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Clothing Pattern Geometry Generation Algorithm Based on Computer Graphics Processing

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Abstract The development trend of personalized customization in clothing production and sales puts forward more demands on the design of clothing patterns as well as the generation of patterns at the level of innovation and diversity. In this paper, the automatic generation method of personalized clothing samples is formed through the extraction of human body characteristic measurement parameters, the design of parametric design model representation and constraint solving methods. Meanwhile, for the pattern design and pattern generation of garments, we take fractal geometry as the entry point, and expound the specific application of fractal geometry in garment design from the two angles of graphic adjustment and craftsmanship. Based on the classic Mandlebrot fractal image, the texture features of the image are characterized by the gray scale covariance matrix, and the texture analysis model of fractal graphics is established. After obtaining the correlation of human body size features and texture characteristics, the constructed fractal graphic texture analysis model is used to design patterns and motifs, and produce a sample garment. The sample garment has three dimensions of pattern, (D2) color, and fabric to obtain the average score of user satisfaction ≧ 4 in the overall evaluation, presenting the high feasibility of this paper's method in the design of garment pattern and pattern processing.

Index Terms grayscale covariance matrix, fractal graphic texture, personalized clothing, human characteristics

I. Introduction

In recent years, along with the continuous improvement of the people's living standards, the public for clothing external requirements have gradually improved, the young people's taste for clothing changes year by year, a school of its own, clothing design affects consumer purchases, so there is an urgent need for the theoretical thinking and practical exploration of clothing design [1]-[3]. Therefore, at this stage, there are numerous guide books on clothing design on the market, and more and more scholars have begun to pay attention to the current stage of clothing design problems that need to be solved. For example, patterns, patterns and other aspects of the design can push the boundaries of both fashion and classic, these problems not only plagued the front-line clothing designers, but also many researchers in the field of apparel design for this effort [4], [5].

Traditional clothing design drawing mainly relies on paper and pen, which is not only time-consuming and laborious, but also quite troublesome to modify. Nowadays, digital drawing software has become the designer's right-hand man. Professional drawing software such as Adobe Illustrator, CorelDRAw, CLO3D, CAD, etc., are easy to operate and powerful, and designers can accurately draw clothing style charts, cutting charts and detail charts through the computer, with precise lines and rich colors, and can edit, modify and improve the graphics at any time, which greatly improves the efficiency and accuracy of design communication [6]-[9]. However, the preset templates of this type of software are limited and cannot meet the diversity of clothing design. In addition, the distortion of two-dimensional patterns designed using three-dimensional clothing is obvious, and the different properties of clothing fabrics lead to different degrees of deformation of patterns, limiting the design of clothing pattern motifs [10], [11].

With the development of intelligent technology, the clothing design industry ushers in new opportunities. The generation of clothing patterns through algorithms makes the efficiency of clothing design greatly improved [12]. And graphics processing technology can screen, analyze, modify and reconstruct digital images to achieve better clarity, contrast and color saturation and improve visual effects [13]. In the field of clothing design, graphic processing technology innovates clothing patterns by arranging and combining geometric shapes, as well as reconstructing multiple graphic elements, quickly generating clothing patterns by using image enhancement technology, artificial intelligence assisted technology, etc., and improving the visual effect and quality of patterns and motifs [14]-[16].

Based on the demand for clothing fit in personalized customization, this paper designs the extraction method of human feature measurement parameters based on the positioning of 3D human body model. It explains the basic principle of parametric design, and further discusses the representation of the parametric design model of human body features and the constraint solving method, and puts forward the automatic generation method of personalized clothing samples. Secondly, based on the similarities between fractal geometry and apparel design, we analyze the graphic adjustment method and craftsmanship of fractal geometry in apparel design. Then, we describe the main contents of classical fractal image (Mandlebrot fractal) in detail and establish the escape time algorithm. Combined with the gray scale symbiosis matrix, we build a texture analysis model of fractal graphics suitable for garment customization. Finally, the correlation between human body size features and texture properties are calculated, and the proposed model is used for garment pattern design and pattern generation to evaluate the overall performance of the garment in the form of user satisfaction.

II. Automatic generation of personalized clothing samples

II. A. Extraction of human characteristic measurement parameters

Tailor-made emphasizes the fit of the garment, so this paper adopts personalized sample, that is, the details of the garment are in accordance with the actual parameters of the human body for drawing. Personalized samples have high requirements for the comprehensiveness and accuracy of human size parameters. According to the needs of human body measurement, the use of three-dimensional human body model positioning measurement of human body parameters required for the reference point and datum line, and complete the extraction of the characteristic measurement parameters, to obtain the human torso characteristics required in this paper size. Based on these data, recognize whether the human body is a special body type and its special body category.

II. B. Representation of Parametric Design Models and Constraint Solving Methods

The basic principle of parametric design is that the system automatically captures the user's intention during the design process, so that the relationship between each design object and other objects in the user's design is recorded, and when the user modifies the design parameters, the system can automatically make the necessary modifications to the drawings, so that the correlation between the various objects in the drawings can be maintained.

The maintenance of associations in parametric design can be expressed as a geometric constraint solving problem. Given a set O of geometric entities (points, lines, rectangles, curves, etc.) and a set C of geometric constraints (distances between points, angles between lines, parallelism, perpendicularity of two lines, etc.) between the geometric entities in the set O, the duality (O,C) is referred to as a geometric constraint problem. The solution of geometric constraints refers to the determination of geometric solid figures that satisfy the set C according to a certain algorithm.

The current methods for parametric design model representation and constraint solving mainly include numerical-based methods, symbolic-based methods, rule-based geometric reasoning methods and graph-theoretic based constraint solving methods, among which the graph-theoretic based methods are widely used as they are faster compared to the other methods and have lower computational complexity than most of the algorithms. In this paper, we propose a graph theory based parametric design model which is based on geometric constraint graphs. The constraint graph is defined as equation (1):

$$G=(V,E) \tag{1}$$

where V represents the set of vertices of the geometric constraint graph, i.e., the set of geometric entities, and edge E represents the set of constraints between geometric entities. Edge E is strictly directional, so it is represented by a directed graph.

III. Specific applications of fractal geometry in clothing design

III. A. Graphic adjustments

Clothing pattern design needs to ensure practicality, adjusted to external conditions such as economic and technical. For this reason, different garments are bound to have different styles of decoration and pattern. For example, silk fabrics are usually more finely textured, and blue prints are mostly coarse and plain. The technical parameters of fractal geometry need to be adapted to the application of the garment. Adjustment of the graphic broadly includes the following ways: First, adjust the color. Fractal graphic mostly colorful, high contrast, applied to clothing design will make the clothing more stable or full of exotic beauty. Through the fractal geometry software to adjust the color of the graphics, according to the application of the occasion to make the clothing show the corresponding artistic style. Second, adjust the structure. According to the needs of designers can directly use the original structure of fractal graphics in apparel design, but the structure can be adjusted to expand the application of fractal geometry space. Generally speaking, printing, weaving and other patterns only need to design an organizational unit of the pattern, you can build a four-way continuous joint pair of flowers. In the application of fractal geometry, patterns can be designed through vertical or horizontal symmetrical repetition. Localized fractal geometric patterns are duplicated to create a sense of pattern wholeness. Design new localizations to guarantee the coherence of the fractal geometry. Cutting the pattern to preserve visual aesthetics and other structural adjustments. It should be noted that if the fractal geometry is used in printing, it needs to be ensured that its dimensions are in accordance with the length specification around the cylinder, whereas in weaving it needs to be ensured that the loop unit pattern is constrained by the width of the loom. Thirdly, to keep things simple. Fractal geometry is characterized by the use of mathematical formulas to be able to local graphics unlimited refinement, and clothing by the carrier restrictions, it is not possible to be as fine as paper, so the need for the graphics of the cumbersome parts of the trade-offs, by way of deconstructing the simplicity of the way to make the clothing more visually appealing.

III. B. Craftsmanship

Fractals, like traditional apparel pattern design methods, are capable of a variety of apparel process techniques to create patterns. The most prominent techniques include printing and weaving. Among them, printing is the most common, which is able to present the image details completely, and has high value for the fractal geometry with rich details. Color weaving has a stronger artistic influence, and its fine craftsmanship can even produce a pattern effect close to that of printing and dyeing, which makes the garment have a better texture, but the cost is also higher. The thick texture and comfortable handfeel make color weaving one of the most important techniques for fractal graphics. In addition, there are many other techniques such as embroidery and openwork. From the point of view of embroidery, its materials and stitches are more abundant, and it can string beads, sequins and other elements. As a special craft in garment design, skeletonization, skillfully combined with fractal geometry, can enhance the artistic style characteristics of the garment.

IV. Fractal graphic texture model based on grayscale covariance matrices

IV. A. Mandlebrot fractal

The Mandelbrot set is clearly the most popular fractal, perhaps the most popular in contemporary mathematics. Some claim that it is not only the most beautiful (i.e., visualized) object one has ever seen, but also the most complex. The complexity of the Mandelbrot set belongs to a completely different category compared to the Julia set, which, on the one hand, has a solid interior without any structure and, on the other hand, has a very complex boundary with an infinite number of different shapes.

Let Eq. (2):

$$f(z)=z^2+c \tag{2}$$

where $z,c\in C$, z is a complex variable and c is a complex constant. Using the escape time algorithm to realize the transformation f, the iterative formula can be obtained as in equation (3):

$$z_{n+1}=z_n^2+c_{pq}, n=0,1,2,\cdots \tag{3}$$

where $z_0=(0,0)$ and c_{pq} is the pixel of the computer screen at position (p,q). Thus equation (3) becomes equation (4):

$$z_{n+1}=\left(\cdots\left(\left(\left(\left(z_0^2+c_{pq}\right)^2+c_{pq}\right)^2+c_{pq}\right)^2+c_{pq}\right)^2+\cdots\right)^2+c_{pq} \tag{4}$$

Suppose N is a positive integer, say 255, i.e., draw a 256-color map. When the pixel is located at the point (p,q) and $n>N$, the modulus $|z_n|$ of the complex number z_n is still less than a preset threshold k, then the coloring at the position (p,q) is 1. Otherwise, when $n\le N$, there is already $|z_n|\ge k$, then the coloring at the position (p,q) is n (i.e., the color of the numerical representation of n), thus , when (p,q) traverses the entire screen, a colored Mandelbrot set is drawn.

The specific steps of the escape time algorithm for Mandelbrot fractal graphs are implemented as follows:

Let Eqs. (5)-(6):

$$Z = x + iy \tag{5}$$

$$C = p + iq \tag{6}$$

The initial value of Z is equation (7):

$$Z_0 = x_0 + iy_0 \tag{7}$$

The values of C range from $p:[p_{\min}, p_{\max}]$ to $q:[q_{\min}, q_{\max}]$, i.e., the parameter window is: $(p_{\min}, q_{\max}) \sim (p_{\min}, q_{\max})$. Assuming that the resolution of the drawing window is $a \times b$, it can display colors $k+1$ (k is the maximum number of colors minus 1), denoted by the numbers 0 to k, where 0 denotes black.

(1) Select the parameter window $p_{\min} = -2.25$, $q_{\min} = -1.5$, $p_{\max} = 0.75$, $q_{\max} = 1.5$ and the escape radius $M = 100$. Set the unit value of the parameter space corresponding to the plotting window to Eq. (8):

$$\begin{cases} \Delta p = (p_{\max} - p_{\min}) / (a-1) \\ \Delta q = (q_{\max} - q_{\min}) / (b-1) \end{cases} \tag{8}$$

For all points (n_p, n_q), $n_p = 0,1,\cdots,a-1$ and $n_q = 0,1,\cdots,b-1$, completing the following loop.

(2) Let Eqs. (9)-(10):

$$p_0 = p_{\min} + n_p * \Delta p \tag{9}$$

$$q_0 = q_{\min} + n_q * \Delta q \tag{10}$$

$k = 0$, $x_0 = y_0 = 0$.

(3) According to equation (11):

$$x_{k+1} = x_k^2 - y_k^2 + p, y_{k+1} = 2x_k y_k + q \tag{11}$$

Calculate (x_{k+1}, y_{k+1}) from (x_k, y_k) by counting $k = k+1$.

(4) Compute equation (12):

$$r = x_k^2 + y_k^2 \tag{12}$$

If $r > M$ then select color k and go to step (5). If $k = K$ then select color 0 and go to step (5). If $r \le M$ and $k < K$ then go to step (3).

(5) Color k for point (n_p, n_q) and go to next point i.e. step (1).

(6) End by reading all points (p, q) in the parameter space.

IV. B. Definition and eigenparameters of the grayscale covariance matrix

The grayscale co-production matrix is a powerful tool to reflect the micro texture of an image region by studying the spatial correlation properties of the grayscale, which is obtained through the statistics of texture features on the grayscale status between pairs of pixel points that maintain a certain spatial relationship. Therefore, the gray scale co-production matrix of an image can reflect the comprehensive information of the gray scale of this image about the direction, the magnitude of change, the adjacent interval, etc. These information quantities are the basis for analyzing the local characteristics of the image, therefore, various statistics about the gray scale co-production matrix of an image can be used to characterize the texture properties of the image.

Assuming (x, y) is a two-dimensional digital image, the grayscale covariance matrix is a count of the number of times a pixel of gray level i in image (x, y) and two pixel pairs of gray level j with a distance of $\delta = (\Delta x, \Delta y)$ appear $P(i, j, \delta, \theta)$. The grayscale covariance matrix is shown in Fig. 1.

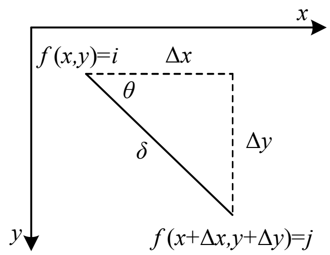


Figure 1: Gray Level Co-occurrence Matrix

This can be expressed in a mathematical formula as equation (13):

$$\begin{aligned} P(i,j,\delta,\theta) = \{ [(x,y),(x+\Delta x, y+\Delta y)] \setminus f(x,y) = i \\ f(x+\Delta x, y+\Delta y) = j; x = 0,1,2,\cdots,N_x - 1; y = 0,1,2,\cdots,N_y - 1 \} \end{aligned} \tag{13}$$

where $i,j = 0,1,2,\cdots,L-1$, x,y are the pixel coordinates in the image. L indicates the number of gray levels of the image. N_x, N_y represent the number of rows and columns of the image. Some parameters that reflect the condition of the matrix can be exported to more intuitively describe the texture condition with the grayscale symbiosis matrix, such as energy, contrast, correlation, entropy, variance and inverse gap, which can be used to extract texture information in the image. In this section, energy and entropy are selected to describe the fineness and irregular structure of the fractal graph according to the structural characteristics of the fractal graph. In order to make the obtained texture features independent of the direction angle, it is necessary to exclude the influence of the direction angle on the feature parameters in the statistics, so it is necessary to make appropriate treatment in the calculation of the gray co-occurrence matrix, and the simple and desirable method is to select the energy and entropy of different directions (0°, 45°, 90°, 135°) and take the average value in the calculation.

The second-order moment of the angle is as follows equation (14):

$$ASM = \sum_i \sum_j P(i,j)^2 \tag{14}$$

The angular second-order moments (also known as energies) are the sum of the squares of the values of the elements in the grayscale covariance matrix, which reflect the coarseness of the image texture and the uniformity of the grayscale distribution. If all values of an image's co-production matrix are equal, then the ASM value is small. Conversely, if some values are large and the rest are small, then the ASM value is large. If the distribution of elements in the gray scale co-production matrix is more concentrated around the diagonal, then it indicates that the image has a more uniform gray scale distribution and a coarser texture, and then the ASM value is large. A large ASM value indicates a more homogeneous and regularly varying texture pattern.

The entropy is shown in equation (15):

$$ENT = -\sum_i \sum_j P(i,j) \log P(i,j) \tag{15}$$

Entropy is a parameter that measures the randomness of the gray level distribution, which reflects the degree of non-uniformity or complexity of the texture in the image. Entropy is greater when the randomness of all elements in the covariance matrix is greater, the elements are distributed in a decentralized manner, and all values in the covariance matrix are almost equal. In short, the more complex the texture of the image, the greater the entropy value. Conversely, if the gray scale distribution in the image is more uniform and the texture of the image is simpler, then the entropy value is smaller.

V. Analyzing the application of texture analysis models for graphs

V. A. Correlation of dimensional characteristics

In this section, 823 members of the general public are randomly selected as experimental subjects, and the designed feature parameter extraction method is used to obtain the feature size data, and the correlation analysis of different features is carried out to provide effective data support for the following clothing design.

V. A. 1) Correlation analysis of measured data

Correlation analysis is a statistical method used to study the relationship between two variables, which is used to measure the strength of the linear relationship between two variables and also to predict the value of one variable based on the value of the other. The human being as a whole, there is a certain relationship between the body parts, in order to further determine the correlation between the dimensions of various parts of the human body, correlation analysis is performed on the data set. Based on the actual situation, the upper limb indicators selected in this paper are (U1) height, (U2) weight, (U3) shoulder width, (U4) arm circumference, (U5) large arm length, (U6) arm length, (U7) elbow circumference, and the correlation analysis of the seven indicators is shown in Table 1.It can be seen that, in the upper limb part of the arm circumference is not correlated with the arm length, the large arm length is not correlated with the elbow circumference, and arm length is correlated with the elbow circumference significantly at the 0.01 level, and the other indicators were significantly correlated with each other at the 0.05 level.

Table 1: Correlation analysis of each part of the upper limb

Index		U1	U2	U3	U4	U5	U6	U7
U1	Pearson correlation	1	0.532*	0.678*	0.535*	0.521*	0.643*	0.751*
	Sig. (Double Tail)		0	0	0	0	0	0
	N	823	823	823	823	823	823	823
U2	Pearson correlation	0.532*	1	0.641*	0.732*	0.968*	0.897*	0.535*
	Sig. (Double Tail)	0		0	0	0	0	0
	N	823	823	823	823	823	823	823
U3	Pearson correlation	0.678*	0.641*	1	0.525*	0.533*	0.597*	0.599*
	Sig. (Double Tail)	0	0		0	0	0	0
	N	823	823	823	823	823	823	823
U4	Pearson correlation	0.535*	0.732*	0.525*	1	0.707*	0.181	0.623*
	Sig. (Double Tail)	0	0	0		0	0.171	0
	N	823	823	823	823	823	823	823
U5	Pearson correlation	0.521*	0.968*	0.533*	0.707*	1	0.578*	0.152
	Sig. (Double Tail)	0	0	0	0		0	0.059
	N	823	823	823	823	823	823	823
U6	Pearson correlation	0.643*	0.897*	0.597*	0.181	0.578*	1	0.272*
	Sig. (Double Tail)	0	0	0	0.171	0		0.011
	N	823	823	823	823	823	823	823
U7	Pearson correlation	0.751*	0.535*	0.599*	0.623*	0.152	0.272*	1
	Sig. (Double Tail)	0	0	0	0	0.059	0	
	N	823	823	823	823	823	823	823

V. A. 2) Correlation analysis of dimensional changes

In this section, the size change of the relevant parts is predicted to provide a data basis for the subsequent generation of loose volume. After many experiments, it is found that the error of predicting the size change of the relevant parts directly through the size of the key parts (the above seven indicators) is extremely large, so it is verified by correlation analysis. Table 2 shows the key part size and non-key part size change indicators, the change amount indicators are: (V1) shoulder width change amount, (V2) chest circumference change amount, (V3) waist circumference change amount, (V4) hip circumference change amount, (V5) knee circumference change amount. It was found that the correlation between the critical part dimensions and their own looseness and non-critical part looseness was extremely low. Therefore, the measured value that produces the maximum rate of change is used as the output value for model training.

Table 2: The correlation of dimensional changes in each part

Index		U1	U2	U3	U4	U5	U6	U7
V1	Pearson correlation	-0.049	-0.1742	-0.301**	-0.190	-0.162	-0.138	-0.19
	Sig. (Double Tail)	0.889	0.066	0.001	0.055	0.123	0.17	0.148
	N	823	823	823	823	823	823	823
V2	Pearson correlation	0.852	-0.036	-0.153	-0.099	0.018	-0.067	-0.001
	Sig. (Double Tail)	0.333	0.622	0.088	0.35	0.901	0.555	0.963
	N	823	823	823	823	823	823	823
V3	Pearson correlation	-0.069	0.055	-0.015	0.09	-0.020	-0.035	0.15
	Sig. (Double Tail)	0.412	0.593	0.926	0.503	0.872	0.619	0.306
	N	823	823	823	823	823	823	823
V4	Pearson correlation	0.239*	0.131	-0.019	0.18	0.251*	0.141	-0.066
	Sig. (Double Tail)	0.013	0.199	0.866	0.125	0.011	0.157	0.524
	N	823	823	823	823	823	823	823
V5	Pearson correlation	0.087	0.041	0.054	-0.038	-0.059	-0.067	0.093
	Sig. (Double Tail)	0.351	0.586	0.666	0.721	0.546	0.453	0.369
	N	823	823	823	823	823	823	823

V. B. Calculation of texture properties

In this section, the statistical 2D autocorrelation function is used to obtain the characteristics of the graphic texture. Based on the graphic texture generated by the proposed model, the search range of Δx,Δy is set to be 0-25, and some of the 2D autocorrelation values are computed as shown in Table 3 (with some of the tails removed).

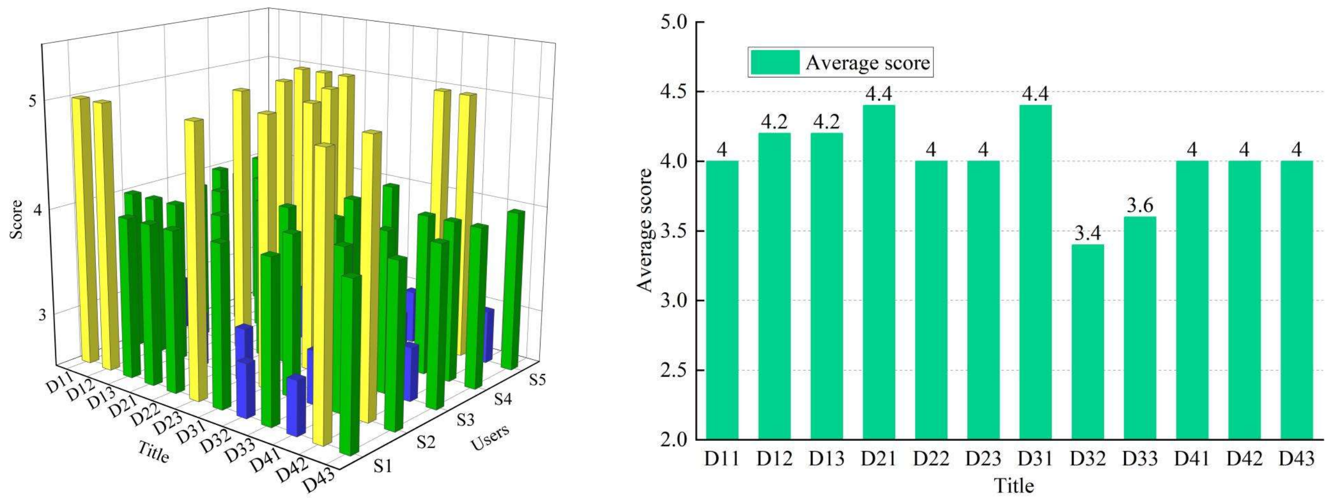
Table 3: Two-dimensional autocorrelation value

(Δx,Δy)	Autocorrelation value	(Δx,Δy)	Autocorrelation value
(0,0)	1.00000	(22,14)	0.47166
(1,2)	0.47043	(23,15)	0.67039
(2,3)	0.08756	(21,16)	0.36228
(3,7)	0.5807	(22,17)	0.90636
(4,5)	0.44284	(23,17)	0.17318
(4,6)	0.09774	(18,19)	0.7787
(4,8)	0.00536	(6,18)	0.86747
(3,11)	0.54741	(9,10)	0.36866
(2,12)	0.51397	(8,12)	0.70309
(1,19)	0.95989	(10,22)	0.24997
(7,8)	0.37815	(22,23)	0.30034
(11,16)	0.45093	(21,24)	0.08459
(12,23)	0.88063	(24,24)	0.87937
(18,24)	0.17744	(15,19)	0.20864
(21,24)	0.40878	(14,17)	0.65849

V. C. Overall assessment results for garments

Combining the analysis results and data from the previous two sections, a fractal graphic texture analysis model based on the grayscale covariance matrix is used to design clothing patterns and motifs, and sample garments are made.

A satisfaction questionnaire was designed based on four dimensions, namely (D1) pattern, (D2) color, (D3) style, and (D4) fabric, with three questions under each dimension, numbered according to the dimension to which they belonged, e.g., the questions under the dimension of (D1) style were numbered as D11, D12, and D13, and the full score of each question was 5 points, and the satisfaction rating was divided into: very dissatisfied (1 point), dissatisfied (2 points), general (3 points), satisfied (3 points), satisfied (3 points), and satisfied (2 points), average (3 points), satisfied (4 points), very satisfied (5 points). Five target users (S1-S5) were selected to rate their satisfaction, and the statistical scoring results are shown in Fig. 2(a), and the calculation of the average score for each question is shown in Fig. 2(b). Among the five users, the four dimensions of satisfaction with the product are centered on very satisfied (5 points), satisfied (4 points), and average (3 points). Based on Fig. 2(b), it can be calculated that the mean satisfaction scores of the four dimensions of (D1) pattern, (D2) color, (D3) style, and (D4) fabric are 4.13, 4.13, 3.8, and 4, respectively, which shows that overall the five target users are more satisfied with the pattern, the use of color, and the fabrics of the designed products (≧4 points), which verifies the validity of the proposed method.



(a) Satisfaction rating result (b) Average satisfaction score

Figure 2: Satisfaction result

VI. Conclusion

In this paper, by designing the automatic generation method of personalized clothing samples, combined with the fractal graphic texture analysis model based on the grey scale symbiosis matrix, not only put forward the geometric algorithm of clothing pattern and pattern generation under the fractal graphic processing, but also realized the personalized clothing design and production integrating the human body characteristics and the graphic texture analysis more successfully.

The human body characteristics data of 823 experimental samples obtained by the automatic generation method of personalized clothing samples are sorted out, and it is calculated that, among the important characteristics of human upper limb, the upper limb part of the arm circumference is not correlated with the arm length, the arm length is not correlated with the elbow circumference, the arm length is significantly correlated with the elbow circumference at the level of 0.01, and the correlation between key part sizes and their own looseness and the looseness of non-critical parts is extremely low. Combined with the results of the calculated graphic texture characteristics, the design of garment patterns and motifs and the production of sample garments. 5 target users in the sample garment satisfaction assessment, the satisfaction of the pattern, color, style, fabric four dimensions of indicators are mainly concentrated in the very satisfied, satisfied, general, and satisfaction scores mean value are: 4.13, 4.13, 3.8, 4.

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