RESEARCH ON INNOVATIVE DESIGN OF DAI PAPER-CUTTING PATTERN EXTRACTION BASED ON SHAPE GRAMMAR[*]

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Abstract

This paper focuses on the national intangible cultural heritage of "Dai paper-cutting". Based on the theory of shape grammar, it explores the extraction methods and innovative concepts of traditional patterns in Dai paper-cutting. Based on the problems faced by traditional patterns such as lack of innovation and single application scenarios, this paper analyzes its original artistic value, and according to the generative rules and derivative rules of shape grammar, geometrically deconstructs and derives specific patterns, and completes the feasibility of applying them to the innovative design practice of coasters. Combining the initial patterns, generation rules and cultural metaphors, this paper finally established the innovative model of "pattern extraction-rule reconstruction-carrier adaptation", and built a methodological system for the transformation of traditional patterns into modern designs, which provides a new reference for the modernization and innovation of intangible cultural heritage skills, and is in line with the goal of improving the innovation and transformation capabilities in the intangible cultural heritage protection plan during the "14th Five-Year Plan" period.

Keywords: Shape grammar, Dai paper-cutting, Pattern extraction, Innovative design

Introduction

Dai paper-cutting, as a treasure of the cultural integration of ethnic minorities in southwest China, was included in the first batch of the National Intangible Cultural Heritage List as early as 2006. Later, it was recognized as an intangible cultural heritage of humanity by UNESCO. It carries the religious beliefs, life aesthetics and ethnic culture of the Dai people in its artistic form, and has profound cultural connotations and artistic value. However, in the process of globalization and modernization, traditional handicrafts are also confronted with the problem of developing in the direction of modernization. At present, there are phenomena such as convergence in design forms and insufficient innovation in the patterns of Dai paper-cutting. How to rejuvenate the traditional patterns of Dai paper-cutting in modern innovative design is the key issue that this article focuses on solving. Most of the existing research focuses on the cultural connotation of Dai paper-cutting, lacking systematic exploration of modern design transformation methods. Based on the guiding ideology of "promoting the creative transformation of intangible cultural heritage" proposed in the "14th Five-Year Plan for the Protection of Intangible Cultural Heritage", this article introduces shape grammar as theoretical support to construct a design transformation path suitable for the patterns of Dai paper-cutting. This article combines shape grammar and pattern innovation methods, with the aim of constructing an innovative design of Dai paper-cutting patterns.

Objectives

1. To study the artistic characteristics of Dai paper-cutting patterns, including patterns and cultural connotations.

2. To theoretically construct the transformation method of Dai paper-cutting patterns, and integrate the innovative path of "pattern extraction-rule reconstruction-coast mat carrier adaptation".

Literature Review

During the current "14th Five-Year Plan" period, the "14th Five-Year Plan for the Protection of Intangible Cultural Heritage" issued by the Ministry of Culture and Tourism clearly states that the level of protection and inheritance of intangible cultural heritage should be further enhanced, and the creative transformation and popularization of intangible cultural heritage should be promoted. Against this backdrop, paper-cutting art, as an important category of intangible cultural heritage, has seen research mainly focus on cultural protection, symbol analysis and application exploration.For instance, Dong Shu and Yue Chen, taking Mianyang paper-cutting as an example, focus on the issue of "integrity protection" of intangible cultural heritage and its cultural space, emphasizing the overall maintenance of the cultural ecosystem. Their approach leans towards the cultural policy and protection practice levels(Dong Shu & Chen, 2024). Yang Li's research on Fujian paper-cutting adopts the semiotic method, systematically analyzing the types and connotations of its image symbols, indicator symbols and symbolic symbols, with an emphasis on explaining the internal cultural semantic structure of paper-cutting art(Li, 2021). At the application level, Pingping Li et al. explored the feasibility of paper-cutting art in the design of ethnic minority costumes in Yunnan. This is an initial exploration of cross-disciplinary application and has not yet formed a systematic design transformation path (Li et al., 2024). To sum up, existing research has conducted extensive discussions on cultural and artistic features, but there are still obvious gaps in the innovative transformation and derivative design paths of its patterns. To make up for the deficiency of this methodology, this study

introduces shape grammar as a theoretical tool. Shape grammar, as a rule-based form generation system, can obtain the initial form of Dai paper-cutting patterns, analyze the core patterns and deduce the rules, thus creating new patterns that conform to modern aesthetic design while retaining their cultural genes. This method not only makes up for the deficiency of existing research in the structuring of the design process, but also provides a verifiable and sustainable innovative path for the modern transformation of intangible cultural heritage patterns.

Methodology

This research adopts a practice-led design research approach, exploring and verifying theoretical methods through specific design practices, with the aim of generating innovative design outcomes. It is mainly divided into the following three stages:

1. Pattern collection and analysis stage

Through on-site investigations, physical objects and images of Dai paper-cutting were collected. Starting from aspects such as cultural connotations, pattern forms and subject types, they were classified and categorized according to different types. Analyze the artistic features and cultural connotations of the patterns, and then make corresponding generalizations and summaries. On this basis, collect and organize the pattern data, screen out the more typical patterns among them, and conduct in-depth analysis and extraction with them as the target.

2. Shape grammar deduction and Innovation stage

This stage is the core innovative link of the research. We take the typical patterns selected in the first stage as the initial form and carry out systematic innovation by applying shape grammar. First, the generative principle is applied

to deduce the individual units of the patterns, and then the generative rule is implemented to evolve them into new basic units. Select representative elements from the initial form of the pattern, apply the basic principles of shape grammar to deduce them one by one, innovatively recombine these elements to create new patterns that conform to aesthetic laws, and on this basis, carry out innovative designs. (The process is shown in Table 5)

3. Design and Application stage

To verify the feasibility of the new patterns generated by shape grammars, this study applies them to the specific design of cultural and creative products. We chose coasters as the carrier because their flat nature can showcase the visual beauty of the patterns. We innovatively combined and adjusted the innovative patterns to make them harmonious with the carrier in terms of proportion, color and composition.

Conceptual Framework

As a rich cultural system, Dai paper-cutting covers a pattern system composed of natural landscapes and cultural symbols. At the historical and social level, it not only carries the collective memory and folk life traditions of the Dai people, but also becomes a vivid medium for cultural inheritance. In terms of cultural expression, paper-cutting takes cultural meaning as the core content, relies on unique hollowing techniques to form a distinctive visual language, and various cultural elements support each other to jointly build a coordinated and unified cultural expression system. In terms of dissemination and preservation, Dai paper-cutting mainly relies on the traditional model passed down from generation to generation to continue to convey its artistic value and cultural spirit. These dimensions are interrelated and together outline a complete picture of Dai paper-cutting from content and historical background to cultural

connotation and inheritance path, providing a systematic framework for in-depth exploration of its artistic characteristics and cultural significance and promoting its modern innovative design. (Figure 1).
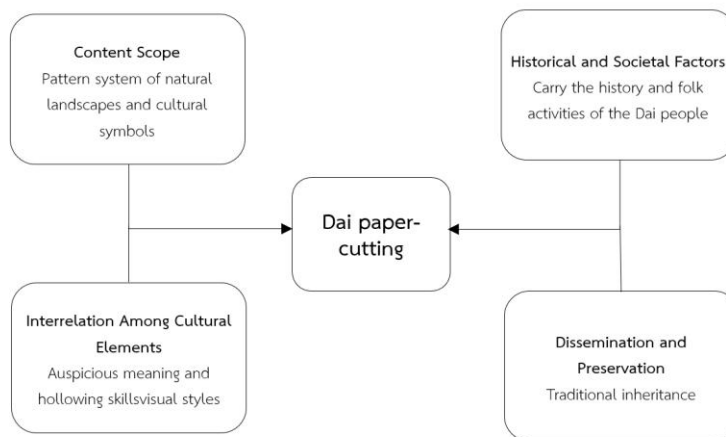
Figure 1 Conceptual Framework (Source: Constructed by the researcher)

Results

1. Analysis of artistic characteristics of Dai paper-cutting patterns

Dai paper-cutting patterns, as a visual expression of the combination of Southern Buddhism culture and traditional nature worship, have artistic characteristics that clearly reflect nationality, religion and regionality.

Dai paper-cutting is usually created on paper of a single color, so it belongs to the category of monochrome paper-cutting. This paper-cutting style is bright and generous, and can highlight the essence of aesthetics and techniques such as the image, composition and knife skills of paper-cutting.

In terms of expression techniques, Dai paper-cutting mainly adopts a combination of Yin shearing and Yang shearing. Yang shearing is a technique that preserves the shape while cutting off the parts outside the shape. The solidity, heaviness and naivety of the Yang lines make the paper-cutting works leave a

deep impression on people. Yin-cutting, on the other hand, uses the blank lines cut out to show the patterns and designs to be expressed. Yin-cutting uses the virtual to support the real, with a strong contrast. This kind of paper-cutting effect is flexible and rich, while being simple and unsophisticated, and can better maintain a sense of hierarchy (Figure 2).

Yang shears　　　　　Yin shearing　　　　　Yin Yang Scissors
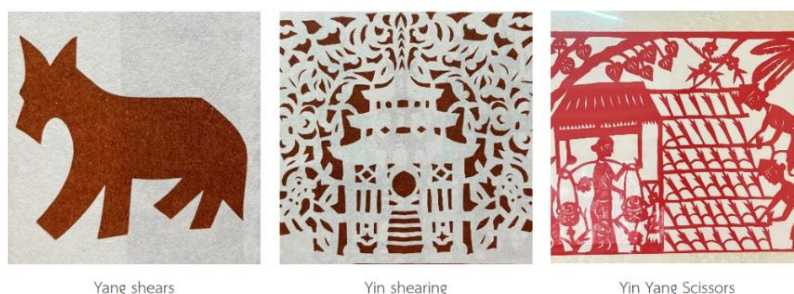
Figure 2 Yang shears, Yin shears, Yin-Yang shears (Source: Photographed by the researcher)

The alternating combination of Yin-cutting and Yang-cutting makes the paper-cutting language richer and can better express the virtual-real relationship and content of the pattern. Through the paper-cutting expression techniques of Yang-cutting, Yin-cutting, or a combination of Yin-cutting and Yang-cutting, Dai paper-cutting artists can always skillfully organize the different parts of the image of the object to be expressed, and through appropriate coordination, create a harmonious and complete beautiful picture.

1.1 Classification and meaning of Dai paper-cutting patterns

Dai paper-cutting patterns are deeply rooted in the natural ecology, religious beliefs and folk culture of the Dai settlements. Its themes are extensive and rich in profound meaning. Common pattern themes can be summarized into four categories. The following is an analysis of typical Dai paper-cutting patterns:

1) Natural Phenomenon Patterns: This type of pattern is often inspired by dynamic elements in nature, and conveys the Dai people's respect for the power of nature through abstraction. These patterns usually depict natural landscapes such as rivers and clouds. They are not just simple imitations of nature, but also a deep understanding and internal embodiment of symbolic meanings (Table 1).

Table1 Natural phenomenon pattern

Cloud Pattern	Swirl pattern	Crescent pattern

2) Animal patterns: They reflect the Dai people's reverence for sacred creatures. Common animal patterns include elephants, peacocks, butterflies, etc. These animal patterns not only enrich the artistic expression of Dai paper-cutting, but also deeply reflect the Dai people's awe and love for nature (Table 2).

Table 2 Animal pattern pictures

Elephant pattern	Peacock pattern	Butterfly pattern

3) Plant patterns: Inspired by the tropical natural landscape of the Dai settlements, they are mainly local plants and emphasize the rhythmic beauty of their growth. These plant patterns not only show the Dai people's love and awe of nature, but also enrich the artistic expression of Dai paper-cutting (Table 3).
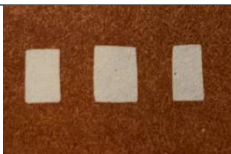
Table 3 Plant pattern pictures

| Bodhi leaf pattern | Lotus pattern | Gardenia pattern |

4) Geometric patterns: Use repetition and symmetry to create decorative patterns, thereby enhancing the visual sense of order. These patterns are generally composed of simple geometric shapes such as squares, circles, triangles, etc (Table 4).

Table 4 Geometric pattern diagram

| Square pattern | Triangle pattern | Circular pattern |

Such designs not only carry the Dai people's reverence for nature and aesthetic expression, but also create a unique Dai cultural symbol system through the integration of religious beliefs and daily life. They are not only an important carrier of national culture, but also a hub for understanding the past and present, tradition and future. Through the study of Dai paper-cutting patterns, we can have a deeper understanding and experience of the Dai people's unique religious beliefs, folk culture and aesthetic system, and feel the rich national charm and cultural heritage. In addition, Dai paper-cutting also provides different sources of inspiration for contemporary design, fully promoting the integration and development of tradition and modernity.

1.2 The Real Dilemma of Dai Paper-cutting Patterns

At present, the problem faced by Dai paper-cutting patterns is the singleness of artistic form. The lines of these patterns often appear rigid and stereotyped, lacking the fluency and vividness they should have. In terms of innovation, traditional patterns seem to have failed to fully absorb modern aesthetic elements, which limits their development in artistic expression and sense of the times. This study takes Dai paper-cutting patterns as the object and constructs a morphological evolution method based on shape grammar, which expands the morphology of patterns and innovates them at the same time. By incorporating the innovative morphology into product design, this study not only promotes Dai paper-cutting, but also provides a new perspective for the innovation of other intangible cultural heritage. Through literature analysis and other methods, this article systematically collects and summarizes Dai paper-cutting patterns, and proposes a design idea based on shape grammar to improve Dai paper-cutting patterns and make them more in line with modern aesthetic standards. In addition, the article also applies the designed new pattern scheme to cultural and creative products for actual verification, providing new ideas for the design innovation of Dai paper-cutting patterns.

2. Basic concepts of shape grammar

According to the definition of Stiny and Gips, shape grammar can be defined as a four-tuple, specifically expressed as SG=(S, L, R, I), where S (shape) is a finite set of shapes, L (label) is a finite set of labels, R (rule) is a finite set of inference rules, and I (initial shape) is the initial shape (Stiny & Gips, 1971). Shape grammar defines a set of shapes and calls this set "text", which means language. This language includes all the shapes derived from shape grammar, and gradually derives according to the rules based on the initial shapes, thus forming a variety of patterns of different shapes and methods (Verniz & Duarte, 2020). The core concept is to decompose complex forms into basic units, and then construct complex forms through orderly combination and transformation. Shape grammar

plays a vital role in pattern innovation design. By applying different rules of shape grammar, it can inspire unlimited creativity and form new patterns. At the same time, it can effectively create new patterns while retaining the characteristics of the original patterns.
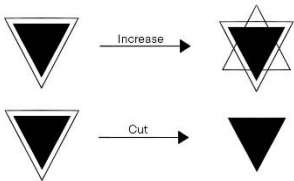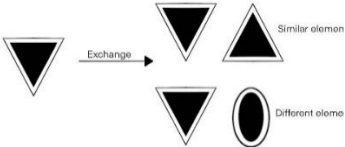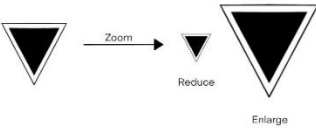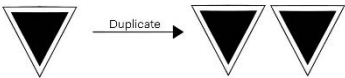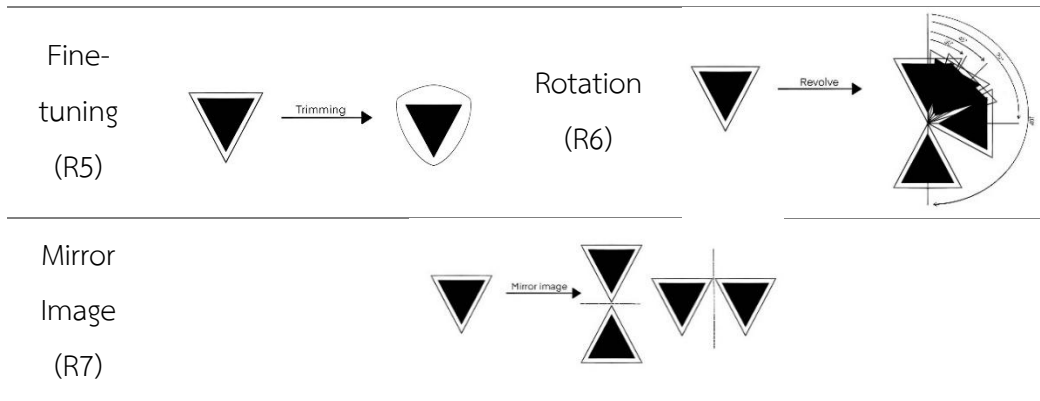
2.1 Basic rules of shape grammar

The reasoning rules of shape grammar can be divided into generative deduction and derivative deduction. Using shape grammar as a design method, the geometric triangle in the Dai paper-cutting pattern is selected as the initial shape for demonstration, and the corresponding derivative shape is constructed using basic deduction rules. As shown in the following table, this process is called generative deduction rules (as shown in Table 5); by continuing to deduce the generated basic graphics according to the rules, richer new graphics can be created. This process is called derivative deduction rules. Such as derivative deduction rules. It arranges and combines one or more basic shapes in a specific spatial relationship according to the grammatical relationship and rules of the shape, thereby creating new shapes and deriving a series of new design schemes, while maintaining a certain degree of continuity. The advantage of shape grammar is that it can make orderly changes to symbolic elements, and the generated graphics not only retain the original cultural genes, but also present a new visual form. Through shape grammar for graphic innovation design, the unique artistic characteristics of Dai paper-cutting patterns can be taken into account. When determining the inference rules, the degree of deformation of the element can be determined according to its importance to the overall style. For elements that have a greater impact on the style, a smaller degree of deformation should be maintained to maintain the continuity of the cultural gene. For elements that have a smaller impact on the style, a larger degree of deformation can be used to achieve a richer and more diverse visual effect.

The evolution rules of shape grammar mainly include multiple operations such as addition and deletion, replacement, scaling, copying, fine-tuning, rotation and mirroring. Addition and deletion operations involve adding or removing certain parts of the shape to form a new figure; replacement is to replace the original elements with similar or different elements; scaling refers to enlarging or reducing the size of the shape in proportion; copying involves copying the original shape and moving it in a specific direction while keeping the shape unchanged; mirroring refers to symmetrical copying along the axis to achieve symmetry on both sides of the axis, including horizontal symmetry and vertical symmetry; rotation refers to the angle transformation of the shape around a certain point or axis to change its direction; fine-tuning is to make subtle adjustments to the shape of the initial figure.

This article mainly uses rules such as addition and deletion (R1), replacement (R2), scaling (R3), copying (R4), fine-tuning (R5), rotation (R6), and mirroring (R7). Taking the geometric triangle pattern in the Dai paper-cutting pattern as an example, the generative rule deduction of shape grammar is demonstrated. The generative deduction rule table is as follows.

Table 5 Generative deduction rules

Rule Number	Schematic diagram	Rule Number	Schematic diagram
Additions and deletions (R1)	Increase / Cut	Replacement (R2)	Exchange / Similar element / Different element
Zoom (R3)	Zoom / Reduce / Enlarge	Copy (R4)	Duplicate

| Fine-tuning (R5) | | Rotation (R6) | |

| Mirror Image (R7) | |

The derivative deduction rules are based on the generative rules. Taking the geometric triangle pattern in the Dai paper-cutting pattern as an example, the rule deduction of shape grammar is demonstrated (Figure 3).
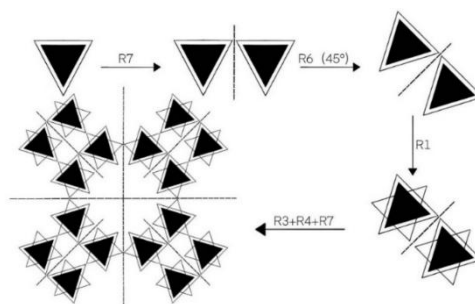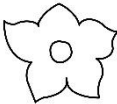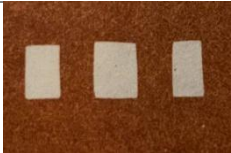
Figure 3 Schematic diagram of derivative deduction rules (Source: Constructed by the researcher)

2.2 Extraction and innovation of Dai paper-cut patterns

As the target patterns of this study, through the above in-depth analysis of Dai paper-cut patterns, the following 12 basic patterns are mainly extracted as research objects. These patterns are classified according to their subject matter and serve as the core samples for the initial shape extraction of Dai paper-cut patterns (Figure 6).
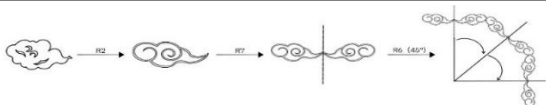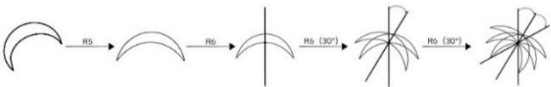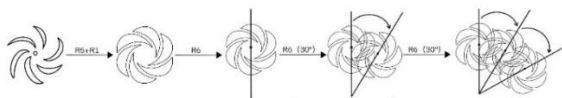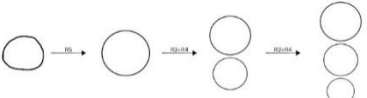
Table 6 Initial pattern morphology extraction table

Cloud Pattern	Swirl pattern	Crescent pattern
Elephant pattern	Peacock pattern	Butterfly pattern
Bodhi leaf pattern	Lotus pattern	Gardenia pattern
Square pattern	Triangle pattern	Circular pattern

3. Innovation practice process of Dai paper-cutting patterns

Generation of basic pattern images: Through the application of shape grammar, the evolution of pattern innovation design can be divided into two main stages. First, the original shape of Dai paper-cutting is transformed into monomer units of basic pattern elements through shape grammar. Then, in the second stage, the newly generated pattern monomer units are evolved using derivative rules to create innovative paper-cutting patt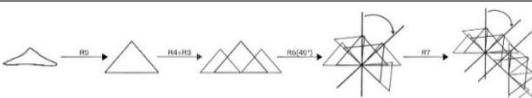erns with Dai characteristics. The following table shows how shape grammar is used in combination in these two stages to form the evolution process of new patterns. Taking natural and geometric patterns as basic elements, graphic innovation is carried out by applying generative rules and derivative rules to achieve diversified design of two-dimensional graphics, and show the new graphics from the derivation process to the innovation.

Table 7 The innovative development process of Dai paper-cutting patterns

Name	Pattern extraction and deduction process	Graphics Innovation
Cloud Pattern		
Crescent pattern		
Swirl pattern		
Triangle pattern		
Circular pattern		

Square pattern		
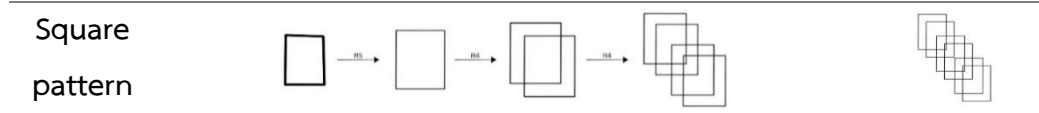
In terms of composition, referring to the above example deduction rule diagram, we selected one pattern from each of the four different subject types and innovatively combined them into graphics. Using the "○" with a sense of order as the outer contour, we innovatively combined the single pattern graphics, as shown in the figure below. By applying the basic rules of shape grammar and the aesthetic principles of symmetrical patterns, we cleverly rearranged the combined elements and finally created a graphic art with a clear theme and balanced layout of paper-cut patterns. While using shape grammar for design translation, we follow the rules of formal beauty, such as harmony, moderation, symmetry, balance, harmony, contrast, unity, proportion, rhythm, rhyme, etc., to innovatively reorganize the basic units of the generated new patterns (Figure 4).
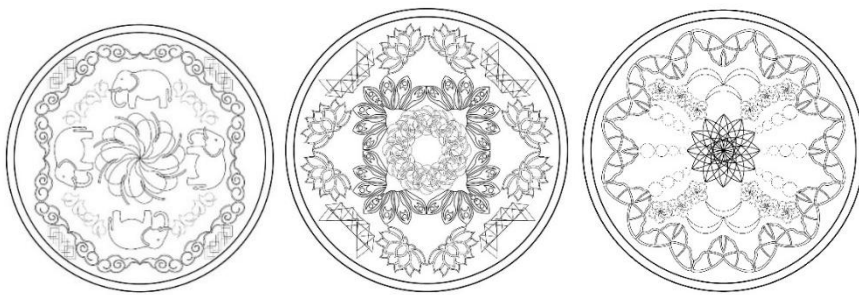
Figure 4 Line drawing (Source: Drawing by researchers)

In terms of color extraction, through field investigation and extensive collection of relevant information, it was found that Dai paper-cutting art usually uses a single color, especially red, as its main color element. Based on these colors commonly used in Dai paper-cutting, the inherent monochrome of the above patterns was selected and these colors were used as the main colors of

the coaster design to reflect the unique charm and cultural connotation of Dai paper-cutting.

Using coasters as a design carrier for inheriting Dai paper-cut patterns highlights the perfect unity of cultural inheritance and innovative use. Design carriers are not only the material basis of cultural elements and creative ideas, but also have a decisive influence on cultural and creative products. This article focuses on coasters as a design carrier, showing the unique charm of Dai paper-cut patterns. Applying Dai paper-cut patterns to coasters is not only conducive to spreading its cultural connotation, but also can enhance decorativeness and inject Dai cultural charm into modern life. The portability of coasters can also make them a high-quality object for promoting cultural and creative products, which is more conducive to the dissemination and development of Dai culture. At the same time, the flat material of coasters (such as bamboo, wood, cork, etc.) echoes the hollow lines of paper-cuts. It can be seen that coasters are undoubtedly a high-quality carrier for Dai paper-cut cultural and creative products. After careful consideration and careful selection of the design carrier, the final innovative product of Dai paper-cut patterns is shown in Figure 5.

Figure 5 Coaster cultural and creative product image (Source: Drawing by researchers)

Discussion

This study systematically deconstructed and innovated the patterns of Dai paper-cutting through shape grammar, verifying its effectiveness in analyzing the formal rules of patterns and promoting modern transformation. Compared with Yang Li's symbol classification and Dong Shu & Yue Chen's holistic protection research, this study further transforms static patterns into operable shape units and constructs new patterns through generation and derivation rules, demonstrating the sustainable development path of contemporary intangible cultural heritage. The limitations of the research are reflected in the imperfect interdisciplinary interpretation of deep cultural metaphors in the model. At both the theoretical and practical levels, this study also offers a new perspective for the innovation of intangible cultural heritage. It has also verified the feasibility of integrating traditional patterns into contemporary life through cultural and creative products such as coasters, providing some new directions for the sustainable development of Dai paper-cutting.

Recommendations

Based on the results and deficiencies of this study, future work can be further deepened from both theoretical and application perspectives:

At the theoretical level, by integrating frameworks such as semiotics and combining them with shape grammar to systematically explain the cultural metaphors behind the patterns, a design system that integrates form and meaning is constructed.

At the application level, future research can also break through static products such as coasters and silk scarves, and should be extended to dynamic media and interactive scenarios, such as AR and immersive Spaces, to promote intangible cultural heritage from static products to multi-dimensional experiences.

This study not only verified the innovative value of shape grammar for Dai paper-cutting in terms of methodology, but also provided a new direction for its modern transformation in practice.

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