rank adaptive fine-tuning. By integrating this approach into embroidery practice and utilising artificial intelligence technology, they have lowered the skill threshold and production costs associated with embroidery training, significantly improved production efficiency, and increased the income of embroiderers. Xu and Liang (2025) explored how artificial intelligence technology can enhance the art of Suzhou embroidery, applying fine-tuned models to the design improvement process to enhance the quality and design innovation of Suzhou embroidery. Daffa Izzuddin Wahid et al. (2025) utilize a latent diffusion model (LDM), low-rank adaptation and classifier-free guided classification to generate detailed descriptions of batik images; they also achieve an innovative combination of multiple patterns and are even capable of creating entirely new designs. Hu et al. (2025) utilized a low-rank diffusion model to effectively transfer the unique structural, symbolic and textural features of Miao batik, whilst combining it with a latent consistency model (LCM) to enhance inference efficiency. Furthermore, the researchers proposed a style-conditioned linear fusion (SCLF) strategy that dynamically adjusts

model outputs based on the semantic complexity of the input prompts, thereby overcoming the limitations of static weighting in existing frameworks. According to existing academic research, diffusion models have driven significant advancements in the preservation of embroidery art; in particular, by incorporating and drawing inspiration from the stylistic characteristics of specific cultural elements, they can significantly enhance the cultural authenticity of the generated images.

In addition to the art of embroidery, many scholars have explored the use of diffusion models for the preservation of intangible cultural heritage. Dai et al. (2024) utilized diffusion models and the Analytic Hierarchy Process (AHP) to examine the digital preservation and dissemination of Chinese paper-cutting as an intangible cultural heritage. Their research demonstrated that diffusion models can effectively enhance the digital presentation and dissemination of paper-cutting art, thereby promoting its digital transmission and development. Wang and Zhou (2025) developed a diffusion model reflecting the style of blue-and-white porcelain and applied it to a museum of intangible cultural heritage, demonstrating the technology's efficiency and practicality in the innovative application of plant-dyed patterns, expanding its potential scope of application, and achieving the digital preservation and innovative reinterpretation of traditional patterns. In their 2025 study, Izani et al. (2025) utilized generative artificial intelligence, combining audio-visual separation technology based on Splitter.ai, motion synchronisation technology from Kling.ai, and other AI technologies to comprehensively process and enhance the audio-visual elements, thereby preserving traditional Malay music in video format (Izani et al., 2025).

In summary, scholars' research is rapidly advancing the innovative application of generative AI image generation technology into practical, systematic and professional contexts. The core objective is to develop a series of intelligent generative systems that combine high fidelity, high efficiency and strong controllability, thereby assisting design experts through human-machine collaboration. This approach aims to enhance their professional capabilities and innovative potential, ultimately facilitating the preservation and transmission of intangible cultural heritage elements. However, there remains a significant research gap regarding the integration of intangible cultural heritage, particularly Bian embroidery; with generative artificial intelligence. Practical research on the sustainable innovation and development of Bian embroidery in a digital context remains limited. Consequently, this study aims to explore innovative pathways for integrating diffusion models with Bian embroidery, thereby providing new perspectives and approaches for the preservation and innovation of intangible cultural heritage. To achieve this objective, the study has established two progressive core objectives: (1) To construct a high-quality image dataset dedicated to Bian embroidery, thereby laying a solid data foundation for the precise training of subsequent models; (2) To utilize mainstream diffusion models for training, enabling them to accurately capture and generate patterns that embody the unique artistic style of Bian embroidery.

Materials and Methods

The framework of this study is shown in *Figure 1*. This paper begins with a literature review to outline research progress on AIGC and the transmission of intangible cultural heritage, thereby clarifying the research focus and theoretical foundation. It then proceeds to address two research objectives: firstly, to analyze the patterns and colour systems of Bian embroidery motifs and construct a standardized dataset; and secondly,

to conduct a systematic analysis of AI-generated Bian embroidery design proposals based on the mechanisms of diffusion models, evaluating their design potential across dimensions such as visual expression and stylistic consistency. Finally, through comparative analysis and comprehensive synthesis, this study explores the application pathways and value boundaries of AIGC technology in the innovative design of Bian embroidery patterns, with the aim of providing theoretical support and practical guidance for the digital transformation and contemporary expression of intangible cultural heritage.

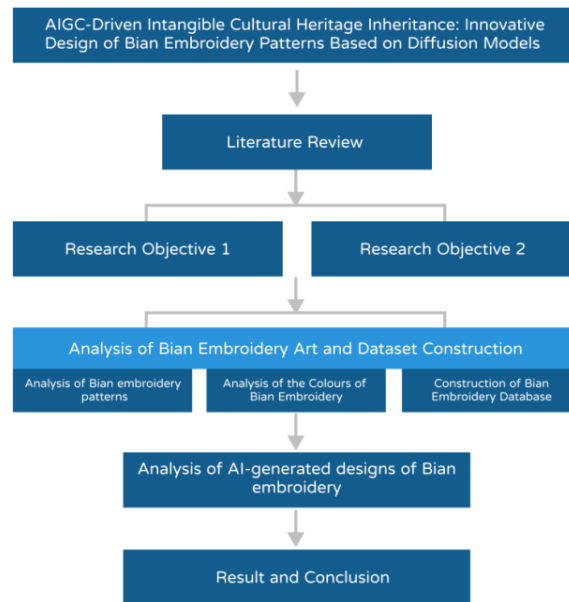


Figure 1. Research framework.

Analysis of Bian embroidery patterns

The motifs of Bian embroidery essentially constitute a history of Chinese art rendered in silk thread. It has successfully transcended the realm of ordinary folk embroidery, which serves merely as a decorative element in daily life, by seamlessly blending the poetic and pictorial qualities of traditional Chinese painting and calligraphy with the play of light and shadow created by the silk threads, whilst making full use of the lustre of the silk and the textural qualities of the stitching techniques. Although deeply influenced by literati painting, Bian embroidery patterns retain a wealth of auspicious motifs from the Central Plains region. The botanical and zoological motifs include flowers, birds, fish and insects; for instance, the peony symbolizes wealth and prosperity, the peacock symbolizes a bright future, and the horse symbolizes success (*Figure 2*). The characteristics of Bian embroidery patterns combine a sense of realism with the logic of geometric equations; they embody the elegance of literati aesthetics whilst embracing the sentiments of Central Plains folklore. It constitutes a visual symbolic system that perfectly encapsulates the principles of classical Chinese art.



Figure 2. Bian embroidery pattern.

Color analysis of Bian embroidery

In the art of embroidery, colour often exerts the strongest visual impact. The choice and combination of each hue are by no means arbitrary, but rather a concrete expression of intrinsic cultural heritage and the public’s aesthetic sensibilities. The colour palette of Bian embroidery deeply embodies the essence of Chinese folk art, characterised by a bright and diverse overall scheme. Taking the common peony motif as an example, the red, pink and yellow of the flowers, combined with the green of the leaves, create a strikingly contrasting composition. To harmonize this intense visual contrast, the embroiderers employ extremely natural gradations of light and shade, as well as subtle transitions between colour tones, rendering the colour clashes in the design soft and seamless rather than harsh. At the same time, to highlight its decorative beauty, Bian embroidery pursues a poetic and picturesque aesthetic in its colour schemes, whilst its compositions are characterized by compactness and regularity. These factors collectively give rise to patterns distinguished by their orderly structure, rigorous technique, and elegant vitality.

Construction of Bian embroidery database

This study created a dataset for diffusion model training. By selecting four representative examples of Bian embroidery, since when analyzing the embroidery, shape, color and texture are important visual features (Kazlacheva et al., 2023). Therefore, the color feature values, cultural theme forms of the patterns, and materials of these examples were extracted to construct a complete prompt word for the image generation of the diffusion model (Table 1).

Table 1. Examples of embroidery features and keywords used for generating diffusion models.

Original Image	Color	Cultural Motif	Texture	Prompt
	 #C38276	Peony	Silk	Traditional Chinese embroidery, Bian embroidery style, silk thread art, a graceful folding branch composition featuring blooming peonies in pink and yellow tones, elegant oriental aesthetic. Detailed gradient blue-green leaves with natural flow. Realistic silk thread texture, visible stitch direction, fine needlework, high satiny luster, rich textile depth, photorealistic material, 8k ultra detail.
	 #E3B5AC			
	 #C9203F			
	 #605533			

		Chrysanthemum Peach	Silk, Visible stitch	A masterpiece of Traditional Chinese embroidery, intangible cultural heritage. A perfect circular composition on a light baby-blue silk background, framed by a black border. The folding branch motif features ripe pink peaches of longevity, a cluster of blue and pink grapes, and blooming yellow-white chrysanthemums. Stylized flying bats flutter among detailed green leaves. Extremely detailed silk thread art, visible stitch direction, satiny luster, textural depth, vibrant gradient colors. Elegant oriental aesthetic, photorealistic textile macro, 8k
		Peony	Silk, Flat stitch	Traditional Chinese embroidery textile design, isolated round emblem on a white background. Inside the circle is a dark blue silk canvas featuring an exquisite yellow peony with flat stitch silk thread texture. Graceful curved brown branches, teal leaves, small leaves with bright orange tips. Luminous silk sheen, intangible cultural heritage aesthetic, rich color contrast, flat lay, high quality, 8k
		Peony	Silk, Satin stitch	A photorealistic macro photography of traditional Chinese silk embroidery. A perfect circular motif featuring gradient magenta and pale pink blooming peonies, interspersed with small vibrant red blossoms. The folding branch composition includes distinctive teal, sky blue, and muted green leaves. Exquisite silk thread needlework, visible stitch direction, highly reflective satiny luster, textural depth. Stitched on a light warm gray silk canvas inside the circle, completely isolated on a pure white background outside. Elegant oriental cultural heritage aesthetic, 8k resolution, highly detailed.

Selection and introduction of diffusion models

In this study, three representative AIGC tools, ChatGPT, Gemini and Midjourney; were selected as the primary platforms for design generation. Although these tools differ in their underlying architectures and modes of interaction, they collectively reflect the current state of the art in diffusion-based or enhanced diffusion-based generative systems (Hu et al., 2025; Daffa Izzuddin Wahid et al., 2025; Dai et al., 2024; Po et al., 2023). The combined use of these three tools enables a comparative analysis of different generative methods within the context of intangible cultural heritage design (Wang and Zhou, 2025; Hu et al., 2025; Dai et al., 2024). By leveraging their respective strengths—semantic accuracy (ChatGPT), multimodal reasoning (Gemini) and artistic presentation (Midjourney)—this study has established a comprehensive experimental framework for evaluating AI-generated Bian embroidery patterns. This selection not only reflects the diversity of current AI content generation technologies but also provides a solid foundation for analyzing their applicability in cultural heritage innovation (Yang and Ismail, 2026; Izani et al., 2025; Wang and Zhou, 2025; Epstein et al., 2023).

Embroidery pattern generation

In this study, utilizing ChatGPT, Gemini and Midjourney, we generated multiple sets of Bian embroidery images under controlled conditions. To ensure consistency across the experimental protocol, the prompts used on each platform remained identical for every case, covering composition, material properties, level of detail and colour

constraints. We refined the prompts iteratively to enhance the accuracy and aesthetic quality of the generated patterns (Daffa Izzuddin Wahid et al., 2025; Hu et al., 2025; Xu and Liang, 2025). The generated results were subsequently screened and filtered. Through this process, we obtained a diverse range of embroidery pattern designs that both preserved traditional characteristics and explored new forms of visual expression. This approach demonstrates the potential of diffusion-based AIGC tools in supporting the creative transformation and digital dissemination of intangible cultural heritage (Yang and Ismail, 2026; Wang and Zhou, 2025; Izani et al., 2025; Dai et al., 2024).

Results and Discussion

This study generated a series of Bian embroidery pattern designs using three AIGC models: ChatGPT, Gemini, and Midjourney; based on structured prompts derived from traditional embroidery features. The results are presented and compared in terms of composition, color performance, and texture representation (*Table 2*). First, in terms of composition, the generated images generally retained the core structural characteristics of traditional Bian embroidery, such as circular layouts and floral-centered arrangements. Among the three models, ChatGPT produced outputs that most closely resembled the original compositions, while Gemini introduced slight variations in motif arrangement. Midjourney demonstrated more dynamic and complex compositions, with enhanced visual layering. Second, regarding color performance, all models were able to reproduce the fundamental color schemes of Bian embroidery. ChatGPT maintained relatively stable and harmonious color relationships consistent with the original images. Gemini showed moderate variation in color distribution, while Midjourney generated more saturated and visually striking color effects. Third, in terms of texture and detail, differences among the models were more evident. Midjourney produced the most detailed results, with clear simulation of silk thread texture and lighting effects. ChatGPT also demonstrated recognizable stitch-like textures, although with less depth. Gemini outputs appeared comparatively simplified in texture representation. Overall, the results indicate that each model exhibits distinct characteristics: ChatGPT shows higher fidelity to traditional patterns, Gemini demonstrates balanced variation, and Midjourney emphasizes visual richness and artistic expression. These differences contribute to the diversity of the generated dataset and provide multiple directions for the innovative design of Bian embroidery patterns.

Table 2. Comparison of the effects of different models in generating Bian embroidery patterns.

Original Image	ChatGPT	Gemini	Midjourney
			



Conclusion

This study explores the application of AIGC technology in the innovative design of Bian embroidery patterns, with a particular focus on diffusion model-based generation methods. By analyzing the visual characteristics of traditional Bian embroidery in terms of colour and pattern, and by constructing a structured dataset, the study lays the groundwork for AI-assisted pattern generation. During the generative experimentation phase, this study employed three representative tools: ChatGPT, Gemini and Midjourney; to generate innovative Bian embroidery designs under standardized prompt conditions. The results indicate that AIGC models can effectively reproduce the key characteristics of Bian embroidery, including pattern composition, colour harmony, and fabric-like textures. At the same time, differences in generative capabilities exist between the models: ChatGPT performs best in constructing traditional patterns, Gemini offers a balanced variation between original and new patterns, whilst Midjourney generates richer visual representations with greater detail. These differences yield diverse design outcomes that embody both heritage and innovation. Overall, this study confirms the potential of diffusion-based AIGC tools in supporting the digital transformation and creative development of intangible cultural heritage. The integration of traditional cultural elements with generative technology offers new avenues for design exploration and cultural dissemination. However, the current research remains primarily qualitative. Future work could incorporate quantitative evaluation methods and user-centred research to further assess the effectiveness and cultural acceptance of AI-generated designs.

Acknowledgement

The authors independently managed the study design, data collection, and analysis. We would like to express our gratitude to Dr Catherina Anak Ugap for providing the necessary academic environment and guidance. Special thanks are also extended to the Universiti Pendidikan Sultan Idris for the studio space and archival access that supported the analysis of embroidery. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

REFERENCES

- [1] Daffa Izzuddin Wahid, R., Yudistira, N., Dewi, C., Nurmala Sari, I., Pradhikta, D., Fatmawati (2025): Prompt conditioned batik pattern generation using LoRA weighted diffusion model with classifier-free guidance. – IEEE Access 13: 2436-2448.
- [2] Dai, M., Feng, Y., Wang, R., Jung, J. (2024): Enhancing the digital inheritance and development of Chinese intangible cultural heritage paper-cutting through Stable Diffusion LoRA models. – Applied Sciences 14(23): 23p.
- [3] Deshmukh, D., Rajput, C.S., Das, S., Alam, M.M. (2024): Sustainability and livelihood of small-scale handicraft producers in India: A SWOT analysis of Dhokra artisans. – Social Sciences & Humanities Open 10: 10p.
- [4] Epstein, Z., Hertzmann, A., Investigators of Human Creativity, Akten, M., Farid, H., Fjeld, J., Frank, M. R., Groh, M., Herman, L., Leach, N., Mahari, R., Pentland, A.S., Russakovsky, O., Schroeder, H., Smith, A. (2023): Art and the science of generative AI. – Science 380(6650): 1110-1111.
- [5] Hu, Q., Peng, Y., Xu, J., Shao, Z., Tian, Z., Chen, J. (2025): Adaptive stylized image generation for traditional Miao batik using style-conditioned LCM-LoRA enhanced diffusion models. – Mathematics 13(12): 24p.
- [6] Izani, M., Gabr, M., Harumaini, H., Trinh, K., Kaleel, A., Assad, A. (2025): An AI-driven workflow for preserving traditional Malay music videos: A case study in cultural heritage enhancement. – 2025 5th International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET) 7p.
- [7] Kazlacheva, Z., Ilieva, J., Dineva, P., Stoykova, V., Zlatev, Z. (2023): Digital color images as a tool for the sustainable use of embroidery elements from folk costumes. – Heritage 6(8): 5750-5778.
- [8] Li, X., Yang, M., Long, L., Liu, M., Liu, H., Liu, J. (2023): Geographical distribution and influencing factors of intangible cultural heritage in the Three Gorges Reservoir Area. – Sustainability 15(4): 22p.
- [9] Liu, X., Pan, H. (2022): The path of film and television animation creation using virtual reality technology under the artificial intelligence. – Scientific Programming 8p.
- [10] Po, R., Yifan, W., Golyanik, V., Aberman, K., Barron, J.T., Bermano, A.H., Chan, E.R., Dekel, T., Holynski, A., Kanazawa, A., Liu, C.K., Liu, L., Mildenhall, B., Nießner, M., Ommer, B., Theobalt, C., Wonka, P., Wetzstein, G. (2023): State of the art on diffusion models for visual computing. – arXiv:2310.07204 34p.
- [11] Ruiting, J. (2023): The application of Bian embroidery in modern fashion design. – International Journal of Global Optimization and Its Application 2(2): 125-134.

- [12] Wang, Y., Zhou, Y. (2025): Artificial intelligence-driven interactive experience for intangible cultural heritage: Sustainable innovation of blue clamp-resist dyeing. – Sustainability 17(3): 18p.
- [13] Xu, J., Liang, Z. (2025): Research on the innovation and development of Su embroidery design based on LoRA fine-tuning model. – In: Chulsoo, K., Phanlukthao, P., Xu, Z., Follesa, S. (Eds.), Proceedings of the 2025 4th International Conference on Art Design and Digital Technology (ADDT 2025), Advances in Computer Science Research 123: 150-165.
- [14] Yang, T., Ismail, M.J. (2026): AI-empowered innovation in Reba dance inheritance: A media convergence approach to digital cultural preservation. – Malaysian Journal of Social Sciences and Humanities (MJSSH) 11(3): 13p.