

Research on the innovative design of composition based on multi-objective optimization in Shaanxi folk women's red ornaments

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ABSTRACT

Shaanxi folk women's red has beautiful graphic patterns, which is a treasure of Chinese folk culture. In order to better realize the inheritance and innovation of folk women's red, this paper refers to the idea of multi-objective optimization, and innovatively designs the composition of ornaments through genetic algorithm and bipartite continuous pattern design method. In order to find out the deep meaning and cultural value of Shaanxi needlework decoration and the unique aesthetic, emotional and life experience of women hidden behind the decoration. In addition, further research on Shaanxi needlework decoration art through multi-objective optimization will not only help to deeply understand the common characteristics of national art, but also help to deeply understand the characteristics of folk art itself. The research shows that the composition scheme designed in this paper has been positively evaluated by experts and consumers, and can promote the inheritance and innovation of Shaanxi folk needlework.

Keywords: Genetic algorithm, bipartite continuous pattern generation, multi-objective optimization, women's red decoration, compositional innovation design

1. Introduction

Female red is an important part of the material and spiritual civilization of the Chinese nation, it is the crystallization of female wisdom and talent, but also the product of women's aesthetic consciousness, in the creation of women full of women's understanding of beauty and the pursuit of the visual and spiritual construction of the Chinese nation's living art library, they nourish the spirit of the nation with the simplicity and grandiose, but also for the world's civilization to add a brilliant color [1-3].

Women's red is the fruit of women's wisdom and creation, but also the product of women's unique aesthetic consciousness, full of women's understanding and pursuit of beauty in the creation of the

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form of beauty and emotion to construct the Chinese nation's historical, living, rich art treasury, which nourishes the spirit of the nation with simplicity and grandeur [4-5]. In today's ever-changing world, women's red as a carrier of women's aesthetic education will be endowed with a new value of the times [6].

Chinese folk art of red women in the process of creating beauty and expression of beauty to enhance women's perception of the beauty of life, and this beauty is expressed through the form of decorations, the study of folk red women's decorations is the study of red women's art of the essence of the art, because the traditional women's embodiment of the beauty and emotion, all through the red women's decorations, the women's emotions in the decorations, borrowed to pass on the feelings [7-9]. In the folk red women's decorations often use exaggerated deformation of the modeling method, through changes in shape to show the beauty of things, fully reflecting the folk women's strong creativity and rich imagination. They are not subject to the constraints of real life in their creations, between the similarity and the dissimilarity, seize the main features and demeanor of things to be handled flexibly, in the limited plane space to show the aesthetic visual effect of three-dimensional space [10-12]. Here in the countryside, women can show their talents and express their feelings, they can paint mountains and embroidered water can also depict dragons and phoenixes, no matter flowers, birds, fish and insects, birds and beasts, myths and legends, and historical allusions can be the subject matter of creation [13]. The profound aesthetic ideas and transcendent modeling skills expressed therein are enough to make people marvel and fall in love with them. In the contents of their works, they are able to combine different time, space and objects together, and combine different shades as well as separate the same shade. The colorful silk thread in their hands is the painter's pigment, and they can paint the ideal picture in their hearts by waving and smearing at will [14-15].

Folk red women's graphic arts have a unique autochthonous cultural system just like other arts, as an important part of women's splendid cultural system, the art of red women's graphic arts has different techniques and procedures, as well as ever-changing decorations and norms, which have inherent creativity and openness, and have attracted attention of the world with their unique artistic connotations and aesthetic values [16-17]. Therefore, a systematic study of folk red women's iconography is not only of great value and significance to the inheritance and development of traditional Chinese national culture, but also has a profound impact on the development and innovation of modern art [18].

This paper adopts genetic algorithm and bipartite continuous pattern design method to generate innovative composition of Shaanxi folk women's red ornaments. The patterns of female red ornaments are combined and arranged, and the initial pattern is designed by two methods: bipartite continuous organizational structure and bipartite continuous formal bone method, and then the continuous pattern is adjusted with the help of the pendulum line, so as to generate the innovative pattern design. On this basis, genetic algorithm is utilized to further perform multi-objective optimization of the generated initial tattoos. The doubles structure is introduced to represent the individuals in the genetic algorithm of real number coding, and the original genetic algorithm is improved by using complex number coding to enhance the diversity of the compositional generation of women's red pattern. Finally, the evolutionary time consuming, evolutionary algebra, eye movement data, expert evaluation and commercial value of the composition generation results are verified respectively.

2. Shaanxi folk needlework figure decoration

2.1. Historical and cultural background of needlework art

2.1.1. Needlework Art. The social division of labor of "male ploughing and female weaving" and "male leading outside and female leading inside" is a generalization of the gender division of labor in Chinese traditional agriculture, and it is also the basic characteristics of people's production and life in agricultural society. Therefore, the term "needlework" is used to refer to the domestic manual work

performed by women, including embroidery, paper cutting, textile, pulp dyeing, sewing, and the finished products of these works.

Needlework art is a unique cultural phenomenon in China. This needlework technique has been passed down from mother to daughter, mother-in-law and daughter-in-law from generation to generation. Needlework, a treasure of folk art, is the perfect combination of traditional Chinese women's emotions and wisdom, which reflects the traditional women's character of tolerance and tolerance, and places their beautiful longing and expectation on life. At the same time, because women have been subject to the patriarchal society for a long time, it is difficult to express their emotions and wishes freely, so they use the graceful, implicit and symbolic methods to vent the complex emotions hidden in their hearts through needlework.

2.1.2. The expression of women's own demands. In the long-term feudal ethical bondage, the love of young men and women is not free, the woman uses the way to throw hydrangeas to choose a partner, and the girl carries the carefully embroidered flower hydrangeas in her hand. The girl saw the young man, then threw the colorful hydrangea to him, the young man took the hydrangea if satisfied with the girl, then his small gift wrapped in the hydrangea to throw to the woman.

The girls embroidered purses, made insoles, woven hand towels, and sewn hydrangeas are some of the tokens of love, some of the supplies for marriage. The pattern content has birds and animals, insects and fish, flowers and fruits, etc., delicate and beautiful and full of creativity, showing a strong rural taste and personal aesthetic hobbies, so needlework is not only a practical item, but also a comfort and sustenance of women's self-feelings in another sense.

2.2. *Features of folk needlework embroidery in Shaanxi*

There are many kinds of folk embroidery in Shaanxi, with a wide range of themes and rich contents, mainly insects, birds, flowers, melons, fruits and trees, fairy tales and so on. Its style is simple, the color is bright, the thread is thicker, the stitch is unrestrained, has the distinct local characteristics. Shaanxi folk embroidery is closely connected with rural customs such as wedding festivals, so these embroidery works have been passed down from generation to generation with traditional customs. Shaanxi folk embroidery is eclectic in needles and threads and color matching. It eulogizes the important and ancient life theme of life reproduction with its strange imagination, full and full composition, bright and strong colors, and flowing and flying momentum, thus forming the basic style of Shaanxi embroidery. A naive and playful fish wagged its head and tail, slipping into the delicate and shy lotus, showing a relaxed look. There is also a pattern embroidered on the child's belly to reveal a white fat baby from the lotus, lovely and full of childlike interest.

Another example is "pomegranate hundred seeds", showing the good wishes of many children and family reunion, and the local working people use this symbolic technique to express love, fertility and descendants. In folk embroidery cloth tiger, cloth lion and cloth pillow, hanging ornaments and other cloth art, called cloth soft carving. Cloth soft carving with embroidery, drawing, spelling, filling and other methods of production, etc., the most representative of which is the pillow, there are frog pillow, tiger pillow, cat pillow, dog pillow, chicken pillow, turtle pillow, cow pillow, etc., the shape of vigorous atmosphere, with the Qin, Han sculpture legacy. There are cloth tigers, dogs, cloth horses and other toys, filled with a strong and warm taste of life. These cloth toys have a unique regional style in shape, and the colors in the folk needlework decorations in Luochuan and Huangling are mainly white, including white tigers, white elephants and white dolls.

3. Innovative design and multi-objective optimization method for the composition of the female red ornaments

3.1. Genetic algorithms

3.1.1. Overview of genetic algorithms. Genetic Algorithm (GA) is one of the best search algorithms and optimization algorithms in mathematics, and this algorithm is mainly expanded with the help of some of Darwin's ideas, focusing on the analysis of the characteristics of heredity, mutation and hybridization. The natural evolutionary process is constantly optimized and unfolded in the process of constructing the model, and the search method evolved by drawing on the mechanism of superiority and inferiority, which has inherent hidden parallelism and a strong ability to search for the best globally. Genetic algorithms start from a potential population, which is a combination of multiple individuals with different codes. Chromosomes serve as the main carriers, which determine the external shape of the individuals. In the initial population, better approximate solutions are gradually generated according to the natural evolutionary principle, individuals are selected based on their fitness, and then combinations of crossovers and mutations are combined to produce a new population. This process enables the new population to be able to be superior to the initial population, and the optimal individuals in the latest population can be used as the approximate optimal solution to the problem [19].

3.1.2. Principles and Applications of Genetic Algorithms. Good global search ability and parallelism combined with the open concept makes the genetic algorithm and other algorithms combined with a very high degree. In order to promote the development of genetic algorithms, genetic algorithms can be continuously improved and refined in accordance with practical needs.

In practice, it can be found that the operation principle of genetic algorithm is simple and convenient, the application is very wide, the use of flexible methods, can be a good solution to a variety of problems.

In order to solve the various shortcomings of the genetic algorithm, it is necessary to combine and improve the genetic algorithm according to the genetic operation and various coding strategies, so as to achieve the optimal solution of the optimization results.

1) Composition of the initial population. A random function is utilized to form an initial population of N number of individuals. The first step is to measure the population size. The commonly used method is to label the size of the population by using 50 or multiples of 50 as the initial value. From past research experience, it is known that the size of the population is directly related to the success rate and quality of the model solution. If the size of the population is not set reasonably, the problem of local optimal solution will occur.

2) Coding scheme. Coding method is the basis of genetic algorithm, and the level of coding directly determines the quality of the solution. Since the genetic algorithm was proposed, after years of development, many different coding methods have been formed, among which the most widely used are hybrid coding, binary coding and real number coding.

3) Selection of fitness function. Selection of the fitness function of the selection of the fitness function must meet two conditions: the early stage does not appear "premature" phenomenon. Later does not appear "decline" phenomenon. Only in line with these conditions of the fitness function in order to improve the fitness of individuals and individuals, reduce the differentiation, from the overall optimal results.

From the practical point of view, this transformation process is relatively simple. The formula is as follows:

$$\min f(x) = \max(-f(x)) \quad (1)$$

When the total take of the desired optimization result is positive, it indicates that the desired optimization result is substantially similar to the problem of individual fitness:

$$F(X) = f(x) \quad (2)$$

Optimization between the corresponding individuals is achieved by adjusting the overall fitness function, objective function and constraints to ensure the optimal solution that can be obtained at the moment:

$$F(X) = \alpha f(x) + \beta \quad (3)$$

Above, $F(X)$ is the fitness function, α is the norm, $f(x)$ is the objective function, and β is the constant coefficient. The objective function can be scaled and translated. Among the coefficients are determined in various ways, for example:

$$\alpha = \frac{(C_{mult} - 1)f_{avg}}{f_{max} - f_{avg}}, \beta = \frac{(f_{max} - C_{mult}f_{avg})f_{avg}}{f_{max} - f_{avg}} \quad (4)$$

Or:

$$\alpha = \frac{f_{avg}}{f_{avg} - f_{max}}, \beta = \frac{-f_{min}f_{avg}}{f_{avg} - f_{min}} \quad (5)$$

3.1.3. Genetic manipulation operators:

1) Selection operator. The selection operator is based on the different fitness of different individuals, the state of the chromosome in the next stage depends on the degree of optimization and limit performance of the chromosome, the individual with high fitness will continue to be replicated in the next stage, and the individual with low fitness will be eliminated in the next stage. The operation strategy is to retain the best individuals, prevent the emergence of local optimal solutions, and adhere to the elite retention strategy. In genetic algorithms, the selection operator plays a role in avoiding the destruction of spacer genes and improving the computational efficiency as a whole. The main selection methods of selection operator are betting wheel selection method and random selection method. In this paper, we mainly choose the betting wheel selection method.

2) Cross operator. Crossover operator is mainly based on specific principles and methods to carry out calculations, in the process of random selection of the whole group, need to ensure that the chromosomes meet the requirements of the relevant exchanges, which can make the overall optimization effect is the best. The main function of the variation operator is to maintain the diversity of the population.

3) Genetic algorithm termination conditions. There are two ways to terminate the genetic algorithm:

(1) Setting the number of iterations of genetic evolution. At the beginning of the actual operation, the number of iterations is set artificially, and the value is stipulated as a fixed value, and when the number of genetic evolution iterations reaches this value, the operation will be stopped automatically.

(2) Utilizing the difference control of fitness value. That is, the observation of the best individual, after a period of iteration number is still no change or change is very small, then at this time can be artificial genetic algorithm has converged and fall into the local optimal solution. The main effect is to ensure that the overall adaptation of the calculation is better, so that in the middle and late genetic algorithm can also be calculated according to the number of iterations to design the overall number of calculations, and to ensure that the adaptation of the target threshold to match each other with the actual.

(3) Genetic algorithm operating parameters control. When using the genetic algorithm, in order to ensure that the algorithm successfully achieves the established goals, first of all, it should set clear control parameters. The control parameters include crossover rate, mutation rate and termination iteration number, etc. In order to optimize the performance, all the main parameters are usually arranged in combinations, and the parameters obtained from these combinations are operated, and the results obtained from the operation are finally compared and comprehensively analyzed to select

the optimal control list. The results are compared and synthesized to select the optimal control list. Or the specific parameter analysis values are determined based on the judgment of professional teachers or scholars and past research experience.

3.2. *Innovative Design Methods for Figurative Pattern Composition*

Women's red decorative composition innovation first need to pattern in accordance with certain rules, combined into a whole pattern, that is, to generate the border pattern. Because of the characteristics of the border pattern, in this paper, we mainly draw on the generation method of bipartite continuous pattern to realize. And with the help of mathematical curves to adjust, making the pattern more vivid and colorful.

3.2.1. Design methods for bipartite continuous patterns. The design method of bipartite continuum can be divided into two aspects: organizational structure and formal bone method [20].

1) Organizational structure of bipartite continuum:

(1) Patterns composed of individual patterns. Including: scattered, horizontal, diagonal, upward, downward up and down. It is a kind of individual pattern as the content, in accordance with a certain order of organization, arranged into a bipartite continuum.

(2) Patterns composed of continuous patterns. Including: continuous circular, circular, water wave, vortex type. This kind of pattern is relying on horizontal lines, wavy lines, or other forms of connecting lines as the basis, and then according to the specific circumstances, fill the unit pattern and composition.

(3) Patterns based on a combination of pattern composition. Including: alternating, layered, interspersed, spaced, and combined and independent. It is a combination of two or more different forms of patterns, compositional patterns.

2) The two sides of the continuous form of bone method. Border pattern in the form of organization not only requires patterns have beautiful and vivid shape, and strive to show the pattern organization of a high degree of formatting and rhythm.

(1) Scattered: in a prescribed length and width of the long strip, according to the need for the length of the unit is divided into equal parts, and then to the left and right (or up and down) on both sides, in order to arrange the unit pattern, between the pattern should maintain a certain spatial distance. Its organization is characterized by its pattern in the composition of a point, the connection between them is mainly a spatial echo, the whole is not connected. Scattered points of the organization should be avoided to avoid scattered, to increase the echo relationship between the strong points, so that the shape of the scattered and temperament coherent. Layout should be large and small points, sparse and dense changes appear lively, rich, showing the characteristics of scattered points.

(2) Linear: the difference between linear and scattered is mainly the different direction of the arrangement of the unit pattern. In the linear style, the unit pattern has a clear direction, can be vertical, can be horizontal, can be up or down, can also be up and down alternately. Can be arranged at an angle, side by side, interspersed and other forms. It can also be arranged in the form of folded lines, with right-angled, acute-angled and obtuse-angled arrangements. The overall effect is crisp and clean.

(3) Interval type: this type of change is rich, characterized by the unit pattern, usually contains a major pattern and a secondary pattern, from which they form an indivisible unity, and repeated successive appearances. These secondary patterns not only have the role of spacing and embellishment, but also can enhance the artistic effect of pattern contrast and change, while improving the pattern structure and rhythmic beauty.

3.2.2. Pattern generation process. The process of designing the composition of bipartite continuous pattern is as follows:

Step1 Select skeleton: You can choose one of the basic skeleton forms such as scattering type,

straight line type, etc.

Step2 Design Patterns: Select the required patterns in the pattern library evolved from the previous contents of this chapter.

Step3 Copy: Copy the selected pattern and fill it into the skeleton.

Step4: Adjust the distance and position between the copies of the tattoos, so as to make them sparse and dense to produce a certain sense of rhythm. In this paper, we have introduced manual adjustment and the use of mathematical curves to automatically adjust the two options.

Step5 coloring: according to the actual need, give the appropriate color to the pattern.

3.2.3. Mathematical curve orthography. Among the many math curves are many beautiful ones. For example, the pendulum line, the cloverleaf curve, the Archimedean spiral, and so on. There are many curves that are very common in our daily life and have very amazing properties in themselves. Pendulum line is also one of the many curves in the mathematical curve, it can not only be used in a variety of mechanical design, itself also has a very strong decorative, this paper draws on the decorative nature of the pendulum line to adjust the continuous pattern.

The parametric equation of the trajectory curve of the pendulum line is:

$$\begin{cases} X = at - d \sin t \\ Y = a - d \cos t \end{cases} \quad (6)$$

Equation (6) shows that the relationship between the sizes of a and d will cause different pendulum trajectories. Through equation (6), we can see that different pendulum trajectories can be obtained by controlling parameters a and d , and the shape of the pendulum is very sensitive to these two parameters, and also consider adding the two characteristics of the thickness and color of the pendulum, so a pendulum can be defined as follows:

$$\text{Cycloid} = (a, d) \quad (7)$$

Where a is the radius of the moving circle and d is the distance between the fixed point and the center of the rolling circle.

The adjustment steps are as follows:

Step1: First determine the center point of each copy, which can be determined by the method of the diagonal intersection of its outer rectangle.

Step2: Design a pendulum line and make the center point of each copy situated at the lowest and highest point of the pendulum line respectively in order. That is, $t = k\pi (k = 0, 1, 2, \dots)$.

Step3: Adjust the shape of the pendulum line by adjusting the parameters a and d , and through the adjustment of the pendulum line shape, in order to achieve the purpose of the positive draft.

Through the process of normalizing, a more delicate and vivid pattern can be obtained. At the same time, the idea of permutation and combination can also be introduced in the process of regular drafting, so that the pattern composition presents a continuous momentum.

4. Analysis of algorithmic experimental results

4.1. Algorithm performance metrics

4.1.1. Total duration of evolution. A comparison of the total evolution time is shown in Figure 1. The total evolution time for each composition case using the composition generation algorithm in this paper is significantly reduced compared to using the comparison algorithm IED. The total time to complete the composition design task for the twenty composition task samples using this paper's algorithm (192.03 seconds) was reduced by an average of 53% compared to using IED (408.61 seconds). This indicates that the samples can obtain a satisfactory compositional solution for the figure decoration in a short period of time using the algorithm of this paper.

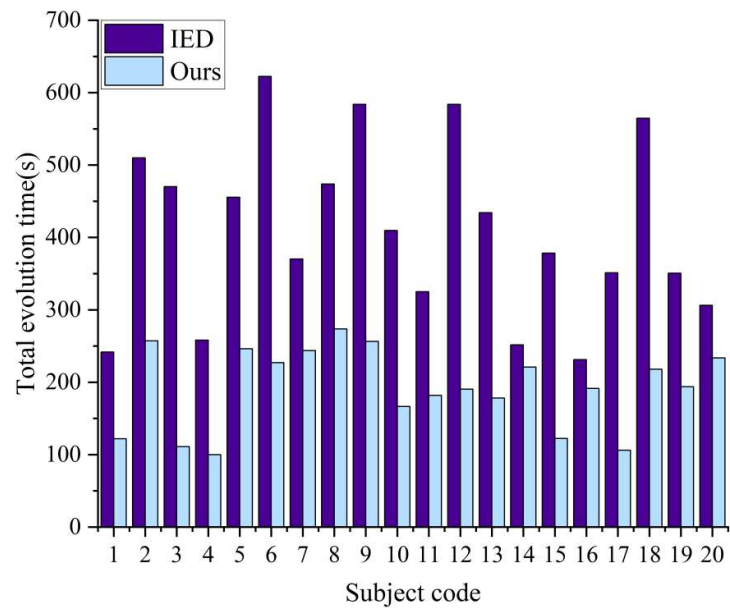


Fig. 1. Total evolution time (Our method vs IED)

4.1.2. Length of evolution of a single individual. The individual composition task time comparison is shown in Figure 2, where all the composition samples completed the composition design task in a shorter time when using this paper's algorithm. Compared with IED (4.13s), the time spent by a single individual of twenty composition samples using the method of this paper (2.3s) is reduced by 44.37% on average. This suggests that the improved genetic algorithm in this paper generates graphic ornament compositions, which effectively simplifies the user operation and thus realizes the innovative design of compositions faster.

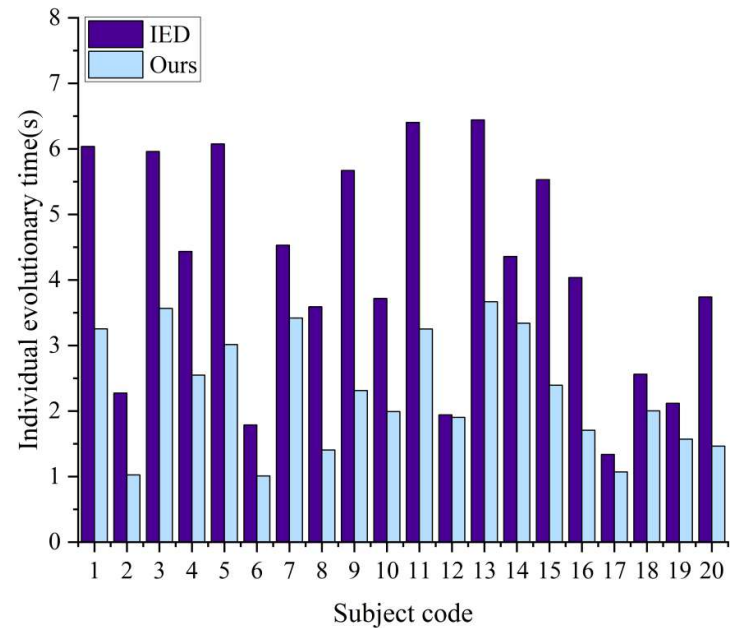


Fig. 2. Time taken to evaluate one individual (Our method vs IED)

4.1.3. Evolutionary algebra. From Fig. 3 is the comparison of evolutionary generations. It can be seen that all the samples are able to select 5 satisfactory solutions within 15 generations, and both of the methods show better evolutionary efficiency. The average number of evolutionary generations using the algorithm in this paper is 0.6 generations less. This represents that the genetic algorithm based on

complex coding is more conducive to improving the search efficiency, which provides a new way for the genetic algorithm in the innovative design of female red figure decoration composition, and the performance of the algorithm is maintained well.

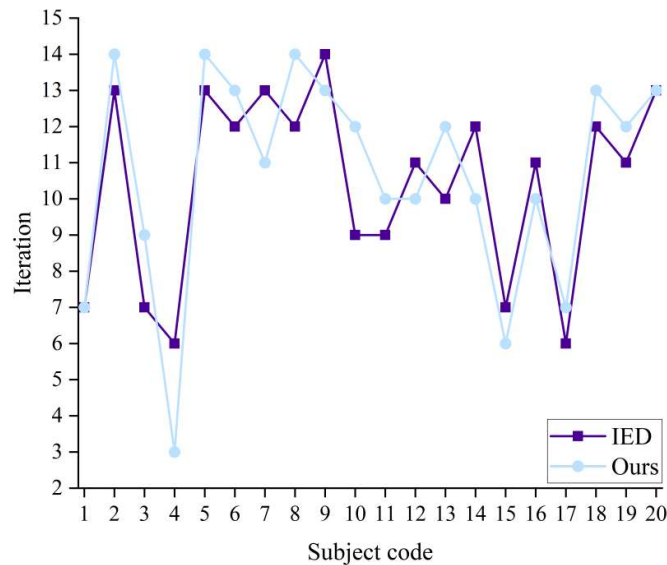


Fig. 3. Iteration comparison

4.2. Analysis of Composition Generation Results

MATLAB R2017 software was used as the optimization tool for the experiments, and the GA local and global acceleration constants $c1=c2=0.148387$, the number of evolutionary times $G=200$, and the population size $S=300$. The tattoo composition design generated by the algorithm of this paper was used as the main element, and the optimization data are shown in Table 1.

Since $x1, \dots, x5$ denote the number of rows, they are rounded. The 5 sets of algorithmic data generated in Table 1 are rounded up and transformed to arrange. And for any pattern if there is a scaling multiplier, the number of patterns increases or decreases by a factor that is inversely proportional to the scaling multiplier.

According to the optimized design of the number of tattoo compositions and the defined scaling ratio, the undefined transformation parameters are defined. Expressions are defined to generate the tattoos based on the five sets of data in Table 1.

Table 1. The five sets of GA data for the pattern composition

	X1	X2	X3	X4	X5
Group 1	20.731	5.628	20.824	6.313	1.997
Group 2	34.826	6.545	18.631	7.563	5.542
Group 3	27.539	4.390	13.531	11.669	3.120
Group 4	15.292	7.030	17.656	10.623	3.639
Group 5	18.010	5.042	22.877	4.746	4.553

Optimization is carried out using a genetic algorithm based on complex coding, and the final optimized data is shown in Table 2, and the design results of the pattern design are shown in Fig. 4.

Table 2. The five sets of plural coding GA data for the pattern composition

	X1	X2	X3	X4	X5
Group 1	21.558	5.028	9.263	4.851	1.377
Group 2	33.539	8.946	7.783	5.594	2.130

Group 3	26.256	5.667	7.610	4.061	3.151
Group 4	15.293	6.205	10.230	6.444	1.559
Group 5	17.457	7.821	7.684	3.371	3.402

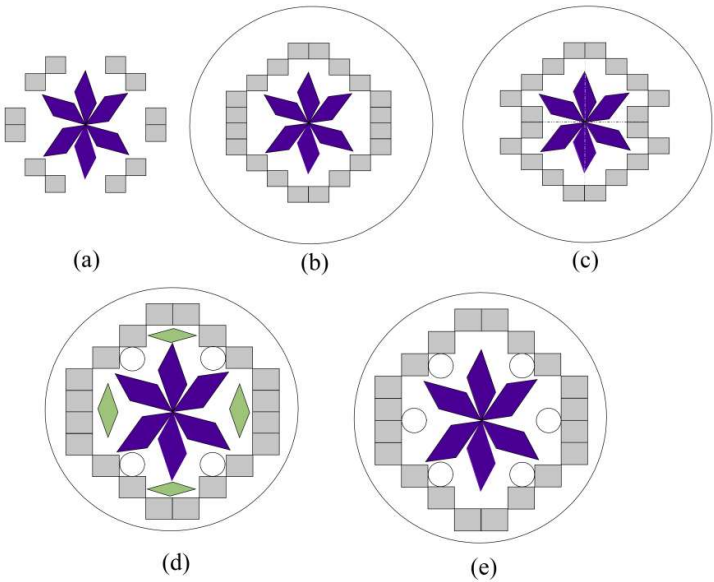


Fig. 4. Design results of the pattern of the picture

In this study, the Eyeso eye-tracker was applied to conduct eye-tracking experiments on five patterns formed after reusing the design based on GA-optimized data. Twenty-five graduate students with naked eye vision or corrected vision of 1.0 or higher were selected for the experiment. The subjects sat at 0.5 m in front of the screen as required, adjusted the angle of the eye-tracker to 20°, and performed the test. The experiment was conducted by arranging the five patterns in a chaotic order into three groups to counterbalance the effect of balancing the difference in the screen display position at which each pattern was located on the experimental results. Figure 5(a) shows the comparison of the mean values of gaze time, and Figure 5(b) shows the hotspot map of the pattern with the longest gaze time.

The experimental results show that the mean values of the gaze time of different patterns are, in descending order: $e > d > c > b > a$. It can be seen that the subjects pay more attention to the patterns formed according to the fifth group of data in Table 2, and the hotspot diagrams show that the subjects pay more attention to the main body pattern elements in the patterns than to the frame elements, so that the focus of the design can be placed on the design coding for the main body pattern elements in the future design. .

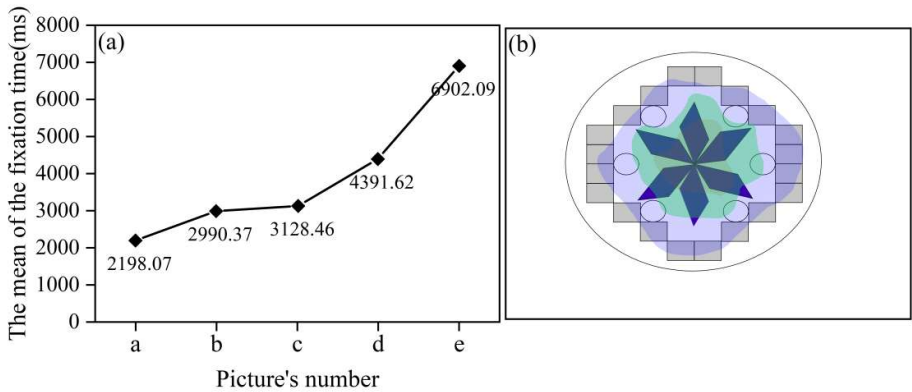


Fig. 5. Eye motion experiment result

4.3. Examples of Algorithm Applications

4.3.1. Manual scoring of design results. The experiment selected 15 designers to participate in the design evaluation, selected part of the previous design results for display, and let the 15 designers evaluate the satisfaction of the 5 patterns, and the results are shown in Figure 6. As can be seen through Figure 6, the 15 designers have a high satisfaction evaluation of the 5 patterns, with an average evaluation result of 82.19%, 83.92%, 84.52%, 85.42% and 90.99%, respectively, and the highest level of satisfaction for pattern e. The results are shown in Figure 6.

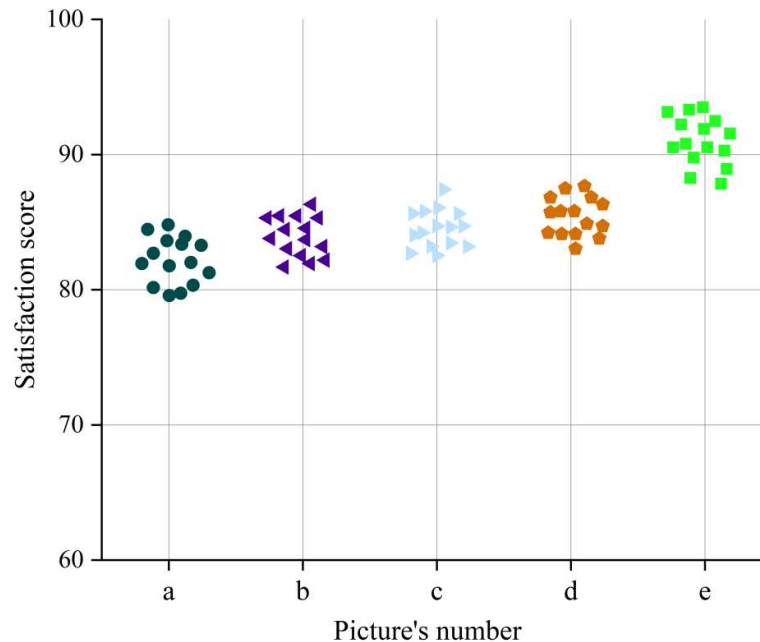


Fig. 6. The designers' evaluation of the design of pattern

4.3.2. Application of New Female Red Tattoo Pattern Composition. The women's red graphic pattern obtained from the design based on genetic algorithm is applied to the lamps to obtain the women's red graphic pattern. Through user research and feedback, the user experience and satisfaction of the customized lamp products with female red pattern decoration pattern were analyzed. Thirty users were selected to participate in the one-month research, and the results of users' evaluation of the product appearance are shown in Figure 7. As can be seen in Figure 7, different users have a high evaluation of the appearance of the five lamps and lanterns products.

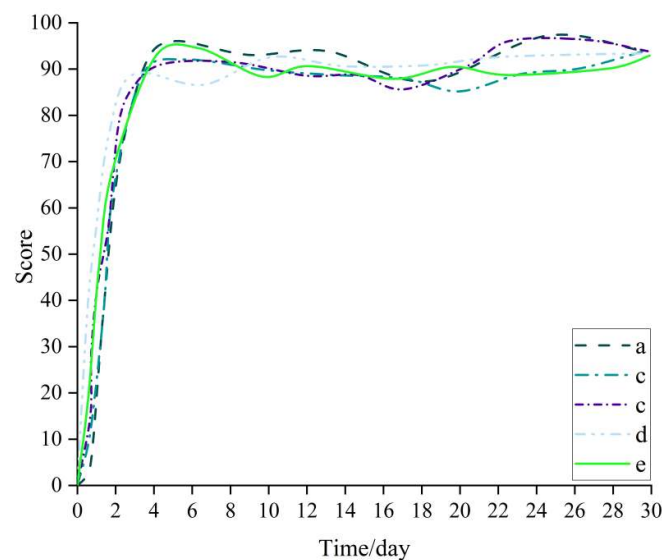


Fig. 7. The users' evaluation of the appearance of the product

Next, the users themselves were allowed to participate in the design of the female red graphic pattern customized lamps and lanterns product, and the participation and ordering rate of the process were compared, and the results are shown in Figure 8. As can be seen in Figure 8, the users' participation in the design of the female red graphic pattern customized lamps and lanterns products is high, with an average participation rate of 95.86%. At the same time, the users' ordering rate of the customized lamps and lanterns products with female red graphic pattern is high, and the average ordering rate is 94.68%. It indicates that the new patterns designed in this paper are favored by users and also help to enhance the commercial value of Shaanxi folk female red.

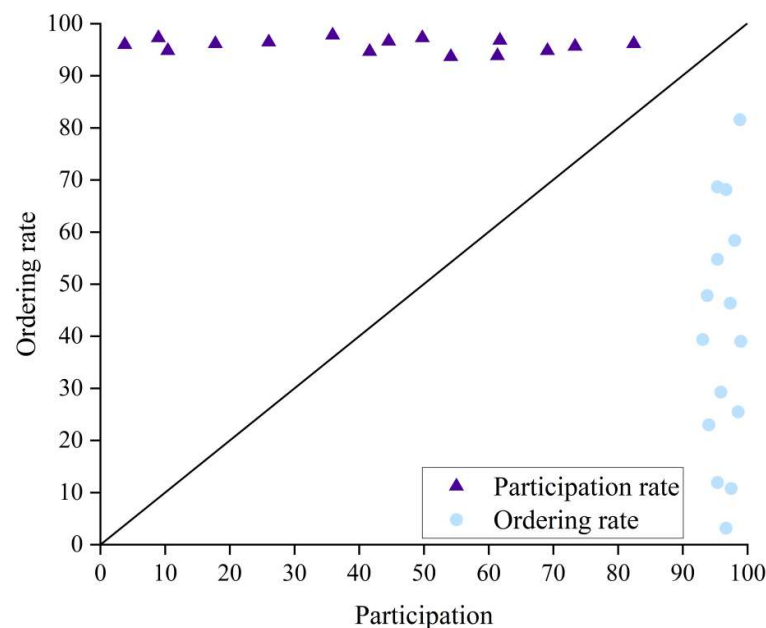


Fig. 8. Users engagement and ordering rate

5. Conclusion

In this paper, we have successively generated the initial female red graphic decorative pattern by bipartite continuous pattern design and genetic algorithm based on complex number coding and

optimized the composition multi-objective innovation. The total time consumed to generate the graphic pattern composition of this paper's algorithm is 192.03 seconds, which is 53% less than the IED method on average, and the time spent for a single individual is 44.37% less than the IED on average, and the average number of evolutionary generations is 0.6 less than that of the IED. The eye movement experiment showed that the experimenter gazed at pattern e for the longest time (6902.09ms), focusing mainly on the main part of the graphic pattern. 15 designers participated in the design evaluation, and pattern e had the highest satisfaction (90.99%). After applying the pattern for decoration, the user's evaluation of the luminaire product is high. It can be seen that the method of this paper is not only able to produce satisfactory female red graphic decorative compositions, but also conducive to enhancing the protection and utilization of Shaanxi folk female red cultural heritage.

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