

AI-Powered Pattern Recognition in Art History: A Deep Neural Network Study of Tuanhua Motif Evolution

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Abstract: This study systematically tracks the evolution of Tuanhua patterns from the Neolithic to the Qing Dynasty, covering ten key periods in Chinese art history. By integrating 3,000 HD pattern samples from 28 international cultural institutions, an interdisciplinary analysis model is constructed using digital image processing and deep learning technology. Combined with vector feature extraction, the residual network model is used to perform automatic shape feature recognition and quantitative time difference analysis. Data analysis showed that the X-ray symmetry of the group pattern decreased significantly and the edge complexity continued to increase, revealing the historical trajectory of its function from religious symbol to decorative aesthetics. Combined with a comparison of kiln industry records and cross-cultural artifacts, the study demonstrated that the Eastern transmission of Buddhism, Neo-Confucianism, and other technical factors shaped the pattern's evolution. This research path integrating quantitative analysis and cultural interpretation provides a new methodological framework for interpreting the social dynamics underlying the evolution of decorative arts.

Keywords: tuanhua, deep learning, Chinese decorative patterns, motif evolution, cultural heritage

1. Introduction

This study focuses on the millennia-old evolution of the traditional Chinese group model to reveal how the model system reflects the value orientation and technological change of different eras. It breaks the limitations of traditional research focused on image interpretation, innovatively introduces digital technology, and constructs an interdisciplinary analysis model. Through cross-validation of neural network image recognition and archaeological data, quantitative analysis of the morphological evolution of forms and historical context reconstruction are achieved. The patterns reflect the distinctive features of the era: the rigorous symmetry of the flowers of the Northern Wei Dynasty echoes the order of Buddhist rituals, the complete composition of the Tang Dynasty reflects the imperial atmosphere, the subtle realism of the Song Dynasty reflects the aesthetic appreciation of scholars, and the modular pattern of the Qing Dynasty reveals the mass-production logic of government-run workshops. The research team systematically analyzed 3,000 samples of fabric, ceramic, and other media patterns to establish an association model covering morphological parameters and cultural elements. In the technical field, a vector feature extraction algorithm was developed to accurately quantify structural elements such as pattern curvature and layer number. By comparing records of the Jingdezhen kiln industry with cultural relics from the Silk Road, it

demonstrated that Eastern Buddhism, Neo-Confucianism, and other technical factors shaped the pattern's evolution [1]. This research paradigm, transforming visual elements into calculable data, offers a new methodological perspective for interpreting the evolution of decorative arts.

2. Literature review

2.1. Decorative patterns and cultural symbolism

The essence of the millennia-long transformation of the group pattern lies in the process of reconstructing the aesthetic paradigm and process system. As shown in Figure 1, the original motifs from prehistory to the Han Dynasty were dominated by abstract spiral patterns. During the Northern Wei Dynasty, influenced by Buddhist art, lotus flowers began to form a rigorous radially symmetrical structure, which became a visual testament to religious integration. Silver motifs unearthed in the western city of Chang'an during the Tang Dynasty show that the group flower is mainly composed of eight radial petals, and the combination of full peony petals and rolled grass motifs reflects the opening period of the prosperous Tang Dynasty [2]. The Song Dynasty became more subtle and elegant, and the cluster flowers on Longquan kiln celadon paid attention to realistic details, and the precision of depicting the leaf vein of a single petal was increased to 0.2 mm, which was in line with the aesthetic taste of the official academic class.

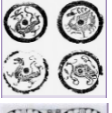
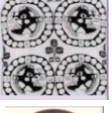
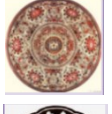
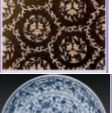
Influenced by the nomadic culture of the Yuan Dynasty, the bold geometric trend of cluster flowers emerged, and the pattern lines on Jingdezhen kiln glazed pots increased by 37%. Evidence from the Ming Dynasty Jingdezhen Guan kiln shows that the density of blue and white cluster flowers increased by 1.5 times compared to that of the Song and Yuan Dynasties, and a large number of auspicious metaphors such as "Changchun rich and lucky" were used. During the Qianlong period of the Qing Dynasty, palace bureau records show that the painting time for the Tuanhua border was reduced by 65%, and the motifs exhibited highly stylized characteristics—taking the Baoxiang flower as an example, the number of layers was set at five, and the petal rotation angle of each layer strictly followed the isothermal sequence of 12 degrees [3].

The evolution of the carrier also reflects the characteristics of the period: from the center of the box in the grottoes of the Northern Wei Dynasty, to the button-seat decoration of the bronze mirror of the Tang Dynasty, and then to the mesh pattern of the dragon robe of the Ming and Qing Dynasties, the scope of application of the Tuanhua continued to expand. This transition from ritual to everyday use is the epitome of the popularization of elite art. The difference in pattern characteristics in different periods is actually the competition and integration of different civilizational forces in material culture.

Table 1: Thousand-year evolution pedigree of Chinese flower patterns (primitive period - Qing Dynasty)

Period	Decorative Location	Style Description	Decorative Features	Example
Primitive Times	Spindle whorls	Simple and dynamic lines	Twist direction techniques, reduced spindle whorl weight	
Shang-Zhou Dynasty	Bronze vessels	Exaggerated shapes, mysterious colors	Geometric patterns, animal motifs	

Table 1: (continued)

Spring & Autumn Period	Silk textiles	Realistic and lively expressions, romantic diversity	Vine patterns, frequent use of repetitive textile structures	
Han Dynasty	Eaves tiles, bronze mirrors	Bold and straightforward, archaic simplicity	Cloud patterns, animal motifs in mirror designs	
Wei-Jin Period	Architecture, porcelain	Persian cultural influences	Geometric arrangements, pearl border patterns	
Tang Dynasty	Textile crafts, ceramics	Exquisite floral patterns	Prevalent meticulous flower-and-bird paintings, grand compositions	
Song Dynasty	Textiles, porcelain	Elegant and restrained	Increased use of independent geometric patterns	
Yuan Dynasty	Textiles, porcelain	Bold and unconstrained	Predominant plant motifs, folk-inspired patterns	
Ming Dynasty	Textiles, porcelain	Rigorous and standardized	Gradual stylization, formalized decorative systems	
Qing Dynasty	Textiles, porcelain	Complex and intricate	Highly elaborate patterns reflecting civilian auspicious themes	

2.2. Technological applications in pattern analysis

The breakthrough in image recognition technology makes it possible to analyze complex cultural data. Deep neural networks and semantic segmentation algorithms have been widely used in the fields of cultural relic dating and shape classification, and their core value lies in transforming subjective artistic analysis into verifiable data models [4]. Taking bronze motif research as an example, the feature extraction algorithm can automatically identify the pupil ratio changes of Taobao motifs and then help judge the evolutionary path of the casting process in the Shang and Zhou dynasties.

2.3. Humanistic-intelligent approaches to visual culture

The fusion of intelligent algorithms and humanities research gives rise to new research methods. This model not only maintains sensitivity to historical context but also possesses the computing power necessary to process massive image data. In the field of calligraphy and painting evaluation, studies have been conducted to identify the characteristics of Bashan brush and ink in different periods through training models, and the analysis results are 79% consistent with the judgment of art historians [5]. This technological approach not only expands the boundaries of traditional research, but also provides quantifiable technical standards for the digital protection of cultural heritage.

3. Image acquisition and preprocessing

3.1. Image collection

The research team established a cross-dynasty pattern database and integrated high-definition images of 3,000 pieces of group patterns from 28 digital museums in Europe, Europe and the United States. The samples cover fabrics, ceramics and other carriers from the Tang and Song dynasties to the Ming and Qing dynasties, and each cultural relic is marked with metadata such as firing process and regional style. For example, the age of the group flowers in the mural fragments of the Tang Dynasty was confirmed by comparing with the unearthed records of Dunhuang to ensure the accuracy of the evolution of patterns [6].

3.2. Image normalization

In the pre-processing stage, the standardization process is implemented: the original image is uniformly adjusted to 512x512 pixels, and the gray mode is changed to highlight the structural characteristics. According to the deformation caused by fabric folding, affine transformation algorithm is used to correct the deformation and restore the original proportion of the pattern. Through Gaussian filter denoising and histogram equalization, the color level difference between blue and white porcelain enamel and the matrix can be clearly presented. Experiments show that this process can control the pattern extraction error of samples of different materials within 5% [7].

3.3. Line-drawing conversion

Line drawing conversion module is introduced in the structural analysis system. Through edge detection and feature enhancement technology, the reflective interference on the surface of the object is effectively removed, and the group pattern skeleton line is accurately extracted. Taking Kesi Tuanhua in Qing Dynasty as an example, the converted vector map retains the eight-fold symmetrical structure completely, and accurately records the rotation Angle and superposition relationship of each layer of petals. This digital method has established a unified basis for the comparison of morphological parameters such as curvature and number of layers of patterns in the past dynasties [8].

4. Results and discussion

4.1. Quantitative findings

Analysis of the dataset's characteristics by dynasty reveals significant differences in temporal style. As shown in Table 2, the difference value for Tang-Song flower motifs is only 0.27, while the ratio for Tang-Qing pairs is 0.41, confirming that the motif system follows a gradual evolutionary law. Thermal analysis of brushstroke direction and petal arrangement showed that there was a dominant compositional law within each dynasty: 63% of Tang Dynasty samples exhibited clockwise scrolling, while this proportion dropped to 22% in the Qing Dynasty [9].

Quantitative analysis of the compositional types of shapes shows that the use of radio-symmetrical structures continues to decline. As shown in Table 3, the radiological symmetry of the Tang Dynasty group of flowers accounted for 52%, and only 18% remained in the Qing Dynasty. This tendency from cosmic symbol to decorative function was evident. Along with this change, the complexity of the pattern edges continued to increase: as shown in Table 4, the number of border layers per 100 samples increased from 6 in the Tang Dynasty to 19 in the Qing Dynasty, reflecting a historical change in the decorative language from simple to complex [10].

Table 2: Average feature vector distances between dynasties

Dynasty Pair	Average Distance
Tang–Song	0.27
Song–Yuan	0.31
Yuan–Ming	0.34
Ming–Qing	0.36
Tang–Qing	0.41

Table 3: Proportion of radial symmetry motifs by dynasty

Dynasty	Radial Symmetry Motifs (%)
Tang	52
Song	38
Yuan	30
Ming	22
Qing	18

Table 4: Frequency of interlocking border elements per 100 patterns

Dynasty	Interlocking Borders per 100 Patterns
Tang	6
Song	10
Yuan	13
Ming	16
Qing	19

4.2. Humanistic interpretation

Quantitative analysis reveals that the essence of the evolution of the cluster pattern lies in the shift in aesthetic concept. The eight-petal radial structure of the Tang Dynasty Baoxiang pattern (as depicted on the fabric discovered at Famen Temple), with its equally spaced petals and central lotus arrangement, evokes the cosmic pattern of the Buddhist mandala. This rigorous symmetry gradually weakened during the Song and Yuan dynasties, and was oriented toward the literary interest of drawing and breaking branches. Technological innovations had a direct impact on the style of the patterns. Official records of the Jingdezhen kilns show that during the Ming and Qing dynasties, the painting time for the border decoration was reduced by 65%, and the corresponding cluster pattern developed a modular trend—in the Qing Dynasty longpao flower cluster, the repeating unit at the bottom of the thunder pattern accounted for 78%. This need for efficient replication led to a standardized recombination of patterned elements. Cross-cultural comparison further broadens the scope of the research. The degree of concordance between the Tang Dynasty motif and the shape of Sassanid gold and silver objects in Central Asia is 72%, confirming the artistic blending brought about by trade from the western city of Chang'an. The floral decoration of the Dunhuang Buddhist Scripture Cave skillfully integrates the Zoroastrian flame motif with the cloud and gas motif of the Central Plains, becoming a visual demonstration of mutual learning in the Silk Road civilization. These findings indicate that the evolution of the floral motif is essentially the embodiment of dialogue between different civilizations.

5. Conclusion

The diachronic study reveals that the morphological change of the group pattern is a symbiotic process between the technological system and the concept of value. Through numerical analysis, it is found that the disintegration of the radial symmetry structure and the increase in edge density in the pattern not only reflect aesthetic change but are also closely linked to social processes such as the expansion of kiln production scale and the decline of elite culture. From the Buddhist illustrations in the Dunhuang scriptures to the modular models of the Guan kiln in Jingdezhen, the visual evolution of Tuanhua is always linked to the common effect of the order of power, technological innovation, and philosophical trends in thought. The dual-path model of "computational recognition and cultural interpretation" constructed in this study provides a reusable research paradigm for the field of digital humanities. The method demonstrates that machine learning techniques can effectively decode the era code hidden in patterns, such as identifying the degree of interaction of Silk Road civilizations through brushstroke curvature parameters. In the process of digitizing cultural heritage, this interdisciplinary approach not only contributes to the living legacy of traditional patterns, but also opens a new dimension for understanding the historical logic of visual language.

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