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# INNOVATIVE DESIGN OF CAISSON LOTUS PATTERN IN DUNHUANG

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## ABSTRACT

The main objective of this research was to propose an innovative design method suitable for the traditional lotus pattern, so that the design objects can better inherit excellent characteristics and meet the aesthetic needs of modern people. The study started from the analysis and summary of Dunhuang caisson lotus pattern types and characteristics, then used the diagramming method by compasses and straightedge ruler to geometricize the lotus pattern structure, and evolved the lotus pattern structure based on the shape grammar rules, through the classic blue and white color to color the pattern, thus derived innovative patterns. Finally, in order to verify the feasibility and effectiveness of the method in this paper, the Kansei engineering theory was used to evaluate the design effect of the new lotus pattern applied to the T-shirts favored by college students born after 1990. The results show that according to the shape of the petals, the caisson lotus pattern is mainly divided into simple round-wheel lotus and flat-petal lotus, the peach-shaped lotus known as the prototype of baoxiang flower, the complex and colorful baoxiang flower which is the most popular form in Tang dynasty, afterwards, it returned to the simple shape but with the rotating effect of the curl petal lotus. Through the analysis of the evaluation score of the design effect of the new patterns, it can be seen that each pattern gives a different feeling, on the whole, the new lotus patterns have unique, simple, innovative and neat characteristics, which basically meet the aesthetic needs of college students, this provides a feasible scheme for the innovative design of traditional patterns.

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**Keywords:** Caisson lotus pattern; innovative design; shape grammar; Kansei engineering

## 1. INTRODUCTION

Dunhuang Mogao Grottoes, commonly known as Thousand Buddha caves, is located in Dunhuang, at the western end of the Hexi Corridor in China. It has a history of more than 1600 years, with 735 caves, among them, there are 492 caves with murals, the mural area is about 45,000 square meters. It is the largest and most abundant Buddhist art place in the world. Dunhuang Mogao Grottoes is famous for its gorgeous and colorful decorative pattern art. Among them, the caisson lotus pattern decorated in the cave is exquisite and gorgeous, and it is the focus of the Dunhuang pattern. The caisson refers to the indoor ceiling in traditional Chinese architecture. In the Dunhuang Dictionary, the definition is as follows: "The square part of the top of the Dunhuang Grottoes" (Ji, 1998), the blue line area in the Figure 1.

**Figure 1:** Caisson in Dunhuang Grottoes

However, due to natural and artificial factors, mural resources are gradually disappearing. According to the latest statistics, more than half of the murals and color sculpture in the caves of Mogao Grottoes have diseases such as discoloration, shedding, etc. (Fu et al., 2019).

On June 27, 2014, the Oriental Morning Post reported that Dunhuang Mogao Grottoes were "going to death at a speed 100 times faster than in ancient times." Fan Jinshi, the dean of the Dunhuang Academy and a scholar, once lamented that the trend of the disappearance of Mogao Grottoes can only be delayed and cannot be reversed. With the development of the protection of intangible cultural heritage in Dunhuang, more and more countries, institutions, artists and scholars have joined the team of excavation, sorting and protection of Dunhuang mural resources. Unfortunately, so far, in the research field of current patterns, few scholars pay attention to and carry out research on caisson lotus patterns in Dunhuang Mogao Grottoes, and they just pay attention to the caisson lotus pattern in some periods, such as the Sui Dynasty (Wang, 2017), Tang Dynasty (Luo, 2018) and the research content is limited to the simple introduction of the types of lotus patterns in different periods. Lack of systematic research on lotus pattern, there are also deficiencies in research on its inheritance and innovation.

In the field of design, there has been an upsurge of innovation and application of traditional culture in recent years. In the field of product design, especially cultural and creative products, furniture products, etc., a design category based on traditional culture and art has been formed, traditional culture and art are attracting more and more attention in today's design field. The caisson lotus pattern in Dunhuang grottoes has been widely used in modern design because of its exquisite shape, rich variety and brilliant color. A large number of cultural and creative products related to caisson lotus patterns have appeared on the market today, however, most designers only apply the lotus pattern in the murals directly to modern products, the lack of innovative design or degree of innovation for the traditional lotus pattern is not enough to get consumers' favor. For the design of traditional patterns, how to retain the characteristics of traditional patterns while improving their innovation has always been a problem in the design field.

Among the existing design methods, shape grammar as a shape deduction method, is not only able to extract the shape features, but also able to carry out the shape deduction design on this basis, to generate a continuous style of product design. Shape grammar was first used in painting and sculpture in 1972, and now has been successfully applied to architectural (Neeta and Alpana, 2019) and industrial design (Hsiao and Watada, 2018) due to its characteristics of formalization, visualization and heuristic reasoning.

Some scholars applied this method to the innovative design of traditional patterns. For example, Lee et al. (2013) studied Bosanghwamun, a traditional Korean pattern, and decomposed its pattern structure step by step to obtain a series of pattern templates. Sayed et al. (2016) proposed a novel approach in generating 3D Islamic geometric patterns using the shape grammar method. Cui and Tang (2013) studied the Zhuang nationality embroidery patterns, realized the automatic generation of new patterns through the shape grammar computer system. From the above research, we can find that the use of shape grammar rules for product design or pattern design can better retain the characteristics of the original object. In view of this, this article will use this method to innovate design of the caisson lotus pattern.

Whether the innovative design of traditional patterns can meet the needs of modern consumers depends on their satisfaction with the design effect. However, for a long time, consumers' perception and evaluation of products involve complex psychological factors, full of ambiguity and uncertainty, therefore, the extraction of the regular of consumer perception has always been a difficult problem. In the face of current consumption trends and research needs, the Kansei engineering method can provide an effective cognitive approach to product modeling, pattern design, and aesthetic evaluation of fabrics (Xia and Wang, 2016).

Kansei engineering emerged in Japan in the of 1970s, it is a method to explore the relationship between human sensibility and product design of function an appearance by using engineering techniques (Mitsuo, 2002), and to try to translate emotions into measurable and physical design specifications (Vieira et al., 2017). In recent years, the research on Kansei engineering in pattern design has also been carried out. For example, Shi and Zhu (2011) and Wang and Liu (2014) respectively studied the correlation between stripes, grid pattern and consumers' perceptual psychology, and found out the relationship between consumers' perceptual demand and elements of patterns. Gu and Wang (2018) used Kansei engineering to evaluate the application effect of blue and white patterns on cheongsam, and constructed the relationship diagram between 18 cheongsam and 3 factors, which can explain the hidden role of different blue and white elements in the visual effect of cheongsam.

Although the above is very rich in the application of shape grammar and Kansei engineering in pattern design, few researchers have applied these methods to the innovative design of caisson lotus pattern. Even some scholars have carried out innovative application of caisson lotus pattern, it is mainly based on the designer's personal subjective preference to redesign the pattern, without evaluating the effect of pattern innovation. However, this plays a vital role in the modern application of traditional patterns to meet the needs of modern consumers. Therefore, the purpose of this study is to propose an innovative design method suitable for the traditional lotus pattern, which not only adds the innovation of the pattern, but also retains the characteristics of the pattern, and also meets the aesthetic needs of modern consumers.

## 2. RESEARCH OBJECTIVES

1. To systematically research the caisson lotus pattern in Dunhuang Mogao grottoes, and summarize its types and characteristics.
2. To develop innovative design methods of traditional lotus patterns, so as to revitalize the classic traditional patterns in the new era.

## 3. RESEARCH METHODOLOGY

In order to make the diverse shapes and colorful caisson lotus pattern rejuvenate in the new era, this study adopts the following methods and steps to innovate design of lotus patterns:

1. Summarize the types and characteristics of lotus pattern in Dunhuang Mogao Grottoes
2. Geometrize the lotus pattern
3. Evolve the lotus pattern based on shape grammar
4. Color the new lotus pattern

### 3.1 Types and characteristics of lotus pattern in Dunhuang Mogao Grottoes

According to the "Contents of Dunhuang Mogao Grottoes" published in 1982 and the 1996 edition of "Dunhuang Grottoes Contents", the number of caves in Mogao Grottoes is 492. This study combines the published "Contents Record", relevant research literature and field investigations of the Dunhuang Mogao Grottoes, the number of caisson caves has been sorted out: Among the 492 caves, there are 7 caves in the period of the Sixteen Kingdoms (Beiliang), including one cave with caisson, 14 caves in the Northern Wei Dynasty and there are no caves with caisson, 6 Western Wei caves, 2 caves with caisson, 17 caves in the Northern Zhou Dynasty, with 8 caves with caisson, among the 95 caves in the Sui Dynasty, there are 53 caves with caisson, there are 278 caves in the Tang Dynasty, with 232 caves with caisson, in the Five Dynasties, there were 27 caves and 12 caves with caisson, 15 caves in the Song Dynasty, with 5 caves of caisson, in 16 Xixia caves, 15 caves with caisson, 9 caves in the Yuan Dynasty, with 3 caves of caisson, 2 caves in the Qing Dynasty, 1 cave has caisson, 6 caves of unknown times, 2 caves with caisson, the details are as follows in Table 1.

**Table 1:** Statistics on the Number of Caves with Caisson in Mogao Grottoes in Different Eras

| Era | Total Number of Caves | Number of Caves with Caisson |
|---|---|---|
| Sixteen Kingdoms (Beiliang) (397-460 AD) | 7 | 1 |
| Northern Wei Dynasty (386-534 AD) | 14 | 0 |
| Western Wei Dynasty (535-556 AD) | 6 | 2 |
| Northern Zhou Dynasty (557-581 AD) | 17 | 8 |
| Sui Dynasty (581- 619AD) | 95 | 53 |
| Tang Dynasty (618-907 AD) | 278 | 232 |
| Five Dynasties (907-979 AD) | 27 | 12 |
| Song Dynasty (960-1279 AD) | 15 | 5 |

**Table 1:** Statistics on the Number of Caves with Caisson in Mogao Grottoes in Different Eras (Continued)

| Era | Total Number of Caves | Number of Caves with Caisson |
|---|---|---|
| Xixia Dynasty (1038-1227 AD) | 16 | 15 |
| Yuan Dynasty (1271-1368 AD) | 9 | 3 |
| Qing Dynasty (1636-1911 AD) | 2 | 1 |
| Other (the era is unknown.) | 6 | 2 |
| **Total** | 492 | 334 |

Through sorting and analysis of 334 caisson patterns, the lotus at the center of the caisson of the Mogao cave is the most exquisite and rich, so this paper mainly studies lotus in the center of caisson.

As a decorative part at the top of the cave, the caisson is mostly a square frame. However, as the visual center of the whole, the caisson center mainly depicts large circular lotus pattern. As the most beautiful geometric figure, circle gives people the feeling of completeness, symmetry and balance. In this study, according to the petal shape of the lotus pattern in the center of the caisson, the lotus pattern is divided into round-wheel lotus, flat-petal lotus, peach-shaped lotus, curl petal lotus, and Baoxiang flower.

Round-wheel lotus: Due to fading and discoloration, the lotus lines are unclear, leaving a strong round-wheel impression, so call it round-wheel lotus. This type of lotus was first appeared in the Northern dynasties (397-581 AD), this period is the beginning of the development of Dunhuang decorative pattern art (Zhou, 2005). After the Sui Dynasty (581-619 AD), the central round-wheel lotus disappeared. It can be seen from the caisson in cave 272, the caisson is a nested structure, the center of the caisson is drawn with a circular lotus, and around it is green pool (Figure 2).

**Figure 2:** Cave 272

Flat petals lotus: Its shape is simple, petals flat, petals are round or square with pointed ends. It appeared in the Sui and Tang dynasties (581-907 AD), there are eight petals, twelve petals and sixteen petals of the common lotus, lotus shape has long and thin geometric shape, but also plump and fat shape. Lotus heart painted with three rabbit patterns, rotating color wheel, seedpod of the lotus, Vajra and so on. As shown in cave 398, the caisson center is a 16-petal large lotus, and the lotus center is painted with a rotating color wheel (Figure 3). Some caisson around the lotus decorated with twining branches lotus pattern, camellia patterns, double dragons, flying Apsaras, winged beast, etc., which makes the caisson heart rich and colorful. Such as cave 159, a flat petal lotus is painted at the center of the camellia patterns garland (Figure 4).

**Figure 3:** Cave 398

**Figure 4:** Cave 159

Peach-shaped petal lotus: The lotus petal looks like a peach, which is the main shape of the lotus in the early Tang Dynasty (618-712 AD). Later, influenced by foreign cultures, it absorbed other cultural elements to form a gorgeous Baoxiang flower that often appeared in the caisson in the middle and late Tang Dynasty. Therefore, it is also known as the prototype of the pattern of Baoxiang flower. For example, in cave 205 (Figure 5), the center of the caisson is a four peach-shaped petal lotus, the lotus petals decorated with honeysuckle patterns, moiré, and ruyi hooks. It is a new style in this period, but the three rabbit patterns in the center of the lotus inherit the style of the Sui Dynasty (581-619 AD), the old and new styles merged and developed in parallel.

**Figure 5:** Cave 205

Baoxiang flower: Baoxiang flower is the most common caisson pattern in the glorious age of Tang Dynasty (650-755 AD). Baoxiang flower is not a flower that can be seen in nature. It gathers the character of the lotus pattern of India, the honeysuckle pattern of the Western Region, the peony pattern and the pomegranate pattern. It is an ideal pattern designed by people. It combines peach-shaped lotus petals, hook pattern, moiré, and leaf-shaped pattern to form a pattern. It runs through the development of the entire Tang Dynasty's Baoxiang flower, and is also the most popular and not controversial type. The center of the caisson in the 331$^{th}$ cave is a four-petal flower, which radiates outward in turn (Figure 6). There are small leaf patterns, peach-shaped petals, moiré, lotus petals, etc., a total of seven layers, the outermost layer is composed of eight peach-shaped petals, and the lotus petals are large and peach-shaped, which are in full bloom. Due to the stability and balance on the composition, it appears to be orderly, fine and delicate, and there is no sense of chaos.

**Figure 6:** Cave 331

Curl petal lotus: Looking from the outside, it is a round shape, the petals are curled inward, and the shape has a three-dimensional sense, like a lotus waiting to be released. In the center of the lotus pattern is sometimes painted with Kalavindotabvka pattern, three rabbits pattern or dragon pattern, the shape is very exquisite. It was a new type of lotus pattern that appeared in the middle Tang Dynasty (782-847 AD) and continued to be used in Five Dynasties (907-979 AD). Such as cave 146 of the Mogao grottoes of the Five Dynasties (Figure 7) is a lotus caisson of tuan dragon and parrots. Caisson center painting tuan dragon curl petals lotus, the dragon is in the green pool, with vivid expression. Outer ring with cirrus moire large garland, the garland is surrounded by parrots, the parrot has green body and blue wings, and the colorful clouds set off. The cyan and green lotuses are blended with the golden dragons, the combination of movement and static makes the picture beautiful and harmonious.

**Figure 7:** Cave 146

In short, in different periods, the caisson lotus pattern has different development paths and evolution processes. With the development and changes of social economy and communication with other countries, people's aesthetic tastes have also changed. The popular shape before the Tang Dynasty was simple round-shaped lotus and flat-petal lotus were replaced by the complex and colorful Baoxiang flowers after entering the Tang Dynasty. Afterwards, there appeared a simple, dynamic curling petal lotus.

### 3.2 Geometrizing the lotus pattern

This article takes the simple shape of the flat-petal lotus as an example, and uses the diagramming method by compasses and straightedge ruler used in the Islamic geometric pattern to geometricize it.

First, take the Cave 401 caisson lotus as an example, using CorelDRAW software to draw, to elaborate on the geometric process of lotus pattern.

(1) Straight line is used to connect AB and CD, the two lines intersect at point O, and O is taken as the center of the circle and OA as the radius, as shown in Figure 7(a). At this time, it can be seen that almost all the tips of the petal are on the circumference.

(2) Using O as the center of the circle, draw the three inner concentric circles, as shown in Figure 7(b).

(3) First, copy line segment AB, and then rotate line segment AB by 45° and 90° respectively, to get line segment EF, GH. The ends of the two segments just fall on the tips of the petal, as shown in Figure7(c).

(4) Line segment AB, CD, EF, GH are combined and copied, and then rotated by 22.5°. It can be seen that the copied line segment fell on the junction of petals, as shown in Figure 7(d). As can be seen from the figure, each petal is located at one eighth of the circle formed by the outermost circle and the adjacent circle.

(5) Copy the outermost circle, scale it to point J. It can be seen from the figure that the red line segment and the red circumference have intersection points, and these intersection points are the key points of petal shape. At this point, the two petals are separated, and the ends of the petals are shaped in an arc, as shown in Figure 7(e).

(6) Connect the key points formed by the red line segment and the red circle with points A, C, H, F, B, D, G and E to form the petal structure line, as shown in Figure 7(f).

(7) Copy the outermost circle and scale to the intersection point K where the blue and white petals intersect. It can be seen that the intersections of blue layer petals and white layer petals are on the blue circle. Then connect these intersection points with the intersection points of the red line segment and the outermost circle respectively, to form a blue petal structure, as shown in Figure 7(g).

(8) Remove the auxiliary lines in the figure to obtain the geometric figure of cave 401 lotus, as shown in Figure 7(h).

According to the above method, the lotus in caves 407 and 249 are geometricized respectively, as shown in Figures 8 and 9. The geometric lotus pattern not only simplifies the lotus pattern shape, but also retains the structural characteristics of the original.

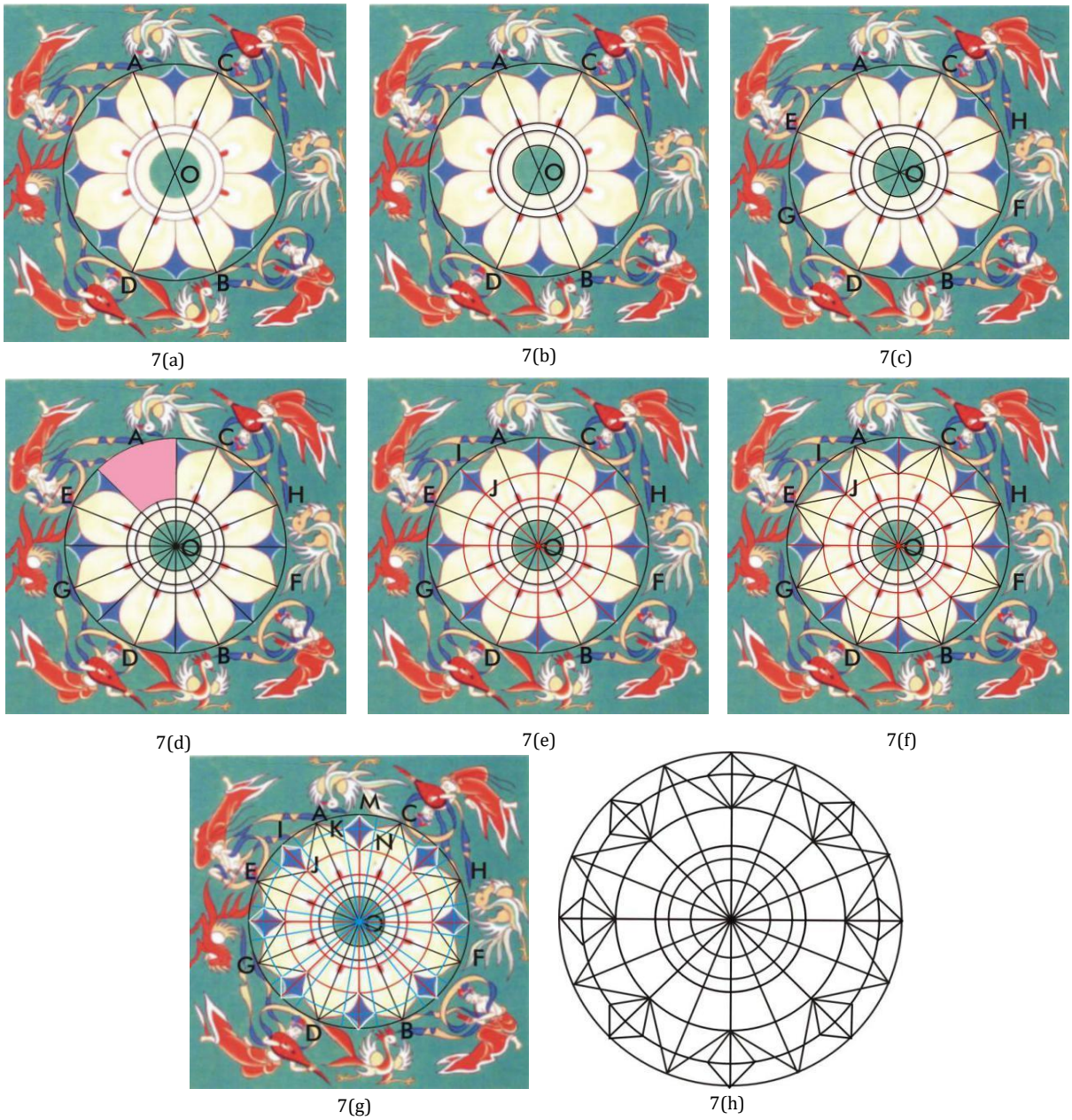
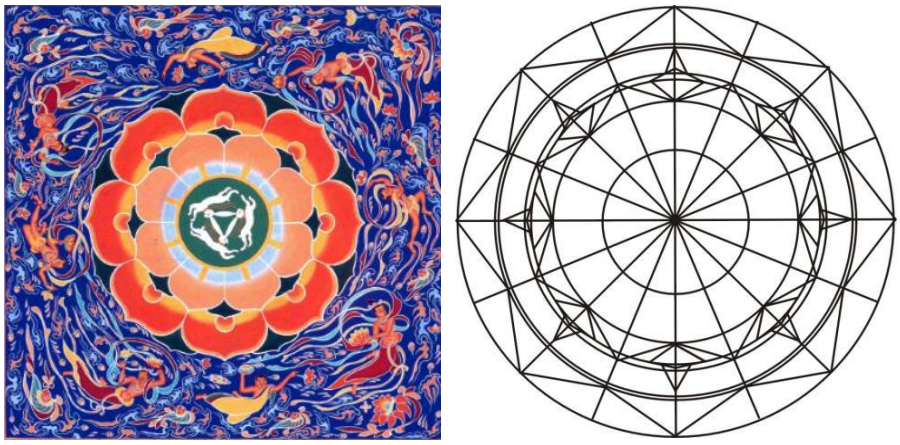



**Figure 7:** Geometric Process of Lotus Pattern



a b

**Figure 8:** Original Image of Cave 407 (a), Geometric Image (b)

a b

**Figure 9:** Original Image of Cave 249 (a), Geometric Image (b)

### 3.3 Evolution of lotus pattern based on shape grammar

The shape grammar was first proposed by George Stiny and James Gips and applied to painting and sculpture creation. It was later extended to innovative design, product brand recognition and other fields. It is a design method based on calculation laws. According to the definition of Stiny and Gips, shape grammar (SG) can be expressed as: *SG = (S, L, R, I)*

In the formula, S is a finite set of shapes, and SG is a shape set derived from S through translation, rotation, mirroring, etc. L is the finite set of labels, R is the finite set of inference rules, and I is the initial shape. During the evolution of the actual pattern, the initial shape is the typical pattern extracted from the pattern. The basic operation is to evolve the shape of the initial shape through certain rules. Commonly used shape grammar evolution rules include translation, scale, mirror, copy, rotate, and adjustment etc. A simple figure is taken as an example to illustrate the process of getting the pattern of the initial shape through different shape rules (Figure 10). The left side is the initial shape, and the right side is the shape generated after applying the evolution rules.

According to the evolution rules of shape grammar, the geometric patterns of Cave 401, Cave 407 and Cave 249 are evolved. In order to retain the structural characteristics of the traditional lotus pattern, this article takes all geometric shapes as the initial shape, and then uses the evolution rules in Figure 10 to obtain new patterns. The specific evolution process is shown in Figure 11.

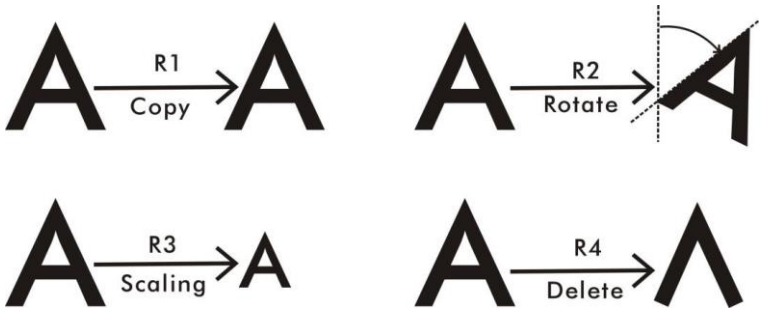



**Figure 10:** Evolution Rules

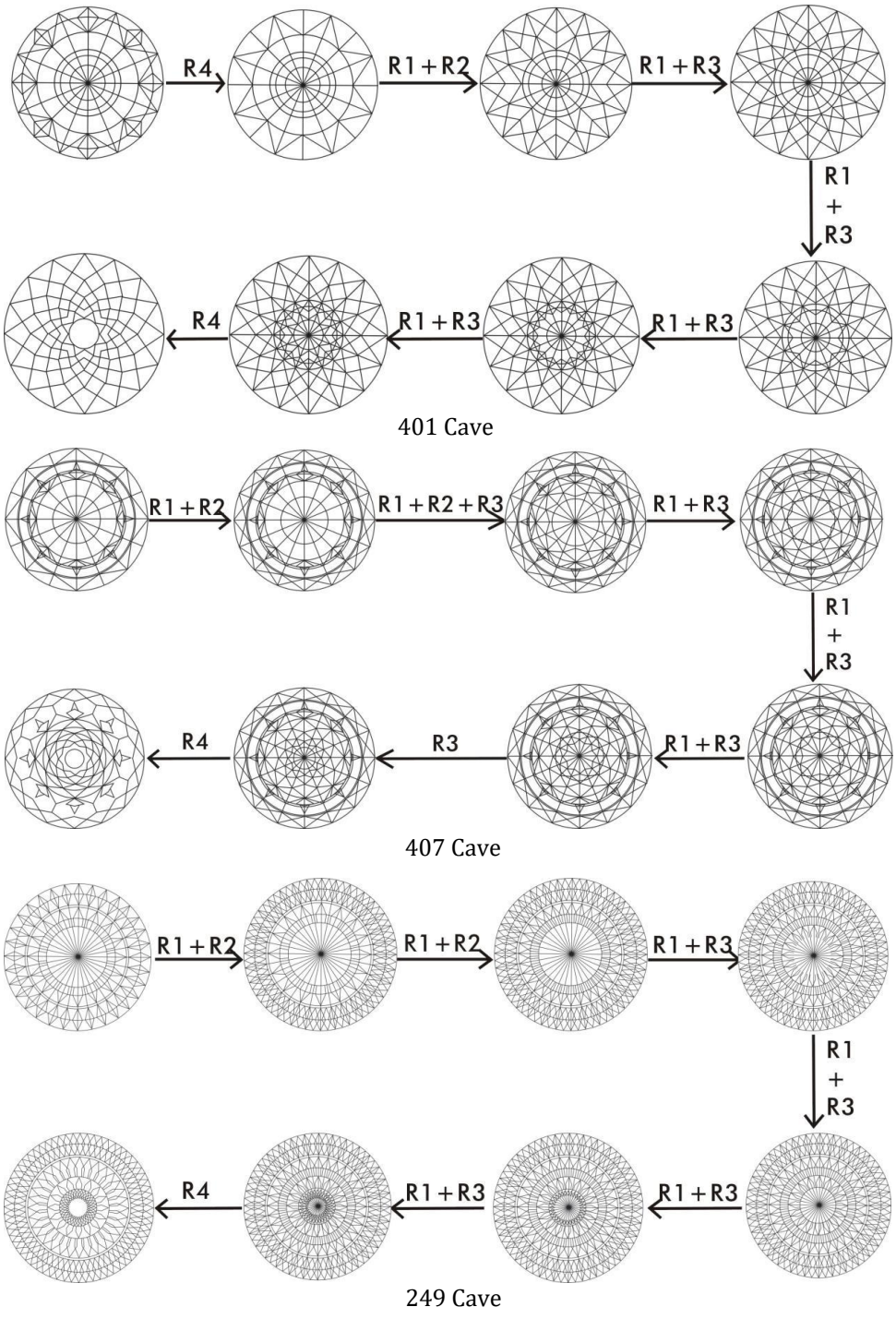



**Figure 11:** The Evolution Process of Lotus Pattern

### 3.4 Coloring the new pattern

After the lotus pattern evolved through the shape grammar, a new pattern was obtained, which was then filled with the classic blue and white colors to simulate the effect of the indigo dye fabric pattern. The effect of the color is shown in Figure 12.

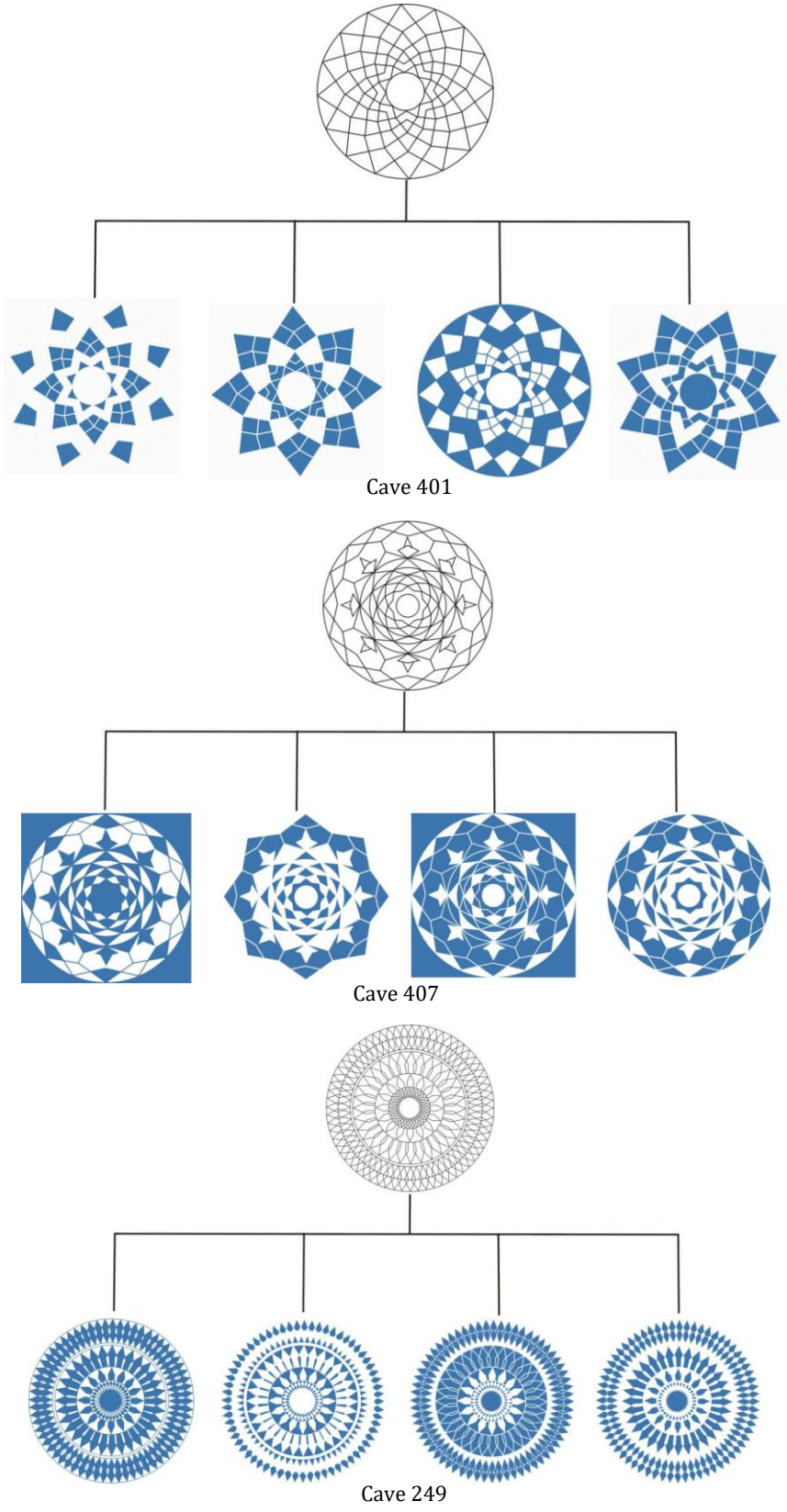



**Figure 12:** Coloring the New Pattern

## 4. RESULTS AND DISCUSSION

In order to verify the design effect, the consumption target of this study is the college students born after 1990 are a special consumer group of this era. Because of their special social roles, their consumption behavior and consumer psychology are more complicated. Studies have pointed out that the consumption potential of this age young people is huge, and it is the diamond consumption class in the new era. In this study, the application effect of the redesigned lotus pattern on T-shirt is demonstrated, for patterns 1, 4, 6, 7, 8, 9, 11, adopt the emphasis principle, only select the part of the pattern to enlarge it, and apply it on the shoulder and front of the T-shirt, which are the visual attention areas, so as to achieve the effect of highlighting the pattern. Patterns 1 and 2 are applied to the left or right side of the front, respectively, giving a sense of asymmetry. The patterns 2, 3, 5, 10, 12 use the repetition principle, and then place it in a more modern triangle, rectangle and other frames, and apply it to different parts of the T-shirt to produce different visual effects, as shown in Figure 13. Then, in the form of a questionnaire, the evaluation results of college students on the T-shirt pattern were collected.

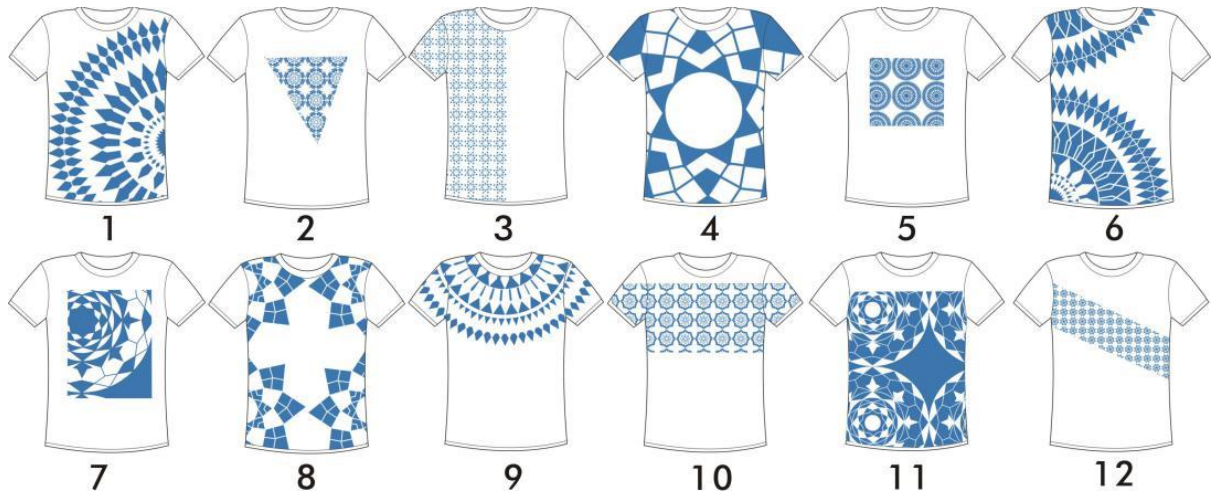



**Figure 13:** Application of the New Lotus Pattern on T-shirts

As for the setting of the questionnaire, this study used the semantic difference method to conduct evaluation experiments, which is commonly used in the Kansei engineering theory. First, invite design related professionals to choose semantic adjectives that can appropriately describe the pattern style from the collected 30 sets of adjectives, after removing the adjectives with overlapping meanings and inappropriateness, the 6 most frequent and appropriate adjectives were selected, they are simple - complex, innovative - outdated, abstract - figurative, quiet - fancy, neatly - disordered, unique - ordinary, respectively. Then, the T-shirt with new lotus patterns and perceptual adjectives are combined using a Likert 5 scale. Take the perceptual adjective "simple - complex" as an example: 1 point is very simple, 2 points are a bit simple, 3 points are neither simple nor complex, 4 points are a bit complex, 5 points are very complex. Finally, online questionnaires were distributed to college students. A total of 100 questionnaires were sent out, 95 valid questionnaires were returned and the recovery rate was 95%. The results of 95 surveys were processed by Excel software, and the average value of each pattern under each perceptual vocabulary was obtained. It has been observed that if the score is 3, it means neutral attitude, but the score is in the range greater than 3 or less than 3, it is difficult to select an adjective with a high score from the 6 pairs of words by simple average value calculation. In order to more clearly express the perceptual trends of the respondents, the data must be further processed. The questionnaire was designed using the five-level scale method. 3 is the watershed, which corresponds to the origin on the coordinates. The further the score is from 3, the fleeing is more obvious. Therefore, the calculation method here is: subtract the score from 3, and then take the absolute value, if the average value score is less than 3, it is mainly a left adjective feeling, if it is greater than 3, it is a right adjective feeling. For example, perceptual adjective simple-complex, if the average value is 2, then | 2-3 | = 1, 1 means simple feeling, if the average value is 4, then | 4-3 | = 1, 1 means complex feeling, the absolute value score is shown in Table 2.

**Table 2:** New Lotus Pattern's Perceptual Evaluation Results

| Sample number | Simple - Complex | | Unique- Ordinary | | Abstract - Figurative | | Quiet- Fancy | | Innovative- Outdated | | Neatly - Disordered | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average value score | Absolute value score | Average value score | Absolute value score | Average value score | Absolute value score | Average value score | Absolute value score | Average value score | Absolute value score | Average value score | Absolute value score |
| **1** | 2.9 | 0.1 | 2.2 | 0.8 | 3.3 | 0.3 | 2.5 | 0.5 | 2.3 | 0.7 | 2.2 | 0.8 |
| **2** | 2.3 | 0.7 | 1.9 | 1.1 | 2.8 | 0.2 | 2.7 | 0.3 | 1.5 | 1.5 | 2.5 | 0.5 |
| **3** | 2.1 | 0.9 | 2.7 | 0.3 | 3.2 | 0.3 | 2.6 | 0.4 | 2.6 | 0.4 | 2.3 | 0.7 |
| **4** | 3 | 0 | 2.8 | 0.2 | 3.5 | 0.5 | 2.8 | 0.2 | 2.8 | 0.2 | 2.7 | 0.3 |
| **5** | 3.4 | 0.4 | 1.8 | 1.2 | 2.4 | 0.6 | 2.6 | 0.4 | 2.1 | 0.9 | 2.4 | 0.6 |
| **6** | 3.3 | 0.3 | 1.6 | 1.4 | 2.6 | 0.4 | 2.4 | 0.6 | 1.8 | 1.2 | 2.6 | 0.4 |
| **7** | 3.3 | 0.3 | 2.4 | 0.6 | 2.8 | 0.2 | 2.4 | 0.6 | 2.7 | 0.3 | 2.9 | 0.1 |
| **8** | 2.7 | 0.3 | 2.6 | 0.4 | 3.4 | 0.4 | 2.5 | 0.5 | 1.7 | 1.3 | 2.6 | 0.4 |
| **9** | 3.2 | 0.2 | 1.9 | 1.1 | 2.6 | 0.4 | 2.3 | 0.7 | 2.1 | 0.9 | 2.5 | 0.5 |
| **10** | 3.1 | 0.1 | 2.6 | 0.4 | 3.3 | 0.3 | 2.7 | 0.3 | 2.6 | 0.4 | 2.4 | 0.6 |
| **11** | 3.4 | 0.4 | 2.7 | 0.3 | 3.4 | 0.4 | 2.8 | 0.2 | 2.8 | 0.2 | 2.7 | 0.3 |
| **12** | 2.8 | 0.2 | 2.6 | 0.4 | 3.7 | 0.7 | 2.6 | 0.4 | 2.3 | 0.7 | 1.8 | 1.2 |

Pick the top two perceptual adjectives with the highest scores from each patterns' absolute value score and the top two patterns with the highest scores for each set of perceptual adjectives (if the scores are parallel, then select the adjectives in parallel), as the main feeling of people.

From the average value score in Table 2, it can be seen that all new lotus patterns have a unique, quiet, innovative and neat feeling, because the score is below 3. Among them, the new patterns of cave 407 and cave 249 are quite unique, scoring less than 2 points. From the top 2 highest scores of the adjective and the absolute value score of each pattern, it can be seen that pattern 1 mainly gives a unique, neat and innovative feeling, pattern 2 is more innovative and unique, and the evaluation score with simple characteristics is also higher among all patterns, pattern 3 gives a simple, neat feeling, the overall feeling of pattern 4 is relatively mediocre, except that the absolute value score of the figurative and neat feeling is slightly higher, and the scores of other adjective groups are relatively close to 0 points, pattern 5 has a strong uniqueness, but also gives an innovative, abstract feeling, the absolute value score of the unique adjective of pattern 6 is the highest among all patterns, and the innovation score ranks in the top 3, and the quiet feeling is also strong, pattern 7 gives people a unique, quiet and a little innovative, complex feeling, pattern 8 is also highly innovative, but other feelings are relatively neutral, except for the quiet feeling, the absolute value scores of other adjectives are all around 0.4, pattern 9 has strong uniqueness and innovation, and the quiet feeling is also the strongest, pattern 10 and 11 are relatively mediocre, except for pattern 10, which gives people a slightly neat feeling, other adjectives score very low, the absolute value score of the adjectives with pattern 11 is relatively low, except that they have a little simple and abstract feeling, and the score is 0.4, while the score of other adjectives is about 0.3, the neat feeling of the pattern 12 is the strongest of all the patterns, followed by abstract and innovative feeling.

In short, each new lotus pattern gives a different feeling, and it is more in line with modern aesthetics as a whole.

## 5. CONCLUSION

By observing and summarizing the caisson lotus patterns, in this study according to the petal shape of the lotus pattern in the center of the caisson, the lotus pattern is divided into round-wheel lotus, flat-petal lotus, peach-shaped lotus, curl petal lotus and Baoxiang flower. The Tang Dynasty was the most prosperous period in Chinese history, and the lotus pattern also changed significantly at this time. Before the Tang Dynasty, the simple shape and color of the round-wheel lotus and the flat-petal lotus were popular. After entering the Tang Dynasty, the peach-shaped lotus was used as the transition, which was then replaced by the complex shape and gorgeous color Baoxiang flower. Later, as the economy went down, people began to pursue the simple shape and dynamic curl petal lotus.

Using the diagramming method by compasses and straightedge ruler, a geometrical lotus pattern structure was obtained. Then according to the shape grammar, the geometric structure is taken as the initial shape, and the four evolution rules of copy, rotation, scaling and deletion are used separately or in combination to carry out the structural evolution of lotus pattern. Finally, the evolving patterns were colored, and the new patterns with both innovative and traditional lotus pattern structure characteristics were obtained.

The Kansei engineering theory was used to evaluate the design effect of lotus pattern applied to the T-shirts that were very popular with the college students, and the quantitative score of the feeling of each pattern was obtained. Through the analysis of the score, it can be seen that the 12 lotus patterns of the innovative design have unique, quiet, innovative and neat features, and the main feeling of each pattern is specifically found out. Among them, patterns 5 and 6 are more unique, patterns 2 and 8 are more innovative, and pattern 3 has a simple feeling, pattern 12 looks more abstract and neat than other patterns, patterns 7 and 9 have a strong sense of quiet, patterns 4, 10, and 11 are relatively neutral, this shows that the design of the new lotus pattern is basically in line with the aesthetics of college students.

It is hoped that the research results in this paper can provide meaningful reference value for the innovative application of traditional patterns, so that traditional patterns can be better passed down and developed.

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