A National Pattern Generation Method Based on Cultural Design Genetic Derivation

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Abstract. It is a great challenge to digitally generate emotionally satisfying patterns with national style characteristics to meet diversified consumer demands for national patterns. As the core of national culture's gestation, growth and development, cultural genes can realize cultural inheritance and maintain national identity. From the view of design, the basic feature elements of cultural genes are extracted by original national pattern deconstruction and semantically summarized to form specific cultural design genes suitable for the rapid design of national pattern. Further, the topology principle and Computer-Aided design is introduced to simultaneously generate pattern shapes using Self-Crossing and Cross-Crossing transformation by shape grammar. Then, the pattern elements are arranged according to the initial ethnic pattern composition rules to generate new series of ethnic patterns. Finally, Chinese Tibetan pattern is patterned as an example to demonstrate that this research can creates patterns faster and in line with the user's intent.

Keywords: National pattern · Cultural design gene · Pattern deconstruction · Shape grammar · Computer-Aided design

1 Introduction

With "shape" and "semantic" features, the national pattern is a continuation and formalized expression of minority culture, mirroring the cultural characteristics and historical changes of ethnic minorities [1]. As products of the times, national patterns should have national characteristics, conform to the "shape" aesthetics of modern society, and also satisfy consumers' intention. Nowadays, the demand for national patterns is growing rapidly, while the design of national patterns is time-consuming and laborious, which generates obvious contradictions between design and fast-paced consumer market [2]. Drawing the pattern based on the designer's own experience and knowledge is complicated and inefficient. Although computer-aided design can help draw pattern outlines to reduce workload, the derivative design and reuse of patterns still need to be completed by designers, with a lack of cultural depth [3].

In the perceptual consumption era, it is of vital importance to extract core connotation of national culture and apply it to pattern to shorten national pattern design cycle and accelerate its success in market [4]. In this paper, we attempt to decompose the original ethnic patterns from the perspective of cultural semantics, and extract the

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design features of the cultural genes that match the user's intentions as the cultural design genes. Further, we transform the process of generating new national patterns into the derivation design of cultural design genes by shape grammar. In addition, we take the Chinese Tibetan pattern as an example to carry out the derivative design research of ethnic patterns, which verifies the effectiveness of this method.

2 Cultural Design Gene Theory

2.1 Cultural Gene

Culture is the crystallization of human collective wisdom. It has different cultural features in different periods, different regions and different races. The development of culture is similar to the process of biological evolution, with characteristics such as inheritance and diversity. Cultural genes are the iconic cultural characteristics of culture that have not been buried for thousands of years. Different from biological genetics, it depends on human, social, and physical factors. Its form can be expressed as: decorative ornament, architectural style and custom. Regarding the theoretical study of cultural genes, Schipper [5] first proposed the concept of cultural gene pool and advocated the establishment of cultural gene pools. Zhao [6] constructed a cultural gene pedigree by deconstructing the intangible cultural genes and material cultural genes in regional culture. Starting with cultural genes Bao [7] explored the development background of Eastern and Western cultures, and compared the thinking and science of East and West. Therefore, cultural genes have realized cultural inheritance and maintained the sense of national identity, which is the core of the birth, growth and development of national culture.

2.2 Cultural Design Gene

Cultural design genes are a manifestation or a basic characteristic element that can be applied to design expression, and it is a core cultural feature extracted from cultural genes [8]. Professor Yair [9, 10] of Sheffield Hallam University in the United Kingdom studied how to extract the cultural characteristics of patterns such as shapes, contours and textures from traditional tin handicrafts from the perspective of applied culture and genetics. Lin [11] in Taiwan University of the Arts studied the cultural characteristics of Taiwan's aborigines, extracted cultural design genes from their living utensils, and applies them to modern design. Wang [12] in Shaanxi University of Science and Technology in China studied the composition of the triangle pattern of ancient Chinese Ban-Po painted pottery. Through the design, the traditional pattern was standardized and unified, and the inheritance of Ban-Po painted pottery culture was realized. Cultural design genes are the basic feature extraction and semantic induction of cultural genes from the perspective of design. Its purpose is to extract cultural connotation features and apply them to design activities. This paper will deeply interpret the cultural design genes from four dimensions: Semantic dimension, User dimension, Composition dimension and Environmental dimension (Fig. 1) [13].

- Semantic dimension: Cultural design genes have dominant semantic and implicit semantic. Dominant semantic refers to the ontological characteristics of cultural design genes, and the implicit semantics reflect the cultural connotation and spiritual symbol of cultural design genes.
- Composition dimension: Studying the Semantic Dimensions of Cultural Design Genes and the Compositional Rules of Cognitive Combinations.
- Environmental Dimensions: Cultural Design Gene Source Environment and Cultural Design Gene Reuse Environment.
- User dimension: the cultural background of designers and users and the user's thinking mode.

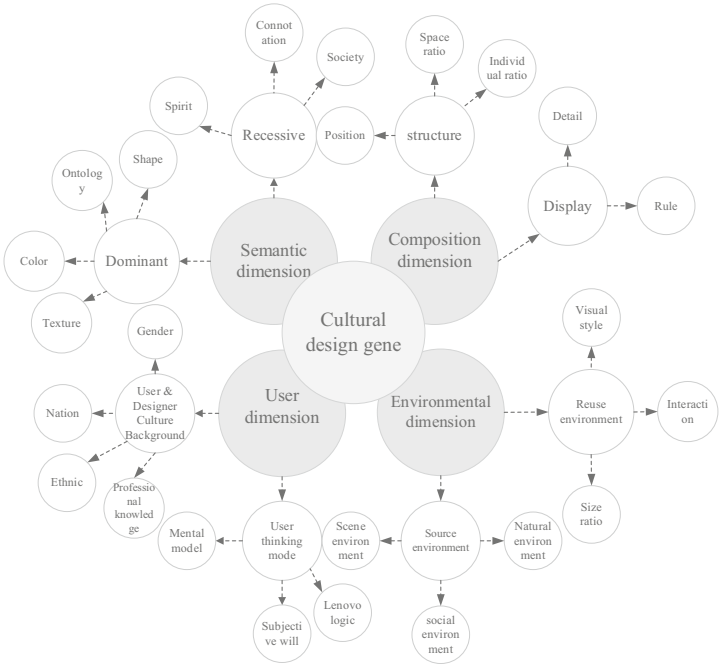

Fig. 1. Cultural design gene interpretation 4 dimensions

3 Pattern Deconstruction Description

3.1 Hierarchical Expression Model

The national pattern itself is highly standardized, and usually arranged by a series of hierarchical elements in a certain proportion, rule, size, and direction. In order to improve the efficiency of national pattern derivation and make its innovative design process intelligent, this paper introduces the conceptual relationship of "national pattern", "pattern primitive", "pattern primitive" and "cultural design gene" (Fig. 2) [14].

The national pattern can be deconstructed into various levels of concept, and the national pattern design can be finally classified into a derivative design based on the cultural design gene.

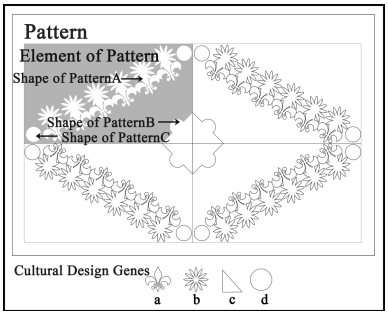

Fig. 2. Example of a hierarchical expression model of a pattern

Definition 1. A pattern with unique ethnic art style, decorative, and well-structured pattern passed down from a nation's dynasties is called national pattern.

Definition 2. The smallest independent information unit in a national pattern that needs to be transformed according to the composition rules is called a pattern element. The national pattern may be composed of one or more pattern elements, and the pattern element may generate a new national pattern according to the composition rules of the initial national pattern.

Definition 3. The so-called pattern shape refers to the shape formed by the cultural design gene derivative design. Different pattern shapes are arranged according to different coding rules to jointly form pattern elements. The pattern elements can be composed of one or more pattern shapes.

Definition 4. Cultural design genes are the smallest structural units that can be used in design, and have a cultural heritage. It has the characteristics of stability, inheritance, culture and indivisibility. One or more cultural design genes can be derivatized to form a pattern shape.

3.2 Pattern Deconstruction Principle

Chinese traditional aesthetics pays attention to the "neutral beauty". Traditional patterns often contain multiple elements. Therefore, it is necessary to decompose the original patterns, simplify the constituent elements, remove the extra decorative parts of the pattern main body pattern, and preserve the main meaning related to the pattern meaning. For the deconstruction and reuse of national patterns, Wang [15] deconstructed the Han costume culture from four aspects: color, form, ornamentation and recessive design factor, and carried out factor extraction and reuse research. Zhao [16] decomposed the Xinjiang national carpet pattern into three types of corners, the main body and the frame, and realized the innovative pattern by adjusting the content and structure of the pattern. Cui [17] integrated the shape grammar into the Zhuang

embroidery design system, and divided the Zhuang embroidery pattern into three categories: single stem, double stem and quadruple stem, and decomposed the shape grammar into two stages: the rough stage and the precise stage. Prats [18] proposed four shape description methods: contour, decomposition, structure, and design. He claimed that specific deconstruction can be used to identify shapes and analyzed their properties. One of the key methods for deconstructing national patterns is to make bold choices for the national patterns containing more cultural elements, to understand the cultural connotations, then to take the essence of them, to maintain the semantic and visual language of the symbols. The key to In-Depth deconstruction of ethnic patterns using "pattern" - "pattern elements" - "pattern shapes" - "cultural design genes" hierarchy concept is the establishment of cultural design genes. (Fig. 3, show examples), the end point of deconstruction is the cultural design gene, which is the smallest structural unit with cultural symbolic meaning. Its morphological structure is relatively stable and cannot be further decomposed. This method effectively helps designers avoid subjective amplification in complex national pattern deconstruction and affects the objectivity of cultural design gene extraction work.

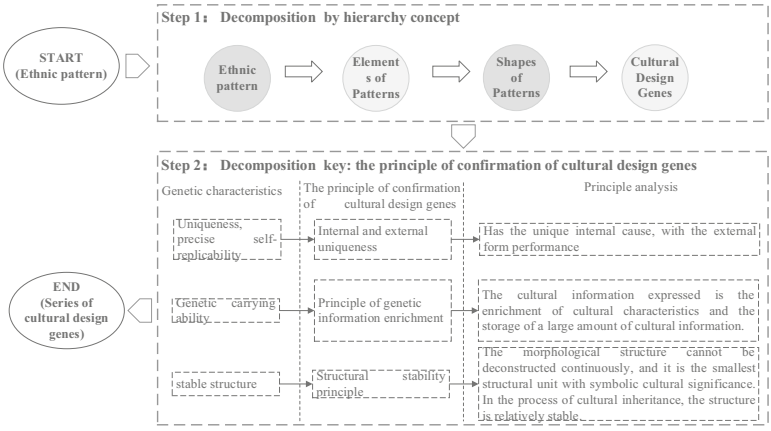

Fig. 3. National pattern deconstruction guide

3.3 Cultural Design Gene Extraction Principle

After deconstructing ethnic patterns at a hierarchical level, how to effectively extract the deconstructed cultural design genes as the initial cultural design genes derived from the new national pattern design is the focus of national pattern design research. Gou [19] studied the culture of Ban-Po pottery, and adopted the gene extraction method based on genetic theory of Ban-Po pottery culture. Liu [20] used quantitative methods to extract four cultural design factors: window, cave, color and implication, constructed the extraction model of Jiangnan garden culture factor, and scientifically extracted the design elements with recognition. As a visual symbol carrier for transmitting national information and transforming into a visual image, the cultural design gene is used to describe the pattern of the national pattern on the one hand, and to bind the national

pattern with the corresponding cultural semantics on the other hand, so the culture extraction of design genes should have the following principles:

(1) Comply with the user's semantic intent. Based on the user's intention, the cultural design genes containing the user's desired cultural semantics are extracted from the deconstructed cultural design genes by the national pattern, so that the information can be expressed more quickly and clearly.
(2) Meet the user's usage intention. The extracted cultural design genes should conform to the use environment of the new ethnic pattern and conform to the user's aesthetic.

3.4 Deconstructive Description of Tibetan Patterns

The Tibetan pattern has a long history and a wide variety of forms. It embodies the profound essence of the Tibetan people and is the perfect combination of art, culture, aesthetics and religion. According to the performance theme, Tibetan patterns can be divided into geometric patterns, animal print patterns, plant pattern patterns, natural sky patterns and Buddhist patterns. Patterns with different symbolic meanings also have corresponding usage scopes. As an aesthetic symbolic language, Tibetan patterns are created to convey specific concepts and emotions, and have symbolic and emotional characteristics. This research takes the Tibetan pattern wisdom sword as an example to carry out the pattern deconstruction description, deconstructs it hierarchically to the cultural design gene with symbolic semantics, and describes it from semantic dimension and context dimension (Fig. 4, show examples). In essence, Tibetan art is a kind of religious art. The image itself is meaningless while the metaphor behind the image is

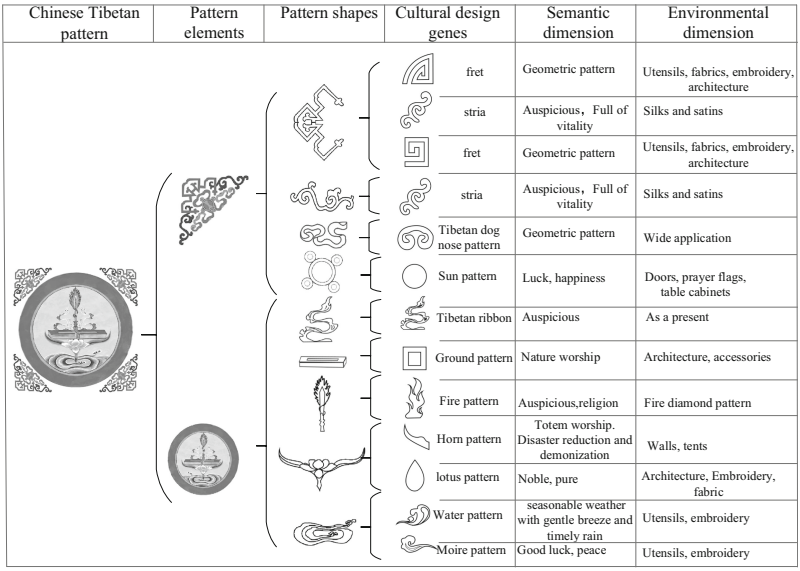

Fig. 4. Deconstructive description of Tibetan patterns

the real intention, such as the symbolic meaning of lotus in Buddhist art. "The Lotus Flower" is a metaphor for lotus, symbolizing the elegance of teaching, and the Bodhisattva image also holds lotus, symbolizing the noble and pure Dharma. "Wisdom Sword" represents Tubo Zanpu Chisong Dezan, who is regarded as the incarnation of Manjushri with the ignorant. Symbolic carriers generally contain deep meanings, which are both normative and customary.

4 Cultural Design Gene Derivation Based on Shape Grammar

In the era of intelligent design, national pattern design will face two problems: 1. How to use the cultural design genes to quickly generate ethnic patterns in accordance with consumer intentions, to meet the diverse needs of consumers for national patterns. 2. How to maintain the continuity and consistency of the digital design of national patterns. In the design research process, it can be found that the same rules and morphological elements can produce a plurality of patterns with similar style images, which is an effective way to solve the above problems. As a derivative design method, shape grammar plays an important role in national pattern design analysis, deconstruction, reuse, and style inheritance.

4.1 Shape Grammar

The shape grammar was first proposed by George Stiny and James Gips, which was originally used in the field of architecture and sculpture, and later extended to the fields of pattern design and industrial design [21]. According to Stiny's definition of the shape grammar, the shape grammar can be represented by a quad $SG = (S, R, L, I)$. Here $S = \{s_1, s_2, s_3, \ldots, s_n\}$ that represents a finite set of shapes. $R = \{r_1, r_2, r_3, \ldots, r_q\}$, which is a finite set of shape inference rules containing the following specific inference rules: $r_1 \leftarrow$ *Replacement*, $r_2 \leftarrow$ Additions and deletions, $r_3 \leftarrow$ *Scaling*, $r_4 \leftarrow$ *D*uplicate, $r_5 \leftarrow$ *Rotating*, $r_6 \leftarrow$ *Shear*, $r_7 \leftarrow$ Coordinate change. The inference rule r is expressed as: $a \rightarrow b$, where a is the shape inference starting shape and b is the ending shape, $a \subset S \cup L$, $b \subset S \cup L$. $L = \{l_1, l_2, l_3, \ldots, l_m\}$, which is a finite set of markers with shape style features, s.t. $S \cap L \neq \emptyset$. I = $\{i_1, i_2, i_3, \cdots, i_q\}$, which is a finite set of initial shapes, s.t. $I \subset S \cup L$.

Shape grammar is a rule-based morphological derivative design method. The graphics of architecture, machinery and other industries are mostly composed of modular parametric graphics. The grammar rules are simple and easy to construct, but for art pattern design, the pattern is complicated and difficult. Therefore, there are few studies using shape grammars for design. Cui [22] believed that shape grammar has good potential in the design and application of art and culture. Based on the shape decomposition method, in the application of Zhuang embroidery, the Two-Level shape grammar with coarse level and refined level has been developed to improve the efficiency of the national pattern generation system. Based on the shape grammar, Zhang studied the rules of drawing and modeling elements in Tibetan Thangka art, trying to explore the

aesthetic standards of Tibetan culture and provide significant guidance for current design [23]. Cui [17] investigated Yunnan national embroidery, and analyzed the characteristics of national embroidery through decomposing the curve embroidery patterns in different colors using shape grammar, and realized the automatic generation of new patterns. Sayed [24] used a parametric shape grammar to design Islamic geometric patterns.

4.2 Tibetan Culture Design Gene Derivation Design

The design process of national pattern can be regarded as the process of derivation of cultural design genes. Designers can create pattern shapes by manipulating the "dominant" and "recessive" patterns of cultural design genes. "dominant" refers to the design features that cultural design genes can be visualized, while "recessive" refers to the images, emotions, and spirits reflected by the design motifs. In the shape grammar, the dominant feature of the cultural design gene can be regarded as the initial shape, a new series of pattern shapes generated after limited rule processing. In the research, the Tibetan design is taken as an example to extract the cultural design genes of Tibetan patterns through the user's semantic intentions and using intentions. Suppose the user needs to design a picture that reflects the vitality, purity and beauty of nature. The cultural design genes extracted through screening include: the "stria" and "lotus petals" culture design gene. Then:

$SG = (S, R, L, I)$

$S = \{s_1, s_2, s_3, \cdots, s_n\}$, represents the pattern shapes.

$$R = \left\{ \begin{array}{l} r_1 \leftarrow \text{replacement}; r_2 \leftarrow add, delete; \mathrm{r}_3 \leftarrow scaling \\ r_4 \leftarrow duplication; r_5 \leftarrow rotation; r_6 \leftarrow \text{superposition} \\ r_7 \leftarrow coordinate, changes \end{array} \right\}$$

$L =$  ,

Where "  " represents the smallest rectangular boundary of the cultural design gene shape; "_____" indicates the length and width of the cultural design gene. The intersection of the two dashed lines uses the red dot "  " to indicate the center point of the gene shape, representing the relationship between the shape rule operation of the cultural design gene and the space.

$I =$ 

When we consider shape grammar as a design method, we can combine a limited initial shape set with the rules in the rule base to generate an infinite shape terminal instance to show the style continuation of the design. On this basis, this paper introduces biological theory and uses two main derivation rules (Self-Crossing and Cross-Crossing transformation) to generate Multi-Patterned shapes. The advantage of this is to ensure that the cultural design gene is the smallest unit of pattern design, and the national pattern design can be regarded as the derivative design of the cultural design gene.

Therefore, in the shape grammar of this paper, the first level is Self-Crossing transformation, which is the design thinking process of the cultural design gene unit and its own multiple execution of inference rules (replication, rotation, superposition, etc.) derived from specific cultural design genes that can eventually form more pattern shapes. The Self-Crossing process of the lotus flower culture design gene is shown in Fig. 5. Multiple transformations can be performed to form a variety of pattern shapes as shown in Fig. 6. The self-crossing transformation process of the stria culture design gene and the resulting are shown in Figs. 7 and 8. The Self-Crossing transformations are applicable to design processes that have only one cultural design gene or are applied to Cross-Crossing transformations.

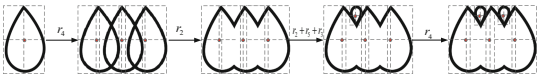

Fig. 5. Self-Crossing of "lotus petals" cultural design genes

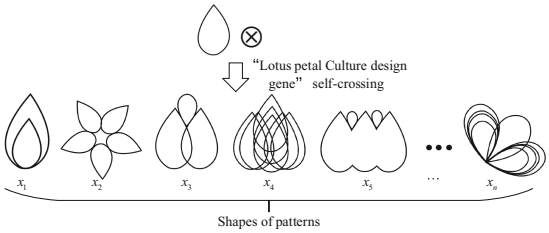

Fig. 6. "Lotus petals" pattern shapes

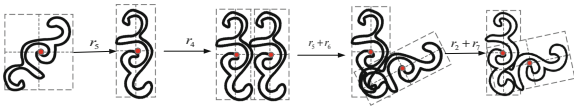

Fig. 7. Self-Crossing of "stria" cultural design genes (Color figure online)

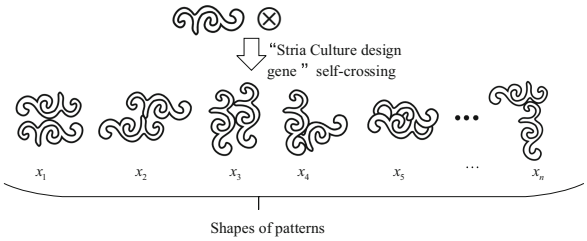

Fig. 8. "Stria" pattern shapes

In the second level, Cross-Crossing transformation, refers to a design thinking process where inference rules (replication, rotation, superposition) are performed multiple times by two or more cultural design gene monomers. The Cross-Crossing transformation process of the "lotus petals" culture design gene and the "stria" culture design gene is shown in Fig. 9; The Cross-Crossing transformation process of the "lotus petals" culture design gene Self-Crossing and the "stria" culture design gene is shown in Fig. 11; The Cross-Crossing transformation process of the "lotus petals" culture design gene and the "stria" culture design gene Self-Crossing is shown in Fig. 13; The Cross-Crossing transformation process of the "lotus petals" culture design gene Self-Crossing and the "stria" culture design gene Self-Crossing is shown in Fig. 15; Each of the Cross-Crossing transformation is formed as shown in Figs. 10, 12, 14, and 16 after a plurality of executions. Each of the cultural design genes may be a monomer, or a complex cultural design gene formed by Self-Crossing transformation or Cross-Crossing transformation of a cultural design gene monomer. The Self-Crossing transformation has higher priority than the Cross-Crossing transformation. If there are more than two cultural design genes, the Cross-Crossing transformation execution order is from left to right; The complex cultural design genes after the Cross-Crossing of the first two culture design genes can be regarded as new cultural design genes, and then Cross-Crossing with the next cultural design gene, until a variety of pattern shapes are derived.

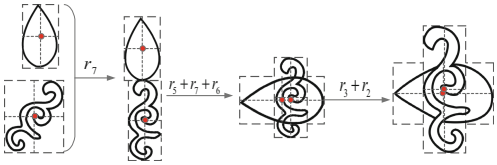

Fig. 9. "Lotus petals and stria" culture design gene Cross-Crossing (Color figure online)

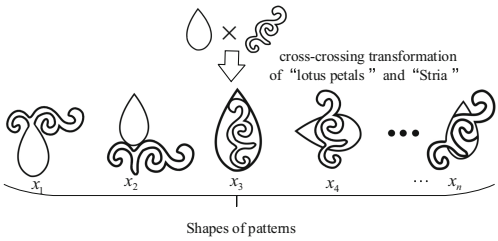

Fig. 10. Pattern shapes of "lotus petals and stria" Cross-Crossing

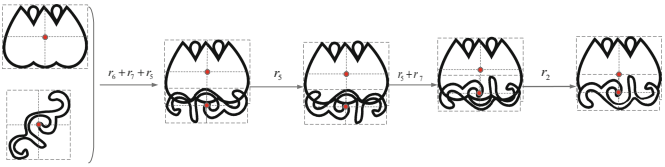

Fig. 11. "Lotus petals Self-Crossing and stria" culture design gene Cross-Crossing (Color figure online)

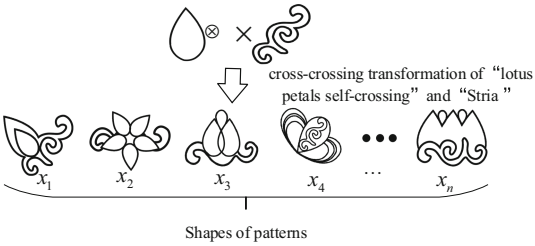

Fig. 12. Pattern shapes of "lotus petals Self-Crossing and stria" Cross-Crossing

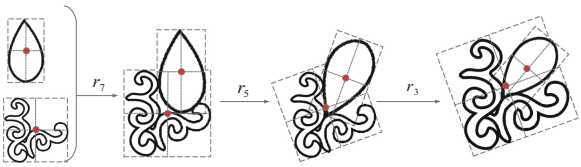

Fig. 13. "Lotus petals and stria Self-Crossing" culture design gene Cross-Crossing (Color figure online)

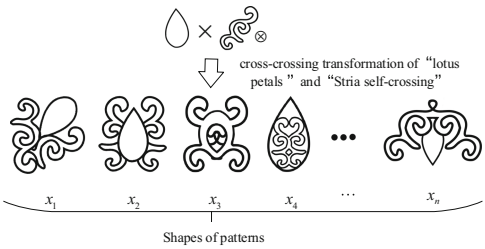

Fig. 14. Pattern shapes of "lotus petals and stria Self-Crossing" Cross-Crossing

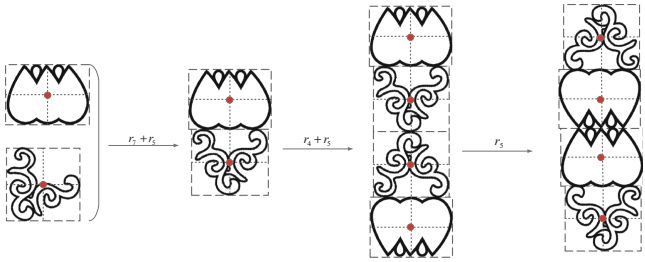

Fig. 15. "Lotus petals Self-Crossing and stria Self-Crossing" culture design gene Cross-Crossing (Color figure online)

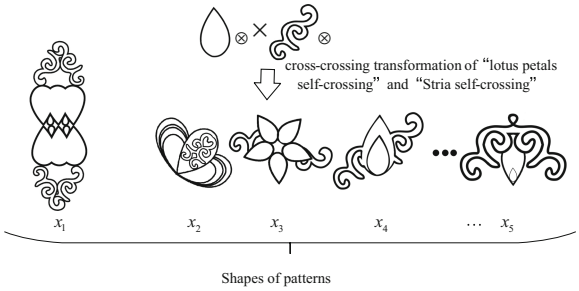

Fig. 16. Pattern shapes of "lotus petals Self-Crossing and stria Self-Crossing" Cross-Crossing

5 National Pattern Generation

The pattern shapes reorganization can generate new pattern elements, and the design process can be combined with processing computer aided design software. The pattern shape position is marked by adopting the rectangular boundary of the shape in the above and the red center dot. The initial Tibetan pattern shape are analyzed, and the initial pattern elements can be considered to consist of two concentric rings and an intermediate portion. The coding rule is formulated according to the position, and the extension idea of "one object, multiple signs, and multiple values" is introduced. Each pattern element position can be placed with a pattern shape class containing different cultural design genes, and each type of pattern element can be a plurality of pattern shape feature values exhibited, the process of which is shown in Fig. 17. The resulting pattern elements pool is shown in Fig. 18.

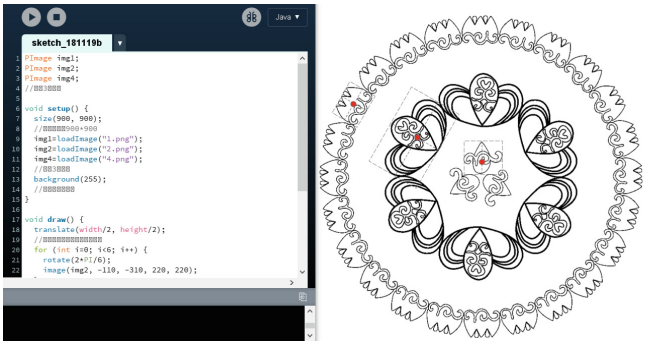

Fig. 17. Processing Computer-Aided design pattern element process (Color figure online)

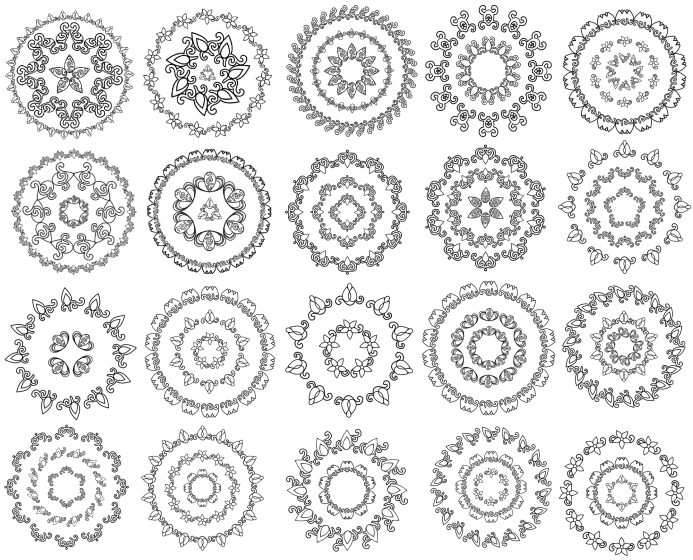

Fig. 18. Pattern elements pool

Taking the Tibetan pattern of China as an example, the pattern composition rules of the initial national pattern are analyzed, and the basic categories and arrangement methods of the pattern elements are sought. The pattern elements can be reconstructed into new series according to the pattern of the original national pattern. The ethnic pattern, (Fig. 3, show examples), achieves the design reuse of the "initial ethnic pattern - cultural design gene - derived national pattern" (Fig. 19, show examples),

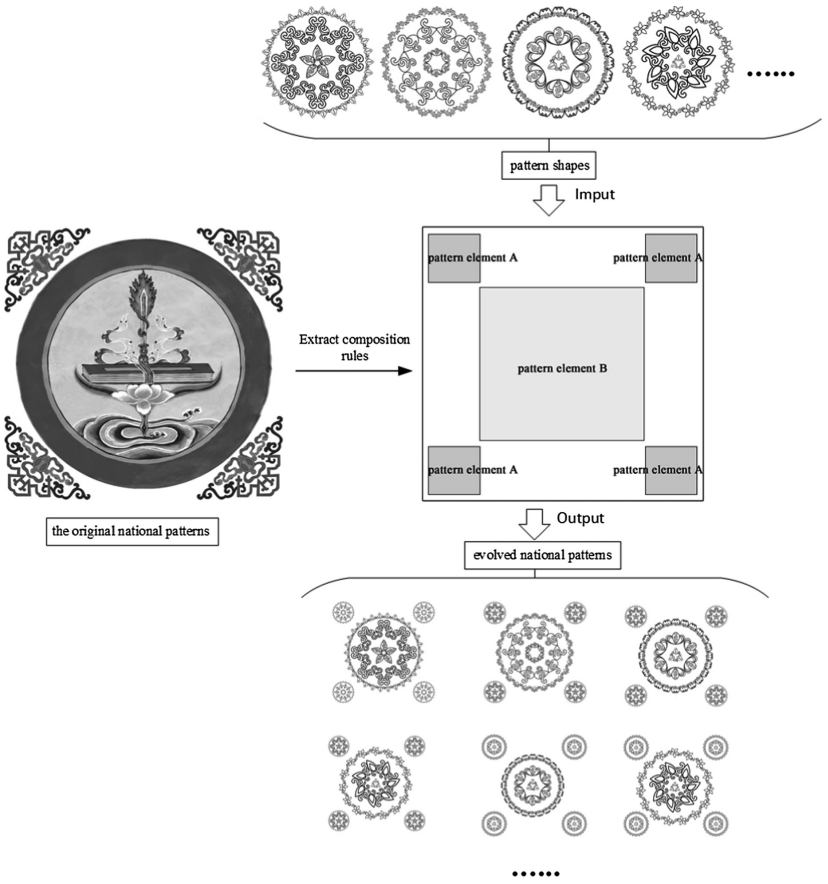

Fig. 19. A new series of national patterns

6 Conclusion and Future Research

In this research, we obtained a Chinese Tibetan pattern as an example to expound national pattern generation method based on cultural design genetic derivation. Under the premise of deep understanding of cultural genes and cultural design genes, concepts, elements of patterns and shapes of patterns and cultural design genes were defined by pattern decomposition to build the conceptual pattern hierarchy. Furthermore, we established the principles of pattern deconstruction and cultural design gene extraction. Based on shape grammar a design method for gene design of Tibetan culture design was proposed which contained two main derivation rules (Self-Crossing and Cross-Crossing transformation). We used Processing computer-Aided design software to assist the redesign of the pattern shapes. The transformation rules of the pattern shapes discharge position are performed by Shape border and red center point, and the topology principle is introduced to generate a plurality of pattern elements. Following the original pattern element composition rules, the pattern elements can form

a new series of national patterns, thus realized the design reuse of "the original national patterns – cultural design genes – evolved national patterns". Taking the Chinese Tibetan pattern as an example, we demonstrated how to obtain the design requirements and how to derivatively design the cultural design genes "lotus petals" and "stria". This paper shed light on how to generate a series of national patterns in line with consumer emotional images, which also demonstrated the national vitality of cultural design genes. Unlike other pattern generation methods, here, a method of generating national patterns was raised based on cultural design genetic derivation as follow: from the perspective of design intent, integrated with the concept of genetics in biology, the problem of ethnic pattern generation can be solved by the derivative design of cultural design genes under computerized parameter constraints, with a large improvement on the pattern design efficiency.

This research can be further studied in several ways. First, to study the genes of national culture design more deeply, the deconstruction method that can be applied to more complex ethnic patterns such as Thangka. Second, the Self-Crossing and Cross-Crossing transformation in the current shape grammar will produce countless kinds of solutions, study optimization algorithms, and converge on thinking. In the current research stage, the computer only plays a role in assisting the designer's design. In the future research, the intelligent design of the national pattern design generation system will be designed and developed for users to directly use, realize the individualization of the design and enhance the user's participation.

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