Research on AIGC-Based Ethnic Pattern Generation and Lacquer Art Cultural Product Design

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Abstract. With the rapid development of artificial intelligence generated content (AIGC), its application in cultural and creative design has shown great potential. This paper proposes an AIGC-based method for ethnic pattern generation and applies it to lacquer art cultural product design. By integrating feature extraction, diffusion-based generative models, and computer-aided design techniques, the proposed framework enables the transformation of traditional ethnic patterns into innovative design resources. Experimental results demonstrate that the method achieves superior performance in visual quality, structural consistency, and cultural relevance compared with baseline approaches. The generated patterns can be effectively adapted to lacquer art products, improving both design efficiency and practical applicability. This study provides a feasible pathway for the digital inheritance and innovative development of ethnic culture.

Keywords: AIGC; ethnic patterns; diffusion model; lacquer art; cultural and creative design; generative design.

1 Introduction

With the advancement of artificial intelligence, AIGC (Artificial Intelligence Generated Content) has been widely applied in creative design fields[1]. It provides new possibilities for the digital transformation and innovative development of traditional cultural resources, especially in the context of intangible cultural heritage preservation[2].

Ethnic patterns, as important carriers of regional culture in Heilongjiang, possess rich visual features and symbolic meanings. However, traditional design methods face challenges such as low efficiency, limited innovation, and difficulty in large-scale application, which restrict their integration with modern cultural and creative industries[3].

To address these issues, this study proposes an AIGC-based method for ethnic pattern generation and applies it to lacquer art cultural product design. The research aims to explore an intelligent design pathway that combines cultural inheritance with technological innovation.

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2 Literature Review

2.1 Digitalization and Design of Ethnic Patterns

In recent years, the digital preservation and transformation of ethnic patterns have become an important topic in cultural heritage research[4]. Existing studies mainly focus on techniques such as image acquisition, vectorization, pattern segmentation, and feature extraction, aiming to convert traditional motifs into standardized digital resources[5]. Some researchers further introduce semantic annotation and pattern classification methods to enhance the reusability of these cultural elements in modern design contexts[6].

However, current research is largely limited to static digitization and database construction. The extracted elements are often used in a direct or simplified manner, lacking systematic design methodologies that integrate cultural semantics with computational creativity. Moreover, there is insufficient exploration of structural rules, generative logic, and adaptive transformation of ethnic patterns, resulting in limited innovation and weak scalability in practical applications.

2.2 AIGC in Cultural and Creative Design

With the rapid development of artificial intelligence, AIGC technologies such as generative adversarial networks (GANs) and diffusion models have been widely applied in image generation, style transfer, and creative design[7]. In the field of cultural and creative industries, these methods provide efficient tools for pattern generation, visual exploration, and design assistance, significantly improving creative productivity[8].

Nevertheless, existing studies often prioritize visual realism and diversity while neglecting deeper cultural connotations and craftsmanship constraints. The generated results may lack cultural authenticity, symbolic accuracy, and practical feasibility, especially in traditional art forms such as lacquer art. In addition, there is still a lack of integrated frameworks that combine data-driven generation with domain-specific design adaptation. Therefore, this study aims to address these gaps by proposing a culturally informed AIGC-based method for ethnic pattern generation and lacquer art product design.

3 Methodology

3.1 System Overview

As shown in Fig. 1, this study constructs an AIGC-driven framework for ethnic pattern generation and lacquer art cultural product design. The overall pipeline consists of four key stages: data acquisition, preprocessing and feature extraction, generative modeling, and design adaptation. Each stage is interconnected through a clear data flow, forming a structured and iterative design process.

In addition, a feedback loop is introduced to refine the generated results. By integrating evaluation metrics such as cultural consistency and design feasibility, the

framework enables continuous optimization. This ensures that the generated patterns are not only visually diverse but also aligned with traditional cultural characteristics and practical application requirements.

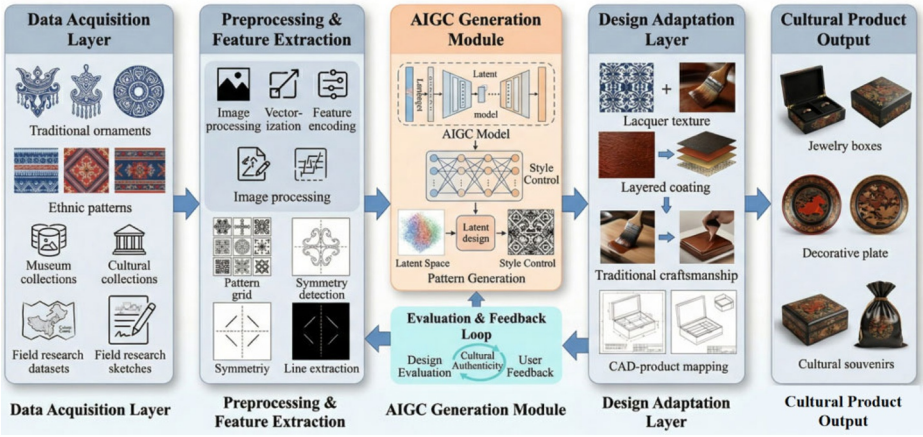

Fig. 1. AIGC-based Ethnic Pattern Generation and Lacquer Art Cultural Product Design.

3.2 Feature Extraction and Representation

In the preprocessing stage, collected ethnic pattern images are standardized and transformed into machine-readable representations. Specifically, OpenCV is used for image denoising, binarization, and contour extraction, while Adobe Illustrator-based vectorization or Potrace algorithms are applied to convert raster images into scalable vector formats. A convolutional neural network (CNN), such as ResNet or VGG, is employed as the feature encoder to extract hierarchical visual features:

$$z=F(I) \tag{1}$$

where z represents the latent feature vector containing both local texture information and global structural characteristics.

In addition, symmetry detection algorithms and Fourier-based pattern analysis are introduced to capture repetitive and geometric structures commonly found in ethnic motifs. These structure-aware features are further used to guide the generation process, helping maintain symmetry, periodicity, and overall structural consistency in the generated patterns.

3.3 AIGC-Based Pattern Generation

This study adopts a diffusion-based generative model, implemented using frameworks such as PyTorch and the Hugging Face Diffusers library. The model is trained on the preprocessed dataset to learn the distribution of ethnic patterns. The forward process adds Gaussian noise to the input data, while the reverse process is modeled by a U-Net architecture to reconstruct meaningful patterns. The objective function is defined as:

$$L_{diff}=E_{x,\epsilon,t}[\|\epsilon-\epsilon_\theta(x_t,t,c)\|^2] \quad (2)$$

where ϵ_θ is implemented as a conditional U-Net, t is the diffusion timestep, and ,c includes conditional embeddings such as style labels or color palettes encoded via CLIP or embedding layers. This allows controlled generation aligned with specific cultural features.

3.4 Design Adaptation and Product Mapping

The generated patterns are further applied to lacquer art product design through a computer-aided design (CAD) workflow. Tools such as Rhino or Blender are used to construct 3D product geometries, while UV mapping techniques are applied to project 2D generated patterns onto complex surfaces. The mapping process is defined as:

$$\mathrm{P} = \mathrm{M}(\mathrm{G}(\mathrm{z}, \mathrm{c}), \mathrm{S}) \quad (3)$$

where G(*) is the trained diffusion model, and S represents the 3D surface model. In addition, material-aware rendering techniques are introduced to simulate lacquer texture, including multi-layer coating effects and gloss properties. Constraints such as color layering, edge smoothness, and manufacturability are incorporated through rule-based adjustments and expert-in-the-loop evaluation, ensuring that the final outputs are both visually compelling and feasible for real-world production.

4 Experiments and Comparative Analysis

4.1 Experimental Setup

To ensure the reliability and generalization ability of the proposed method, a hybrid dataset was constructed by integrating multiple authoritative sources. The dataset includes publicly available ornamental pattern images from open-access museum collections (e.g., The Metropolitan Museum of Art Open Access dataset) and digital heritage resources, combined with self-collected ethnic pattern data from Heilongjiang regional field studies. The collected data mainly involve ethnic groups such as Hezhe, Oroqen, and Daur. All publicly sourced data are obtained from open-access platforms, and field data were collected following standard research practices. After preprocessing, a total of approximately 5,000 high-quality images were used for training and testing.

The model was implemented using PyTorch and trained on an NVIDIA RTX 3090 GPU. Key parameters were set following standard diffusion model configurations.

For evaluation, both quantitative and qualitative metrics were adopted, including Fréchet Inception Distance (FID) to assess generation quality and Structural Similarity Index (SSIM) to measure pattern consistency. In addition, expert evaluation was conducted to assess cultural authenticity and design applicability. Specifically, a group of design professionals and cultural researchers evaluated the generated results using a

5-point Likert scale, considering criteria such as motif authenticity, stylistic coherence, and cultural relevance.

This multi-dimensional evaluation provides a structured and interpretable assessment of the generated patterns, while also emphasizing cultural respect and avoiding inappropriate use or distortion of traditional ethnic motifs, thereby enhancing the reliability and credibility of the experimental results.

4.2 Main Experimental Results

The proposed AIGC-based method demonstrates strong performance in both visual quality and cultural consistency of generated ethnic patterns. Compared with traditional GAN and style transfer methods, the proposed approach achieves more stable structure and richer detail representation.

Compared with the Stable Diffusion + LoRA baseline, the proposed method shows better structural consistency and cultural coherence, while the Stable Diffusion-based method tends to produce less stable symmetry and weaker alignment with traditional motifs.

As shown in Table 1, the proposed method achieves the lowest FID and highest SSIM, indicating improved realism and pattern consistency. It also obtains the highest cultural score, suggesting better preservation of ethnic characteristics..

Table 1. Quantitative Comparison of Different Methods for Ethnic Pattern Generation.

Method	FID ↓	SSIM ↑	Cultural Score ↑
Style Transfer	68.4	0.71	3.8
GAN-based Method	52.7	0.76	4.1
Stable Diffusion + LoRA	38.6	0.80	4.3
Proposed Method	34.9	0.83	4.6

Overall, the results demonstrate superior performance of the proposed method across multiple evaluation metrics.

4.3 Discussion

The results show that the proposed method is effective in combining ethnic cultural features with contemporary design. Compared with GAN-based methods and Stable Diffusion + LoRA, it generates patterns with better structural integrity and cultural consistency.

Quantitative results are consistent with expert evaluation, indicating that the generated patterns are both visually realistic and culturally meaningful. In contrast, Stable Diffusion-based methods show limitations in maintaining symmetry and structural regularity.

However, limitations remain in dataset scale and complex product adaptation. Future work will explore larger datasets and more advanced controllable generation methods.

5 Conclusion

This study proposes an AIGC-based framework for ethnic pattern generation and its application in lacquer art cultural product design. By integrating data-driven feature extraction, diffusion-based generative modeling, and design adaptation mechanisms, the proposed method effectively bridges traditional cultural resources with contemporary computational design technologies. Structure-aware feature extraction is incorporated to preserve symmetry and periodicity, enabling the transformation of ethnic patterns into design-ready visual assets.

Experimental results demonstrate that the proposed method outperforms conventional approaches in terms of visual quality, structural consistency, and cultural relevance. Compared with GAN-based methods and diffusion-based approaches such as Stable Diffusion with LoRA, the proposed method achieves lower FID and higher SSIM scores, while also receiving positive expert evaluations. These results confirm its effectiveness in maintaining both structural integrity and cultural coherence, supporting its applicability in lacquer art product design.

Despite these contributions, limitations remain in dataset scale and complex product adaptation. Future work will focus on expanding culturally representative datasets, improving multimodal and 3D-aware generation models, and exploring more advanced controllable generation methods. Overall, this research provides a feasible pathway for the digital inheritance and innovative development of ethnic culture..

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