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AI-driven digitalization of intangible cultural heritage and innovative ethnic graphic design

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Abstract Intangible cultural heritage (ICH) is an important part of traditional culture, carrying deep historical and cultural values. With the advancement of science and technology, the application of Artificial Intelligence (AI) technology provides a brand new idea and method for the digital translation of non-heritage culture. This study explores the method of translating non-heritage ethnic graphic designs based on AI technology, and proposes an innovative path combining shape syntax and parametric design. Samples of Xiangxi Miao embroidery patterns are digitally collected, and image processing techniques such as bilateral filtering and rolling bootstrap filtering are used to preprocess the sample patterns so as to improve the accuracy of pattern extraction. The study uses the improved Canny operator for pattern extraction, and the experimental results show that the method in this paper has a significant advantage in the effective number of patterns extracted and the accuracy, and the extraction accuracy reaches 96.95%, which is far more than the traditional method. In order to verify the effectiveness of the method, the study also conducted expert scoring and user experience tests. The results show that the innovative design solution based on AI technology shows significant advantages in terms of satisfaction, visual experience and aesthetics of the work, and the comprehensive user score is 3.82 points higher than that of the traditional design solution, and the difference is statistically significant. The results of the study show that AI-assisted design not only enhances the artistic expression of traditional ethnic graphics, but also strengthens the user's sense of identity and experience of traditional cultural works.

Index Terms Non-heritage Culture, Artificial Intelligence, Ethnic Graphics, Shape Grammar, Parametric Design, Canny Arithmetic

I. Introduction

Ethnic graphics are the pictorial forms of various ethnic groups in a specific spatial and temporal environment and cognitive mode, in order to convey the aesthetic interests, cultural thrust and philosophical concepts of the ethnic groups, with the help of certain carriers, to express the characters, animals, plants, artifacts, scenery, celestial phenomena, myths, religions, ideas and so on by means of arts and crafts [1]-[4]. Ethnic graphics generally present the characteristics of history, epoch, commonality, locality, symbolism and decoration, which is an important part of the new era of NRL [5], [6]. However, with the passage of time, many ethnic graphics face the risk of damage and disappearance [7]. In the context of artificial intelligence, the emergence of digitization technology provides a new way for the protection and inheritance of ethnic graphics [8].

Through digitization technology, ethno-graphics can be preserved in the virtual world through digital design [9]. Artificial Intelligence technology enables ethnic graphics guardians to digitize, archive and disseminate ethnic graphics more efficiently in order to protect them from the external environment [10]. Artificial intelligence technology provides coherent and continuous technical support for the digitization and protection of ethnic graphics with the help of technologies such as object recognition, machine learning and natural language processing [11], [12]. At the same time, AI technology can also analyze the data of ethnic graphics to determine the interaction and influence of different factors in cultural inheritance [13], [14]. For example, by analyzing the popularity of ethnic graphics in different time periods and locations, AI technology can enable professionals to better assess the value and importance of ethnic graphics, and thus better protect them and pass on the culture [15], [16].

This study proposes an AI-based method for digitizing and translating non-heritage through the combination of artificial intelligence and traditional non-heritage graphic design. Firstly, for traditional ethnic graphics such as Xiangxi Miao embroidery, pattern extraction is carried out through pattern acquisition, data processing and improved Canny algorithm to ensure high-precision pattern extraction effect. On this basis, combining shape syntax and parametric design, AI is utilized to carry out innovative design of non-heritage patterns. In the experiment, this paper also compares the innovative design results with the traditional design methods, and adopts the methods of user evaluation and expert scoring to comprehensively verify the effectiveness of AI design methods in the innovation of non-heritage graphics. Through this research idea, it aims to provide technical support for the inheritance and innovation of non-heritage ethnic graphics and provide new ideas for the development of cultural industry.

II. Design strategy construction of non-heritage ethnic graphics

The world is rapidly entering a new era of Artificial Intelligence (AI), and generative AI and big language modeling applications represented by ChatGPT are leading a new round of information technology changes, with many new technologies emerging and rapidly iterating and updating. Combining AI technology with non-heritage culture can help further realize the digital translation of non-heritage culture and provide reliable support for the innovative design of innovative non-heritage ethnic graphics.

II. A. Digital Translation of NRM in Shape Grammar

II. A. 1) Shape syntax base rules

Shape Grammar is a design and analysis method based on the study of symbolic language theory, which focuses on the operation of “shapes”. According to the definition of Shape Grammar, it can be expressed as follows:

$$SG = (T, L, R, I) \tag{1}$$

where T is the set of shapes, L is the set of labels, R is the set of inference rules, and I is the set of initial shapes.

Commonly used shape syntax inference rules include methods such as move, replace, scale, add, delete, mirror, copy, rotate, and switch. Move, a change that alters the position of an initial shape curve by shifting its coordinates. Displacement, a change that replaces the initial shape curve with a curve from another product. Scaling, which reduces or enlarges the curve in the initial shape. Add or delete, add or delete curves in the initial shape. Mirror, flip the curve of the initial shape on its axis. Duplicate, copy and move changes to the initial shape curve. Rotate, changes to the angle of the initial shape curve. Toggle, the change of the coordinate value of the curve while retaining the characteristics of the initial curve.

In the specific design and application process, there are a large number of intersections and repetitions of the reasoning rules of the shape, such as the copy of the shape also belongs to the increase, and the simple change of coordinates can also realize the scaling, rotation and switching. In order to inherit the image of the product, the application of scaling, rotation and switching operations can better realize the continuation of the shape style than simple movement, while movement is often used in the local transformation of curves.

II. A. 2) Digital Translation of Non-Heritage

At present, the rapid development of science and technology has brought about brand-new industrial changes for all walks of life, and the innovation of digital technology has also provided a brand-new path for the promotion and innovation of traditional culture. The use of digital technology means in the design innovation of non-heritage ethnic graphics can inject fresh vitality into the digital translation of non-heritage, update the creation of a large number of pattern materials that meet the aesthetic needs of the times, and add more possibilities for the development of non-heritage cultural and creative products [17].

Combining shape grammar with parametric and visualization algorithms, artificial neural networks, evolutionary algorithms and other means are used to automatically generate and iterate a variety of appearance forms of products. Shape grammar, on the other hand, can, with the help of computer programs, follow the principles of aesthetics and the rules of geometric composition, automatically arrange, rotate, mirror, miscut or change the position of the basic graphic elements in the non-heritage ethnic patterns, and then combine with the modern design language to organize, filter and reorganize the graphics to form new graphic schemes, which can lead to the generation of a large number of series of innovative patterns. Not only can it save labor and shorten the design cycle, but also because the newly deduced innovative patterns are based on the derivation of traditional non-heritage ethnic patterns. Therefore, the use of shape syntax to design innovative patterns can also well inherit the culture and connotation in traditional patterns.

II. B. NRM Ethno-Graphic Innovations Combined with AI

II. B. 1) Diversification of AI generation results

Artificial intelligence-driven innovative design is the trend of the future, along with the rapid development of modern science and technology, more and more computer technology intervenes in ethnic graphic design, the application of artificial intelligence and parametric design has brought new creative ideas and design trends for modern design.

Technology not only provides more diversified creative methods for design, but also provides designers with more diversified design analysis perspectives. With the help of mathematics and technology, designers are able to better understand, split and organize the reconstruction of visual images. This also brings new vitality to the design of non-heritage living heritage transformation, presenting a diversified contemporary combined with traditional art style [18].

As an important part of geometric patterns, the regular pattern and structure of non-heritage ethnic graphic patterns are very strict and mathematical, so they are very suitable for creating ethnic graphic patterns through shape syntax and parametric design. Using AI technology as an assistant, combining shape syntax and parametric design to write the design language into parameters and processes, when designing ethnic graphic patterns, the designer will record the visual graphics in their own logical form with shape syntax in the form of parameterization. And can modify the parameter conditions, directly through the computer to calculate again, so as to get a brand-new ethnic graphic design results. In traditional mapping software, if the designer wants to fine-tune some organizational details on the basis of the original pattern to design a new pattern, it is equivalent to drawing a pattern again. Parametric design undoubtedly realizes the automation and convenience of the design process, and also realizes the adjustability of the design results.

II. B. 2) Ethnic graphic design for NRHs

Based on the previous analysis, this paper takes AI technology as the basis, combines shape syntax with parametric design, and constructs the non-heritage ethnic graphic design strategy as shown in Fig. 1, which mainly includes three steps of reference diagram selection, cue setting and AI tool selection.

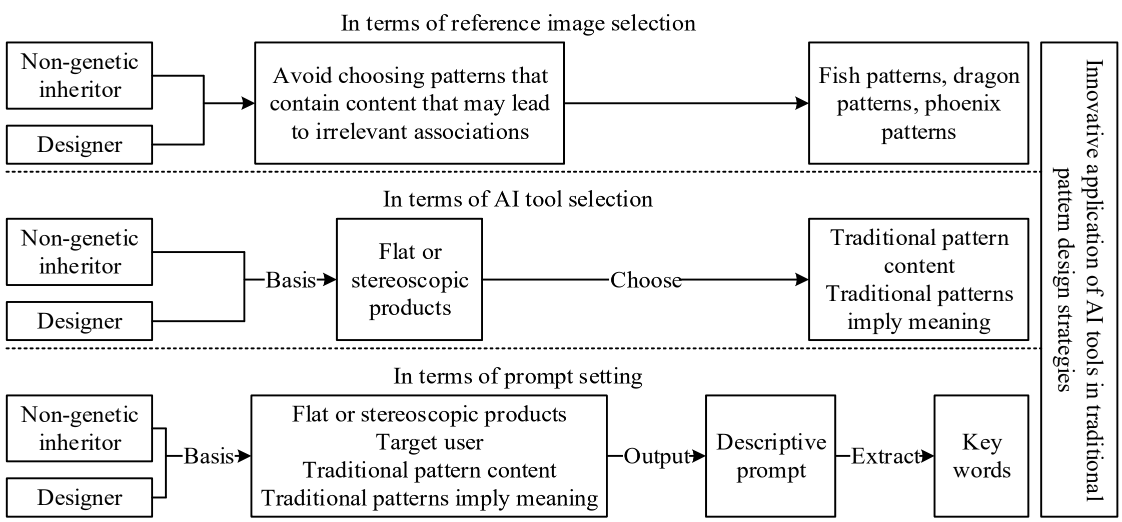

Figure 1: Graphic design strategies for intangible cultural heritage ethnic groups

(1) On the selection of reference diagrams. When utilizing AI tools for pattern innovation design, NGTs should be cautious in choosing multi-semantic patterns containing content that is easy to produce irrelevant associations as the reference chart of AI tools.

(2) In the setting of prompts. Nongenetic heritage bearers can communicate with designers to select keywords as cue words according to the design objectives, starting from the characterizing elements such as the type, style, shape, color, material, style, cultural attributes, function, target users, traditional pattern content and symbolism of the target product. As the state and society pay attention to non-heritage, more and more non-heritage databases will be established in the future, which will increasingly help non-heritage bearers and auxiliary designers to innovate using AI so as to achieve the desired goals.

(3) In terms of AI tool selection. Nongenetic bearers and auxiliary designers can choose appropriate AI tools based on the goal of designing flat or three-dimensional products. Such as when you want to get a flat pattern with painting effect, you can choose domestic AI tools. If you want to get a strong sense of realism of three-dimensional product patterns, you can choose foreign AI tools.

III. Pattern Extraction Methods for Non-Heritage Ethnic Graphics

As an important part of regional cultural genes, intangible cultural heritage plays an indispensable role in the development of outstanding traditional culture. With the rapid development of digital technology, the combination of intangible cultural heritage and artificial intelligence digitization has received widespread attention. While providing a new way of thinking for the protection and inheritance of ICH, computer technology also brings more application potential for ICH. In addition, the diversity of non-heritage culture also provides rich application scenarios for computer technology. The digitization of non-heritage has a profound cross-disciplinary connection, which realizes a revolutionary breakthrough in the digital protection and inheritance of regional cultural heritage with the help of advanced technology, and provides a wider range of choices and opportunities for the development of Chinese traditional culture.

III. A. Ethnographic Data Collection and Processing of Non-Residue Ethnographic Data

III. A. 1) Ethnographic data collection

The selected non-heritage ethnic graphics in this paper are mainly Xiangxi Miao embroidery patterns, which are mainly from the homes of some villagers in Xiangxi, China.Between June and September 2024, the research team went to Xiangxi to investigate the protection of the intangible cultural heritage of the Miao embroidery in Xiangxi and collected a total of 240 samples of the traditional patterns of the Miao embroidery from the Xiangxi area by taking photographs. The samples were photographed horizontally to minimize the effects of perspective generated by the camera lens.

After shooting to obtain sample data, the sample picture is divided into 4*4 squares containing 16 regions, and then processed into square sub-pictures with 1280*1280 resolution and aspect ratio lines. A complete large picture of Xiangxi Miao embroidery pattern can be processed into 16 sub-pictures with the same size and resolution, but with different unit patterns. When processing samples of non-heritage ethnic pictures, it should be ensured that each sub-picture is of the same size and resolution. When shooting, the sample picture area with perspective angle is eliminated to minimize the effect of perspective. The total number of available NRM picture samples after processing is 8,400, with a total of 1,576 different types of patterns, which provides data support for the pattern extraction of NRM graphics later on.

III. A. 2) Ethnographic data processing

(1) Noise Smoothing and Yarn Texture Elimination

The noise signal introduced during the acquisition of ethnic pattern images and the texture structure contained in the yarn bring inconvenience to the extraction, in this paper, a bilateral filter is used to preprocess the ethnic pattern pictures. Bilateral filter is a nonlinear filtering technique that combines the spatial distance between different points and pixel difference information. In order to achieve this purpose, the bilateral filtering algorithm combines the Gaussian filter function in the color domain and the filter function in the spatial domain, which ultimately smooths the noise while keeping the image fine color boundary information intact. The bilateral filtering algorithm is as follows:

$$I_{if}(p)=\frac{1}{W_p^{q\in N(p)}}\exp\left(\frac{-\|p-q\|^2}{2\sigma_s^2}\right)\exp\left(\frac{-\|I(p)-I(q)\|^2}{2\sigma_r^2}\right)I(q) \tag{2}$$

$$W_P=\sum_{q\in N(p)}\exp\left(\frac{-\|p-q\|^2}{2\sigma_s^2}\right)\exp\left(\frac{-\|I(p)-I(q)\|^2}{2\sigma_r^2}\right) \tag{3}$$

where $N(p)$ is a rectangular window of size $k\times k$ centered at point p, $I(p)$ represents the pixel value at point p, $I_b f(p)$ represents the pixel value output after filtering at point p, and W_p is used to normalize the output value.

(2) Tissue texture removal of non-heritage ethnic patterns

Non-heritage ethnic pattern images have many levels of structure and edges, such as pattern edges and fabric tissue structure, the tissue texture will have an impact on the accuracy of pattern extraction, so the tissue structure needs to be processed in a certain way to eliminate these effects. Common filtering algorithms, such as median filtering algorithm and Gaussian filtering algorithm, use uniform filtering parameters for all structures, which cannot ensure clear edges of the texture pattern while smoothing the tissue structure. In order to remove the image texture region while still ensuring the clarity and accuracy of the pattern structure, this paper proposes a texture filtering method based on the roll-guided filtering algorithm.

The roll-guided filter is an effective scale-aware filter, and the algorithm first removes the image tissue texture structure using Gaussian filtering, after which the original image is used as a reference to introduce the joint bilateral filtering formula to recover the blurred pattern edge structure through multiple iterations of computation. Namely:

$$G(p)=\frac{1}{K_p}\sum_{q\in N(p)}\exp\left(-\frac{\|p-q\|^2}{2\sigma_s^2}\right)I_{bf}(q) \tag{4}$$

where $G(p)$ is the output pixel value at point P after Gaussian blurring, and K_p is used to standardize the output value.

By iterative calculation, the clearness of the pattern edge structure of the picture obtained by each calculation will be better than that of the previous calculation, and the pattern edge structure of the picture can be recovered to the level of the original picture after 3~5 iterations in general. Although the blurred pattern edge information will be recovered during the iteration process, the fabric organization structure that has been completely eliminated will not be recovered.

$$J^{t+1}(p)=\frac{1}{K_p q\in N(p)}\exp(-\frac{\|p-q\|^2}{2\sigma_s^2})\exp(-\frac{\|J^t(p)-J^t(q)\|^2}{2\sigma_r^2})I_{bf}(q) \tag{5}$$

where initial J^o is the image G after Gaussian blurring and $J^t(p)$ is the pixel value at the t th iteration output map point P.

III. B. Improved Canny operator for texture extraction

III. B. 1) Canny Edge Detection Algorithm

Canny edge detection operator is a multilevel edge detection algorithm and gives the following three criteria for determining the optimal edge.

(1) Signal-to-noise ratio criterion. That is, the probability that a non-edge point is judged to be an edge point or an edge point is judged to be a non-edge point is as low as possible, and both of these 2 probabilities decrease as the signal-to-noise ratio increases. The mathematical expression for signal-to-noise ratio (SNR) is:

$$SNR=\frac{\left|\int_{-\omega}^{+\omega}G_{(-x)}f_{(x)}dx\right|}{\sigma\sqrt{\int_{-\omega}^{+\omega}f^2(x)dx}} \tag{6}$$

where $f(x)$ is the impulse response of the boundary filter, $G(-x)$ is the edge function, σ is the mean square deviation of the Gaussian noise, the larger the SNR, the higher the correct rate.

(2) Localization accuracy criterion. That is, the distance between the detected edge point and the actual edge point is minimized, and the mathematical expression of positioning accuracy is:

$$L=\frac{\left|\int_{-w}^{+w}G'(-x)f'(x)dx\right|}{\sigma\sqrt{\int_{-w}^{+w}f'^2(x)dx}} \tag{7}$$

where $G'(-x)$ and $f'(x)$ are the 1st order derivatives of $G(-x)$ and $f(x)$, respectively. The larger the value of L, the higher the positioning accuracy.

(3) Single edge response criterion. That is, the probability of a single edge generating multiple responses is as low as possible, maximizing the suppression of responses from spurious edges. To ensure single-edge response, the average distance $D_{(f)}$ of the zero-crossings of the impulse response derivatives of the detection operator should be satisfied:

$$D_{(f)}=\pi\left(\frac{\int_{-\infty}^{+\infty}f'^2(x)dx}{\int_{-\infty}^{+\infty}f''^2(x)dx}\right)^{\frac{1}{2}} \tag{8}$$

where $f''(x)$ is the 2nd order derivative of $f(x)$.

The steps of the traditional Canny algorithm are as follows:

(1) Noise elimination. The traditional Canny algorithm uses a two-dimensional Gaussian filter, in which the 1st order derivatives are utilized to convolve the original image by rows and columns respectively for noise reduction, so as to obtain a smooth non-legacy ethnic graphic image.

(2) Calculate the gradient magnitude and direction. The finite difference of the 1st-order partial derivatives of the 2 × 2 neighborhood is used to calculate the gradient magnitude $G(x,y)$ and gradient direction $\theta(x,y)$ of the smoothed image, i.e:

$$G=\sqrt{G_x^2+G_y^2} \tag{9}$$

$$\theta = \arctan(\frac{G_y}{G_x}) \tag{10}$$

(3) Non-extreme value suppression. Non-extremely large value suppression is used to exclude non-edge pixels, in which only some fine lines are retained and used as candidate edges.

(4) Lag Thresholding. The lag threshold has 2 thresholds, i.e., high threshold and low threshold. If the magnitude of a pixel position is greater than the high threshold, it is considered as an edge pixel. If the magnitude of a pixel position is less than the low threshold, the pixel is excluded. If the magnitude of a pixel position falls between the 2 thresholds, the pixel is retained only when connected to 1 pixel above the high threshold.

III. B. 2) Improved Canny operator extraction

When extracting and edge detecting ethnic graphic patterns in the process of digitizing and translating non-heritage, the selection of double thresholds needs to take into account the characteristics of the image and the application scene, and the result of the bumpiness calculation directly affects the effect of edge detection. Therefore, how to select appropriate thresholds according to different images and application scenes, and accurately calculate the degree of concavity and convexity is the difficulty of image edge detection. The traditional Canny method has a weak adaptive ability in threshold parameter selection, so it is necessary to manually set the parameters to enhance the edge detection performance of the Canny operator. Reasonable threshold can improve the detection efficiency of Canny algorithm, this paper improves the Canny operator through the bump detection method, analyzes the histogram of gradient magnitude of dynamic image, and selects the adaptive double threshold according to the image features, so as to improve the Canny operator. The Canny operator is improved by utilizing the results of concavity detection and dual threshold selection. Convexity information and dual thresholds are introduced at the stage of non-extremely large value suppression and threshold selection to enhance the performance of edge detection.

The Canny operator algorithm mainly obtains the pixel point with the local maximum gradient magnitude in the image and detects the point where the second order directional derivative of the image is over 0, which can be expressed as:

$$\frac{\partial^2 (G * I)}{\partial \theta^2} = \frac{\partial(\partial G / \partial \theta * I)}{\partial \theta} \tag{11}$$

where θ is the gradient direction, * is the convolution, G is the Gaussian function, I is the base image and ∂ is the bias.

The image has been denoised and smoothed earlier. In this section, the extreme value of the image gradient is derived for the smoothed image to determine the edges of the image.

First, the gradient magnitude and gradient direction of the smoothed image $R(i,j)$ are calculated and expressed by the formula:

$$M(i,j) = \sqrt{f_i(i,j)^2 + f_j(i,j)^2} \tag{12}$$

$$H(i,j) = \arctan[f_i(i,j) / f_j(i,j)] \tag{13}$$

where i is the piecewise derivative function of image $R(i,j)$ along the i direction and j is the piecewise derivative function of image $R(i,j)$ along the j direction, then:

$$f_i(i,j) = R(i,j+1) - R(i,j-1); f_j(i,j) = R(i+1,j) - R(i-1,j) \tag{14}$$

Non-maximum control is applied to each of the four directions of the image, and if the gradient magnitude of two pixel coordinate points next to each other in the gradient direction is less than the gradient magnitude of the pixel coordinate point, then this point is considered to be perhaps an edge point of the image. Instead, this point is removed from the edge points of the image.

Finally, the high threshold and low threshold of the gradient image are found, the high threshold is used for image edge joining, and the weaker image edge points are found in the low threshold, which are used to fill the edge gaps of the high threshold image, until the end of the process when no weak edge points can be found adjacent to the low threshold.

In a dynamic image histogram, impute 256 steps of gradient magnitude values and keep the two points of the histogram, the non-zero start point and the non-zero end point. Extrapolate the slope of the magnitude value from

i_{start} to i_{end}. The extrapolation process is done in the histogram. Then find the maximum value of the slope and the corresponding magnitude value, a bump in the gradient histogram is $[i_{peak}, h(i_{peak})]$.

The minimum convex polygon $h(i)$ of an enveloping histogram $\bar{h}(i)$ is obtained through the N convex points of the histogram and the concave value of the histogram is imputed $c(i)$, i.e.:

$$c(i) = \bar{h}(i) - h(i) \tag{15}$$

When the gradient magnitude is high threshold T_h and low threshold $T_1 = 0.4 \times T_h$, the concavity value is selected as the maximum value.

Through the above steps, the Canny operator is improved by using the concavity detection method to complete the selection of adaptive dual thresholds to realize the edge detection and extraction of non-heritage ethnic graphic images.

IV. Verification of Pattern Extraction of Non-Heritage Ethnic Graphics

In today's rapid development of science and technology, the cross-disciplinary attribute of design makes the cross-border of non-heritage culture possible. At present, in the non-heritage design project, emerging digital technologies such as virtual reality and augmented reality have begun to be widely used, which enhances the sense of experience and affinity of non-heritage. At the same time, the rapid development and popularization of intelligent generation technology has allowed artistic design creation to enter a new turning point, and its automated, quantifiable design method is conducive to making up for the lack of innovation and the shortcomings of the non-heritage culture visual design team, such as the solidification of thinking. The combination of non-heritage culture and intelligent generation technology makes the inheritance and development of non-heritage culture produce new forms of expression and artistic characteristics, and has a considerable effect on the enhancement of national cultural soft power.

IV. A. Verification of the effectiveness of the improved Canny operator

IV. A. 1) Ethnic pattern extraction accuracy

In order to objectively evaluate the extraction effect and verify the effectiveness of the algorithm, this paper adopts the pattern extraction accuracy index proposed by existing research, that is, the ratio of the number of patterns with complete edges and clear outlines to the number of all complete and effective patterns in the image. The pattern extraction accuracy index (ACC) and pixel accuracy (PA) values of the proposed method are quantitatively compared with the pattern extraction accuracy, PA value and edge detection algorithm running time obtained by using Sobel operator, traditional Canny operator, threshold based on gradient amplitude maximization between classes, Otsu threshold, adaptive Canny operator of hybrid frog jumping algorithm, and threshold calculation method of genetic algorithm based on Otsu. Table 1 shows the accuracy comparison results of the algorithm in this paper and other algorithms in extracting the patterns of intangible cultural heritage ethnic groups.

In terms of tattoo extraction effect, the number of effective extraction of tattoo samples using this paper's algorithm is 1528, and the extraction accuracy and PA value reach 96.95% and 0.971, respectively, which is significantly higher than the other five methods. This indicates that the algorithm in this paper is better than the other six algorithms in the pattern sampling extraction effect, but the use of adaptive threshold selection strategy greatly improves the operation efficiency of this algorithm. In terms of the running time of the algorithm, this algorithm is slightly slower than Otsu+Canny, BF+Otsu+Canny, SFLA+Otsu+Canny, and GA+Otsu+Canny algorithms, because the gradient magnitude-based Otsu algorithm has additional steps of noise suppression by Gaussian filters, calculation of gradient magnitude and directional maps, and non-maximum suppression of the gradient magnitude map than the Otsu algorithm. The pattern extraction task is different from road edge detection, pedestrian detection and other tasks, which do not require real-time performance, so the pattern extraction accuracy is more important than the algorithm running time. To summarize, the algorithm in this paper is superior to the other six algorithms and has better results in performing NRM ethnic pattern extraction.

IV. A. 2) Ethnic pattern extraction results

In order to further verify the extraction effectiveness of the proposed method, 12 patterns with different numbers of patterns and more distinctive pattern features are selected to detect the extraction effect of SFLA+Otsu+Canny, GA+Otsu+Canny and the method of this paper on the non-legacy ethnic graphic patterns, and the comparison results are shown in Table 2.

The experimental results in the table show that the proposed method accurately extracts a higher number of pattern geometric patterns than the other two methods, and the other two methods have more multi-extraction problems. It is calculated that the proposed method extracts 12 pattern geometric patterns with an average extraction accuracy of 97.75%, while the average extraction accuracy of the 12 patterns in the non-heritage ethnic patterns extracted by the SFLA+Otsu+Canny and GA+Otsu+Canny methods is only 89.15% and 88.07%, respectively. The extraction accuracy of the proposed method is significantly higher than that of SFLA+Otsu+Canny and GA+Otsu+Canny, which verifies the extraction effect of the proposed method on the patterns of non-heritage ethnic patterns.

Table 1: Accuracy of ethnic pattern extraction

Method	The actual number of patterns	The number of effectively extracted patterns	ACC/%	PA	Running time/s
Sobel	1576	975	61.87	0.647	2654.28
Canny	1576	1127	71.51	0.776	23.67
Otsu+Canny	1576	1243	78.87	0.875	148.52
BF+Otsu+Canny	1576	1169	74.18	0.963	4951.24
SFLA+Otsu+Canny	1576	1351	85.72	0.924	199.38
GA+Otsu+Canny	1576	1464	92.89	0.899	186.41
Ours	1576	1528	96.95	0.971	282.72

Table 2: Extraction results of different patterns

No.	Number of features	Ours	SFLA+Otsu+Canny	GA+Otsu+Canny
1	40	38	34	32
2	55	54	50	51
3	63	62	53	55
4	81	79	76	73
5	74	72	65	62
6	60	58	53	54
7	108	107	101	99
8	124	122	112	115
9	115	113	103	104
10	92	90	85	82
11	47	46	41	40
12	68	67	59	57

Based on the shooting of the non-heritage ethnic patterns usually have different degrees of interference noise, interference noise on the pattern pattern pattern extraction results have a great impact, statistics in the pattern to add 20dB interference noise when the extraction of the three methods to extract non-heritage ethnic pattern pattern extraction results, to verify the proposed method to extract non-heritage ethnic pattern pattern interference resistance, and its comparative results are shown in Table 3.

As can be seen from the experimental results, the extraction accuracy of the proposed method for extracting non-heritage ethnic pattern tattoos increases and the extraction time improves with the addition of 20dB interference noise, but compared with SFLA+Otsu+Canny and GA+Otsu+Canny methods, the extraction accuracy and the extraction time of the proposed method are still higher than those of the other two methods. The average extraction time of the 12 non-heritage ethnic patterns extracted by the proposed method is only 62.25ms, and the average extraction accuracy is as high as 98.03%, while the average extraction time of SFLA+Otsu+Canny and GA+Otsu+Canny methods is as high as 112.83ms and 134.58ms, respectively. analyzing the experimental results, it can be seen that the proposed method not only has a higher The proposed method not only has a high performance of extracting non-heritage ethnic patterns, but also can quickly extract non-heritage ethnic pattern patterns, and can still maintain a high extraction accuracy and a better extraction performance in the presence of noise interference in the pattern, which indicates that the proposed method has a high robustness of non-heritage ethnic pattern pattern extraction, and it can provide diversified pattern support for the non-heritage ethnic graphic innovation and design.

Table 3: Comparison of extraction results under 20dB interference noise

No.	Ours		SFLA+Otsu+Canny		GA+Otsu+Canny	
	Time/ms	ACC/%	Time/ms	ACC/%	Time/ms	ACC/%
1	50	97.29	82	93.83	93	92.98
2	63	98.81	100	95.38	122	94.69
3	68	98.46	97	94.99	137	93.45
4	53	97.53	103	96.17	164	93.35
5	61	97.22	102	94.65	158	94.02
6	62	96.67	105	93.02	142	93.46
7	59	99.71	107	94.94	139	93.11
8	65	98.78	128	95.73	131	92.46
9	72	98.96	136	95.45	136	94.09
10	67	97.15	129	94.68	127	94.73
11	63	97.23	131	93.56	135	92.22
12	64	98.52	134	96.16	131	94.44

IV. B. Example Analysis of Ethnic Pattern Extraction Applications

IV. B. 1) Expert Scoring of Pattern Extraction

In order to further illustrate the effectiveness of the method of this paper, the core factors of Xiangxi Miao embroidery ethnic graphic patterns are extracted based on the Xiangxi Miao embroidery ethnic graphic patterns dataset obtained in the previous paper. Firstly, 10 descriptive words will be given according to their characteristics and roles, and then 60 design students will be researched, and all the descriptive words will be screened at an important level with the help of a five-point scale. Comprehensively analyzing the data, it is found that the mean value of the words of era (M1), inheritance (M2), aesthetics (M3), artistry (M4), and novelty (M5) are higher, so these words are used as the references for the selection of patterns. The pattern factors that can be extracted from Xiangxi Miao embroidery ethnic graphics are numbered, and 12 industry experts (6 design professors, 3 product designers, 3 practitioners related to Miao embroidery craft) are organized to score the main visual element types of Xiangxi Miao embroidery ethnic graphic patterns extracted by the algorithm through the scoring method using the core vocabulary screened above as a criterion, and their final results are shown in Table 4.

The expert scoring results show that “combination pattern” is the most representative Xiangxi Miao embroidery ethnic graphic pattern element, and its average score reaches 90.51 points, which is 7.00%, 8.80%, and 16.40% higher than the average score of single flower, landscape, and human figure patterns, respectively. Based on the data results of user research, a series of combined pattern types of Xiangxi Miao embroidery ethnic works were selected as the initial model for design, and the graphic denoising was carried out by using rolling bootstrap filtering, so as to make it scientifically and intuitively represent the graphic contour. The extracted pattern factors are combined with modern aesthetics to reason and evolve, so that the traditional pattern modeling factors and modern aesthetic elements are harmoniously blended, and a new graphic is obtained that has the characteristics of Xiangxi Miao embroidery national graphic art and meets the aesthetics of modern design.

Table 4: Expert scoring results on the selection

Pattern type	Average score of experts					Average score
	M1	M2	M3	M4	M5	
Combined	89.51	92.43	93.65	89.23	87.74	90.51
Flower	92.06	81.57	83.79	82.54	83.01	84.59
Landscape	83.48	84.09	86.32	83.98	78.06	83.19
Character	83.79	76.34	78.51	76.34	73.82	77.76

IV. B. 2) Ethnic graphic design assessment

Based on the graphic patterns of Xiangxi Miao embroidery extracted by the improved Canny operator, and then combined with the results of expert scoring to carry out the innovative design of Xiangxi Miao embroidery ethnic graphics. In order to verify the validity of this design, 50 senior design major background students, who had no contact with the experimental materials before the experiment, were selected and divided into 2 groups of 25 each according to the test requirements, and all the subjects were free of color blindness and color retardation, and had normal corrected visual acuity.

The materials used in this test are the innovative design results of Xiangxi Miao embroidery ethnic graphics. In this experiment, the control group saw the results of Xiangxi Miao embroidery graphic design based on the traditional method, and the scheme was labeled as S1. The experimental group saw the results of Xiangxi Miao embroidery graphic design based on the method of this paper, and the scheme was labeled as S2. After completing the experimental operation, they filled in the NPS scale (1-10 points), which mainly included the satisfaction with the design result, the satisfaction with the visual experience, the willingness, and the aesthetics, and objectively evaluated their experience during the experiment. , objectively evaluating their experience in the experimental process.

The questionnaire design for the evaluation of Xiangxi Miao embroidery ethnic graphic design experience first invited three associate professors and three doctoral students to pre-test the questionnaire, and they assessed the usefulness, validity and wording of the questionnaire variables. At the same time, a combination of online and offline methods were used to conduct a simple reliability and validity test and to revise and improve the questionnaire. The questionnaires were formally distributed after the reliability and validity tests to obtain questionnaire data for subsequent data analysis. After removing invalid questionnaires, 22 valid questionnaires were collected from each group, totaling 44 questionnaires. By using Excel and SPSS and other software for data processing, combined with quantitative data for t-test analysis, the main conclusions of the study were finally obtained. The results of the t-test analysis of the test data of Scheme S1 and S2 are shown in Table 5.

It can be seen from the table that by using the t-test to study the differences between Scheme S1 and Scheme S2 in the four aspects of "satisfaction with the work", "satisfaction with the overall process experience", "willingness" and "aesthetics" in the ethnic graphics of Xiangxi Miao embroidery designed by different methods, it can be seen that the two schemes show significant differences in all four aspects ($P<0.01$). Moreover, the average comprehensive score of Scheme S2 was 8.39±1.21 points, which was 3.82 points higher than that of Scheme S1, and there was still a significant difference ($P<0.01$). In conclusion, the improved Canny operator presented in this paper can accurately extract the characteristics of ethnic graphic patterns in Xiangxi Miao embroidery and apply it to the innovative design of ethnic graphics. This effectively enhances users' satisfaction with ethnic works and improves their experience satisfaction. In the future, they will be more willing to continue to experience traditional culture through this method.

Table 5: Analysis results of t-test of data

Item	Scheme S1	Scheme S2	t	P
Design results satisfaction	4.21±1.48	8.21±1.05	9.574	0.000
Visual experience satisfaction	4.49±2.05	8.42±1.17	8.636	0.002
Willingness	5.23±1.94	8.57±1.09	6.593	0.001
Aesthetics	4.36±2.27	8.35±1.38	6.485	0.000
Comprehensive assessment	4.57±2.16	8.39±1.21	8.471	0.000

V. Conclusion

In the pattern extraction method based on improved Canny operator proposed in this paper, the processing results of Xiangxi Miao embroidery patterns show high extraction accuracy. Through experimental verification, the accuracy of the pattern extracted using this method reaches 96.95%, which is significantly better than other methods in the comparison of several different algorithms, and also maintains a high efficiency in processing time. In practical applications, the method in this paper also shows excellent anti-interference ability when dealing with interference noise, and can still maintain high accuracy under 20dB noise interference, with an extraction accuracy of 98.03%. In addition, through expert scoring and user experience evaluation, the ethnic graphics designed by this paper's method are highly evaluated in terms of artistry, contemporaneity, and aesthetics, with a comprehensive score of 8.39±1.21 points, which is 3.82 points higher than the traditional design scheme. This result proves that the innovative program of non-heritage ethnic graphic design based on AI technology can not only accurately extract the characteristics of ethnic patterns, but also improve the user's satisfaction with the design work. In the future, AI-assisted design will play a more important role in non-heritage cultural inheritance and innovation.

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