AUTEX Research Journal, Vol. 23, No 2, June 2023, DOI 10.2478/aut-2022-0001

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ARCHAEOLOGY AND VIRTUAL SIMULATION RESTORATION OF COSTUMES IN THE HAN XIZAI BANQUET PAINTING

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Abstract:

Based on 3D virtual fitting technology, this paper simulates and reproduces the fabric patterns and sewing processes of 12 characters' costumes in different scenes on the basis of completing the archaeology of the characters' costumes in the painting, so as to realize the 3D virtual sewing and digital simulation restoration of the characters costumes. This paper draws the style diagram, structure diagram and 3D virtual simulation diagram of the character costumes in the painting. The article further improves the research on the costumes of the Five Dynasties and Ten Kingdoms, which has a certain reference value for the study of ancient character costumes and the promotion of Chinese garment culture. At the same time, it provides a reference for the design of artistic works such as character costumes in film and television and games.

Keywords:

the Han Xizai Banquet painting; cultural heritage; archaeology; virtual simulation; restoration; ancient costume

1. Introduction

As an inseparable part of the soft power of national culture, material cultural heritage has distinct characteristics of its times and regions. It is the crystallization of the civilization and wisdom of the Chinese nation, the embodiment of different national spirits and values, and the link of cultural exchanges among different ethnic groups [1]. Historical and cultural heritage plays an extraordinary role in displaying cultural diversity, studying human history and promoting the progress of human civilization. The protection of material cultural heritage is of great significance to the transmission of Chinese traditional culture from generation to generation [2]. Museums are important for the protection and inheritance of material cultural heritage. Visitors can look at the cultural relics by watching them in the exhibition hall or a glass cabinet. They also learn about cultural relics by using audio guides, leaflets or written guides [3].

China is known as the "Kingdom of the garment." As a special cultural heritage, ancient garments are not only an important part of national culture, but also among the symbols of historical development [4]. There are many records in the history of the culture of ancient Chinese costumes with respect to the splendor and prosperity of costumes in the Tang Dynasty and the etiquette and precision of costumes in the Song Dynasty. However, there is little mention of the Five Dynasties and Ten Kingdoms that briefly existed in the replacement of the two dynasties. The Five Dynasties and Ten Kingdoms are the important turning point of the transformation from the Tang Dynasty to the Song Dynasty, so it is necessary to study the cultural characteristics of the costumes. Ancient painting is a valuable cultural heritage, and the content of calligraphy and painting not only express the artist's point of view, but also can directly reflect the social situation at that time [5]. In this paper, the research on the archaeology and restoration of costumes in the Han Xizai Banquet painting is a supplement to the research of Chinese traditional culture, and at the same time, it can better inherit and protect the historical cultural heritage.

Digital technology is the product of the development and dissemination of the Internet. It is widely used in archaeology, education, clothing and other aspects [6]. Digital technology has the characteristics of interaction, entertainment, and a wide audience. It provides a powerful means for the protection of material cultural heritage and gradually replaces the traditional forms of heritage protection and inheritance such as word of mouth and written records [7]. Since the 1990s, digital technology, including data acquisition, digital modeling, and so on, has been used in the field of cultural heritage [8]. Fangjin Zhang et al. [9] introduced the archaeological process of using digital technology for exploring cultural heritage and the subsequent restoration research and believed that this method is usable by any researcher. George Pavlidis et al. [10] listed 3D digitization methods suitable for ancient cultural heritage records. He believes that the complete recording of cultural heritage is a multi-level process that mainly involves 3D digitization, digital data processing and storage, archiving and management, performance, and reproduction. Maria Higueras

et al. [11, 12] applied photogrammetry and digital 3D modeling techniques to the restoration of architectural ornaments, and the latter also analyzed their limitations, requirements and specifications. In this context, the museum experience is also changing [13]. The development of digital technology promotes the construction of digital museum of material cultural heritage, which is conducive to the protection and inheritance of material cultural heritage. Cultural heritage can be transformed into 3D models to facilitate future generations' learning and observation [14].

3D virtual display technology enhances the reality of digital information with a high degree of reduction by simulating the vision, hearing, and touch of virtual space or applying virtual information to the real world [15]. Using 3D virtual reality technology for garment display is not only beneficial for improving the quality of garments, but also for the application of new technology and many other fields [16]. For example, Yuwei Meng et al. [17] proposed an interactive virtual try-on garment design system, which achieved real-time simulation and a visual design effect by virtually stitching complex garment patterns on a manikin, and they proved the stability of the system through this virtual try-on with respect to complex garment styles and cloth simulation. Jin Wang et al. [18] introduced the interactive technology of designing 3D garments conveniently and accurately by using constraint contour curve and style curve. Example shows that this method can make 3D garment design more flexible. Yuwei Meng et al. [19] proposed a new computer-aided design solution, which is used for virtual fitting, fitting evaluation, and style editing to speed up the garment design process. Olaru Sabina et al. [20, 21] used virtual reality technology to enable users to design realistic clothes in 3D space. Pascal Volino et al. [22] introduced a method to meet the requirements of 3D virtual garment simulation design, which focuses on interactive design, simulation and visualization.

The digital virtual display of historical relics is the trend of development of the times. For example, virtual reality projects such as "Walking along the River during the Qingming Festival" launched by the Palace Museum not only can enhance the immersion of tourists, but also can achieve the effect of publicizing historical cultural knowledge and effectively protecting cultural relics. Hasan Fırat Diker et al. [23] described the restoration and exhibition process of weapons and armor in the Topkap Palace Museum. The aesthetics of the Ottoman Imperial heritage are displayed online through the digital virtual museum, and viewers can get a complete sensory experience as long as they use the equipment. For garment restoration, in recent years, interactive technology has introduced more virtual elements for digital restoration, so it goes beyond the traditional restoration of cultural relics [24]. Victor Kuzmichev et al. [25–27] reconstructed and restored historical men's garments and riding skirts in the late Victorian era, which indicates that it is a feasible approach to restoring garments by using virtual reality. With this background, we have tried to use the 3D digital restoration method to realize the virtual restoration of character costumes in the painting, which provide a new idea for the protection and inheritance of traditional costume culture.

The Han Xizai Banquet painting is a treasure of ancient figures collected by the Palace Museum. It is the only painting handed down from Gu Hongzhong, a painter of the Five Dynasties and Ten Kingdoms. It is also an unparalleled masterpiece of ancient Chinese figure painting. The Han Xizai Banquet painting is rich in content, covering furniture, music and dance, garments, and other aspects of Chinese culture. The painting reflects the garment style at that time. It is not only one of the most important paintings in the study of garment history, but also an important reference for the study of garment in the Five Dynasties and Ten Kingdoms period. The painter records the continuous pictures in the way of painting. The composition of the painting is rigorous and exquisite, and the characters in the painting are elegant and vivid. The plain makeup and gorgeous garments of ladies are in sharp contrast to the blue and black clothes of the men's guests, which fully reflect the style of figure paintings of the Five Dynasties in terms of skills and style.

In this paper, the archaeology and virtual simulation restoration of costumes in the Han Xizai Banquet painting is based on image materials. First of all, we analyze the character scene, the characteristics of the character costumes in the painting and the selected 12 sets of restoration objects. On the basis of completing the archaeology of paintings and characters' costumes, we use virtual fitting technology to convert 2D images into 3D costumes and complete virtual simulation restoration of 12 sets of garments. The material cultural heritage is the treasure of China's excellent material culture. It is an essential cultural heritage material for people to understand the society, economy, culture and art at that time. The virtual restoration of costume by using digital technology can effectively avoid the possible secondary damage to cultural relics in the process of cultural relics display and research. The garments restored by virtual reality technology are not limited by time and space and can be displayed on the network platform after digital rendering. The viewer can more intuitively understand the characteristics of garments and cultural relics. The viewers can immerse themselves in watching and operating at any place and time and feel the connotation and appeal of ancient garment cultural heritage. The virtual simulation restoration of ancient garments is conducive to the construction of a Museum of digital garments, the inheritance and development of ancient garment culture, and the protection and development of material cultural heritage.

2. Methodology

2.1 General Scheme

The archaeology and virtual simulation restoration of costumes in the Han Xizai Banquet painting is based on image materials. On the basis of completing the archaeology of paintings and characters' costumes, we use virtual fitting technology to convert 2D images into 3D costumes and complete virtual simulation restoration. The implementation process is shown in Figure 1, and the specific operation process is as follows:

The Han Xizai Banquet painting is divided into five banquet scenes. First, we study and analyze the characters, costumes,

and painting contents in each scene. Second, we discuss the men's and women's costumes in the banquet from different aspects, mainly including the style, color, fabric, and pattern of male and female costumes. On this basis, the selected 12 sets of character costumes are further analyzed, and the garment style map is drawn, and then the pattern is drawn according to the garment size determined. Finally, the garment pattern is read in the 2D and 3D garment visualization space, the fabric pattern modeling is carried out, the virtual sewing process is realized, and the 3D virtual simulation restoration and display are completed.

2.2 Scene analysis of painting

The Han Xizai Banquet painting is the only precious material of realistic painting of the Five Dynasties and Ten Kingdoms period. It is an important work of ancient figure painting in China. The painting is 335.5 cm long and 28.7 cm wide. It was painted by Gu Hongzhong, a court painter in the Southern Tang Dynasty, and now exists in the Palace Museum in Beijing, as shown in Figure 2. The painting reproduces the scene of the banquet guests at Han Xizai's house more than 1,000 years ago. The whole painting is divided into five scenes to show

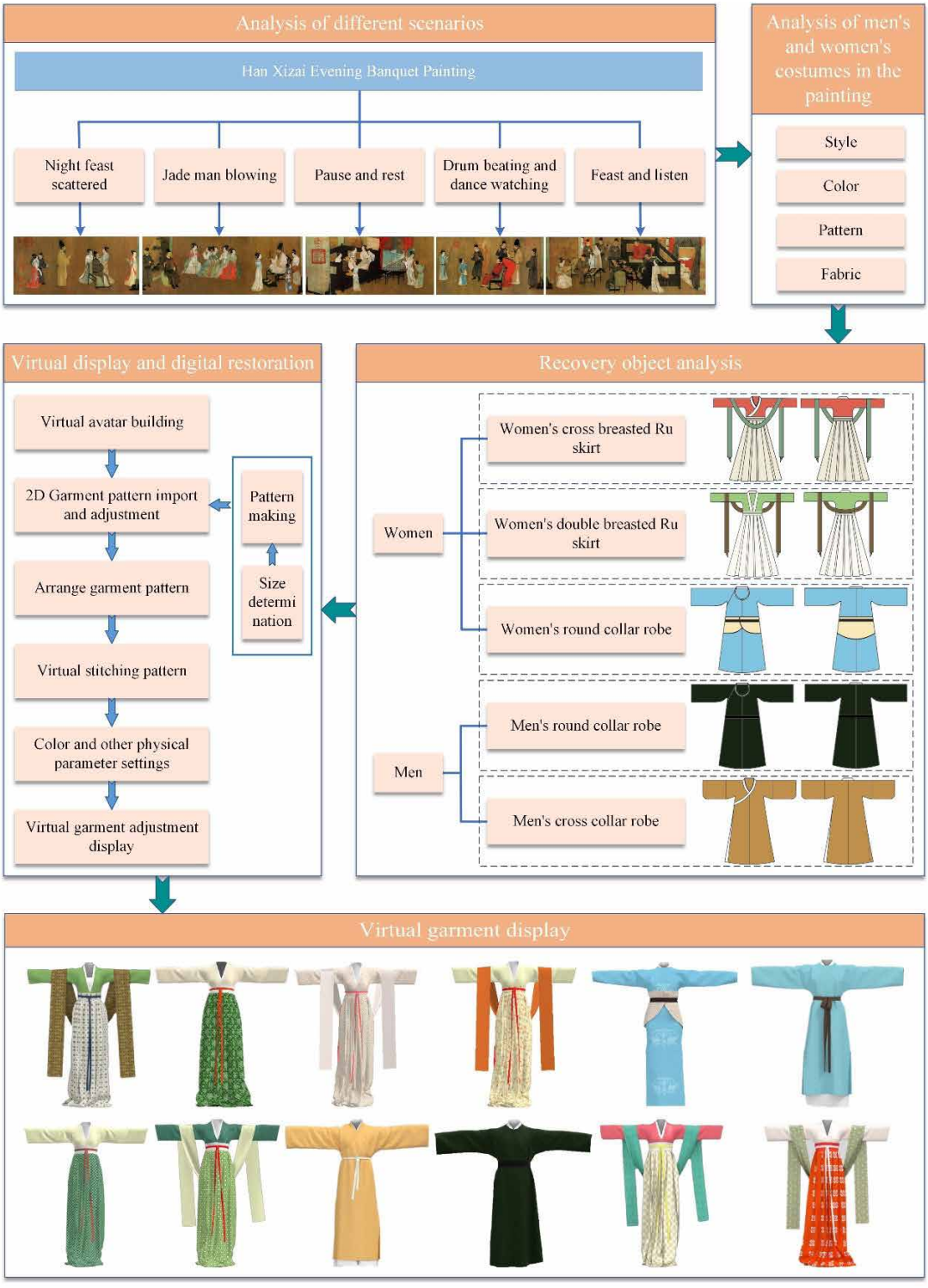

Figure 1. General scheme.

the banquet process including feasting and listening, beating drums and watching dance, pausing for rest, the jade man blowing scene, and the night feast scattering scene. The painting depicts five scenes of different periods in the form of comic strips, each of which is cleverly separated by a screen. The scenes are connected and separated from each other, and the scene is unified and complete.

Scene one, feasting and listening, describes the room environment, the costumes and gestures of guests and ladies when listening to music, as shown in Figure 3. The protagonist Han Xizai sits cross-legged on the bed, and Lang Can, wearing a red round neck robe, sits with the bed. Sitting by the bed is Zhu Mian, and standing next to him is Shu Ya, a disciple of Han Xizai. The one wearing a round collar robe, with a belly around her waist is called Wang Wushan. The favorite prostitute Ruo Lan, who is exposed and hiding behind the screen, listens to music. Sitting next to Wang Wushan is Chen Zhiyong. Facing the Li Ji, sitting upright is Li Jiaming, the vocal music director. Everyone in the painting focuses on Li Ji, who is holding a lute and wearing a double-breasted Ru skirt.

Scene two is beating drums and watching dance. It describes people watching the Six Xuan dance performed by Wang Wushan, as shown in Figure 4. Han Xizai rolls his cuffs, holds a drumstick, and hits the Jie drum, and the dinner activity reach a climax. Lang Can, a young man in a red garment, sits in a chair and leans against the drum. Beside the vocal music supervisor clapping accompaniment, Shu Ya, who is a disciple of Han Xizai, hits the board and accompanies Wang Wushan at the same time.

Scene three is a pause for rest. It depicts Han Xizai and others sitting on the couch to have a rest and chat. Wang Wushan holds a gold basin and waits on the protagonist to wash his hands. The overall atmosphere is relaxing. A maid next to him brings tea, and another musician walks to the bed with an instrument to play for him. The seemingly quiet scene indicates that a concert will begin soon, as shown in Figure 5.

Scene four is jade man blowing. In the painting, Li Jiaming beats the tooth plate, and five women playing music sit in a row, each of them with their own posture, which makes people feel rich in wind harmony. The protagonist, Han Xizai, holds a square fan, with open chest and breast, and sits cross-legged on the chair. Next to the screen, a male guest is whispering with the woman outside the screen, which naturally leads the viewer's attention to the next picture, as shown in Figure 6.

Scene five is night feast scattering. It depicts the end of the banquet and the departure of the guests. As shown in Figure 7, a guest in front of the Han Xizai painting sits sideways on a chair and shakes hands with two ladies. The guests standing behind him embrace the ladies, while Han Xizai in yellow seems to stop beating the drums and stands up to greet the guests with his hands.

The Han Xizai Banquet painting has the features of realism and integrity. The costumes of the characters in each scene are clearly depicted by the painter. The costumes, postures, actions, and expressions of different characters are very different, and the costume colors of men and women form a sharp contrast. The painting truly reflects the garment characteristics and people's living conditions in the time of the Five Dynasties. The garment in the painting can be considered representative of the Five Dynasties and Ten Kingdoms costumes, which is of great significance for the research of the Five Dynasties costumes.

2.3 Analysis of men's and women's garments

Due to the short existence time of the Five Dynasties, the Five Dynasties garment is similar to the characteristics of that of the Sui and Tang Dynasties. Compared with women's garments in the Tang Dynasty, the same point is that Ru is tied in the

Figure 2. Volume of the Han Xizai Banquet Painting in the Palace Museum in Beijing, China.

Figure 3. Feasting and listening.

Figure 4. Beating drums and watching dance.

Figure 5. Pausing for rest.

Figure 6. The Jade man blowing scene.

skirt and the waist is tied. The difference is that the waist line in the Tang Dynasty is higher, the skirt is wide and long, and it is tied under the armpit. During the Five Dynasties, the waist line moved down obviously, the sleeve became narrower, and the skirt became thinner and longer. Men's garments have not changed, except that the shape of Fu Tou has become hard and warped. Compared with the rich and beautiful costumes of the Tang Dynasty, the costumes of the Five Dynasties are

Figure 7. Night feast scattering scene.

mostly light colors with fewer patterns. Most of the costumes are matched by colors.

The overall style of the Han Xizai Banquet painting is elegant. The overall costumes of the women in the painting include the Ru skirt and round collar robe. A Ru skirt includes an upper bodice skirt, cross collar coat, and a belt and lower body long skirt. The round collar robe was originally a men's garment dating back to the Sui and Tang Dynasties. The man in the painting is dressed in a black, red, and dark green round collar robe and yellow cross collar robe, and another is wearing a white cross collar robe. Gowns are basically divided into round collar gowns and cross collar gowns. The color of round collar official garments is basically fixed black and red, and the color requirements of cross collar robes are not strict. Men in jade man blowing wearing a white cross collar robe is underwear. It can be seen from the neckline of others' garments that they all wear white cross collar underwear.

The Han Xizai Banquet painting adopts red, blue, pink, white, green, and yellow in many places. The color of the painting is relatively saturated, and the layers are rich and beautiful. The color of the painting gives people a strong sense of visual impact and obvious color contrast and lifelike character image. It is the retention of these colors that provides a theoretical basis for many researchers to study the costumes of the Five Dynasties.

To judge from the description of garment patterns, the types of costume patterns presented in the Han Xizai Banquet painting are quite rich, and the ways of expression are very diverse. The large parts of garment patterns are visible in the music playing woman's garment in the jade man blowing, the bird pattern on the back of round neck robe dressed by Wang Wushan, and the skirt of the women embracing the lute, etc. It is found that the patterns of women's garments include a big couplet bead pattern, a blue-green stripe, small group flower pattern, diamond pattern, hexagon pattern, pair bird pattern, and so on.

In order to make the costume restoration results achieve the visual sense in the painting, we redraw the Five Dynasties costume patterns by comparing the costume patterns of Tang and Song Dynasties and applying them to the costume restoration. The patterns drawn include geometric patterns, hexagonal patterns, small group flower patterns, precious flower patterns, small flower patterns, small cluster flower patterns, and pair bird patterns, as shown in Figure 8.

The five scenes in the painting reflect the lifestyle, etiquette, garment shape, and color in the Five Dynasties. From the brush strokes of the painter, it can be clearly judged that the women's garment is light and soft in texture, and the fabric will change with the swing of the human body, thus presenting the elegance of silk fabric. The garment fabric in the Five Dynasties were the same as those in the Tang Dynasty. Silk, brocade and gauze were the main fabric of garment. Ladies' costumes are light and thin, the polyester belt tightens the waist, and the two ends droop freely. The combination of brocade and gauze with different colors and patterns makes the decoration of garments simple, which also makes the fabric art stand firm in the painting industry.

2.4 Recovery of object analysis

According to the analysis of the styles, colors, patterns and fabrics of men's and women's garment in the painting, we select 12 representative character costumes for virtual simulation restoration, including 2 sets of men's garments and 10 sets of women's garments, as shown in Figure 9.

The first object to be restored is the garment dressed by Li Ji in Feasting and Listening. Li Ji with a lute in her arms sits on the left side of the scene of feasting and listening and wears double-breasted Ru skirts, as shown in Figure 9 (a). The Ru with blue color, the skirt with light color and there are still some square patterns on it. The color of silk cape is brown, bypassing the back of the woman playing the lute, and both ends droop with her arms.

The second object to be restored is the lady's garment in Feasting and Listening. The lady stands on her side and wears a cross-breasted Ru skirt. The Ru is light colored, the skirt is green, and the waist is tied with a red polyester belt. The length of the polyester belt falls below the knee, as shown in Figure 9 (b).

The third object to be restored is the lady's garment in Feasting and Listening. The lady stands sideways beside the bed and

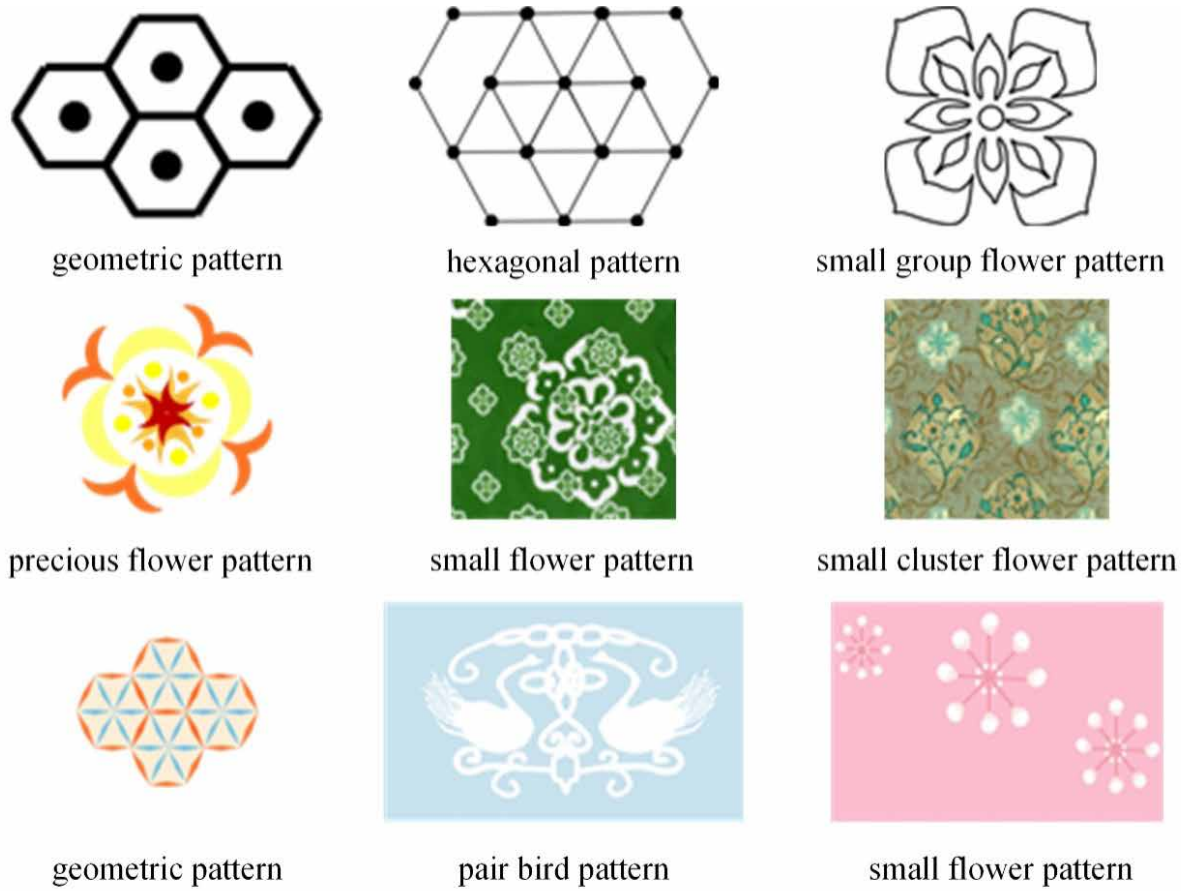

Figure 8. The costume patterns in the Han Xizai Banquet painting.

wearing a light Ru skirt, as shown in Figure 9 (c). The overall color of the cross-breasted Ru skirt is light pink, the color of silk cape is light, and the red polyester belt is tied at the waist.

The fourth object to be restored is the garment dressed by Li Ji in Pause and Rest. Li Ji appears in the scene of Pause and Rest for the second time. In the painting, Li Ji holds a lute in hand and wears a cross collar light Ru skirt. The patterns of small clusters of flowers on the skirt are particularly exquisite, as shown in Figure 9 (d).

The fifth object to be restored is the garment worn by Wang Wushan in Beating drums and Watching Dances. Wang Wushan appears three times in the whole Han Xizai Banquet painting. In the first, second, and fifth scenes, the costumes of the Dancing Lady Wang Wushan are narrow sleeved round collar robes with a belly around the waist, which are fastened at the waist by a leather belt. In the scene of Beating drums and Watching Dances, Wang Wushan wears a narrow-sleeved robe with slits on both sides and his back to the audience, as shown in Figure 9 (e).

The sixth object to be restored is the lady's garment in the Beating drums and Watching Dances scenes. The maid wears a round collar, narrow-sleeved gown like Wang Wushan. The difference is that the lady does not have a belly or a leather belt at the waist. They just fasten the round collar gown with a dark polyester belt, and the two ends of the belt are vertical to the knee, as shown in Figure 9 (f).

The seventh object of restoration is the costumes of female musicians playing music in the Jade Man Blowing scene. The costumes of the female musicians in this scene are taken as a typical study by researchers. The lady holds a scarf and wears a cross collar Ru skirt. The skirt is blue color, and the polyester belt is tied at the waist, as shown in Figure 9 (g).

The eighth object to be restored is the costumes of female musician playing music in the Jade Man Blowing scene. The musician who wears a dark cyan upper garment, matched with a light green skirt, supplemented by light yellow silk cape, and the garment color combines light and dark, as shown in Figure 9 (h).

The ninth restoration object is the garment worn by Han Xizai, the protagonist in the painting. Han Xizai appears most frequently in the five scenes. In the first four scenes, Han Xizai wears a green round collar robe and a black leather belt around his waist. In the Night Feast Scattering scene, Han Xizai wears a light yellow right lapel robe, as shown in Figure 9 (i).

The tenth object of restoration is the guests' costumes in the Han Xizai Banquet painting. Except for those of Han Xizai, all the costumes in the painting have green round collar short crotch robes with slits on both sides of the body and lace up at the waist, as shown in Figure 9 (j).

The eleventh object of restoration is the costumes of female musicians playing music in the Jade Man Blowing scene. The matching method of the upper Ru and lower skirt is the only

choice for the ladies. In this scene, the musician on the left wears a silk cape in a different way from other ladies. The two ends of the silk cape are hung on the ladies' arms, and the middle part falls on the chest in a U-shape, as shown in Figure 9 (k).

The twelfth object of restoration is the lady's garment in the Night Feast Scattering scene. The lady leans next to the guest with her left hand covering her lips and her right hand hanging down naturally as shown in Figure 9 (l). The bright red pleated skirt is matched with the light-colored upper Ru. The turquoise silk cape is laid flat on the back, and the two ends of the silk cape bypass the ladies' arms and float with the wind.

2.5 Size determination and pattern making

The selected 12 sets of restored garment categories include five categories, which are women's the cross-breasted Ru skirt, women's double-breasted Ru skirt, women's round neck robe, men's round collar robe, and men's cross-collar robe. Due to the lack of reference of physical data, the size data of the restored garment is mainly combined with the basis of human

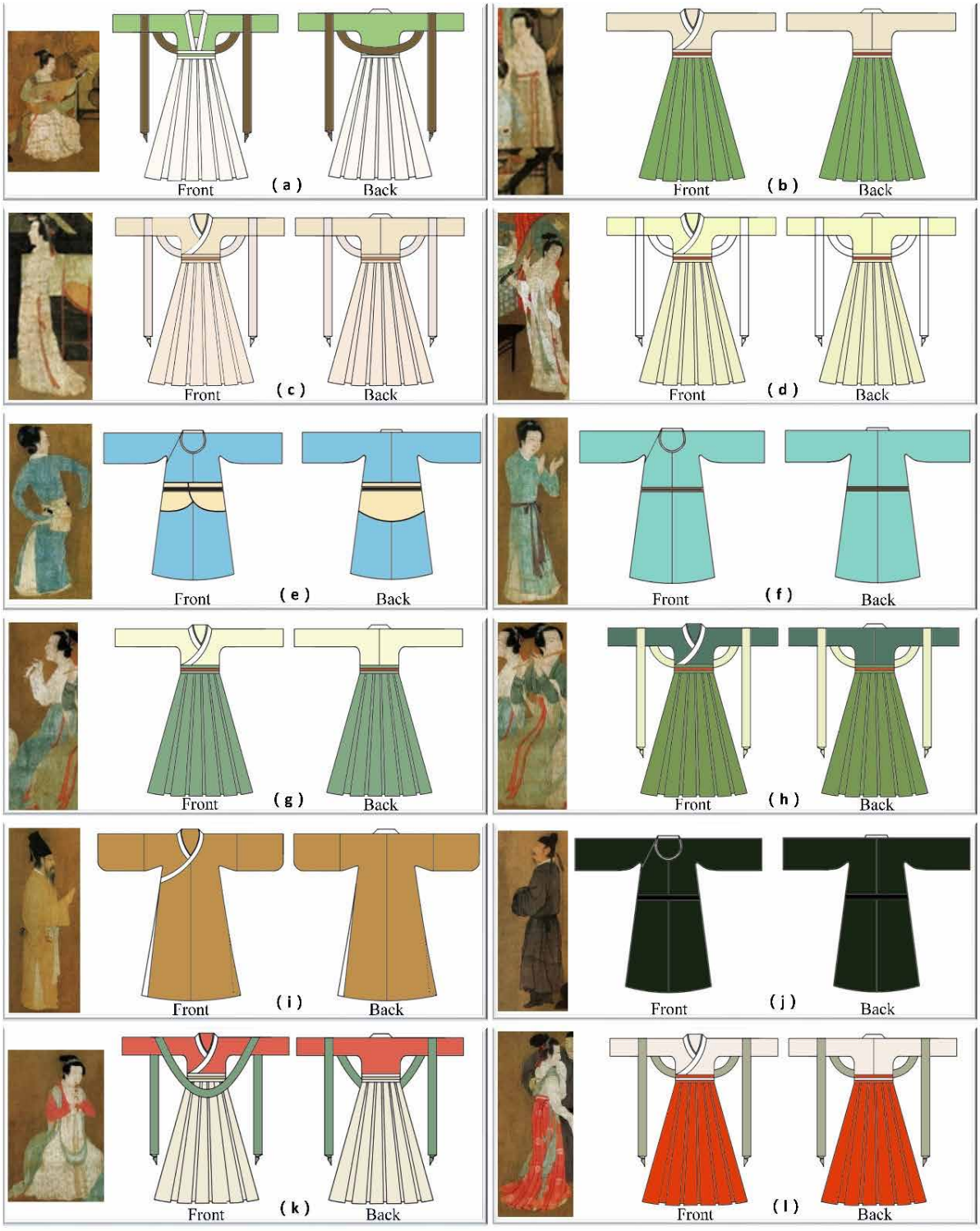

Figure 9. Style of 12 sets of restored costumes in the Han Xizai Banquet painting.

body, human body proportion and the wearing effect of people and garment. At the same time, we infer and calculate the size data of the restored garment based on the contract era, the same type of garment, and other image data. From the human body, we determine the relationship between the body parts and garment parts of the character through observation and obtain the corresponding human body size data. For example, if the sleeve length of the character in the painting restored image just reaches the wrist, the corresponding sleeve length is about the arm length of the human body.

In addition to the structure that can be determined according to human body parts, the width and length of most garments, such as spliced lengthened sleeves and widened sleeves, exceed the range of human limbs, and the size of the garments should be calculated using the relationship of the proportions of the human body. That is to say, the height of the body is divided into seven units, with the waist line as the node, and the upper and lower parts are three heads and four heads respectively. First, we need to determine the head point, front neck point, and waistline midpoint of the character image. Then connect the three points in a straight line to form two straight lines. If the included angle of the two straight lines is close to 180°, that means that the corresponding limb is not bent, and the nodes of the first and third parts can be directly connected in a straight line. Then measure the 3D straight line length n between the two nodes, and the corresponding length n_1 between the two joints in the standard human body can be obtained. We measure the length m of a part of the garment in the image, and calculate the length data m_1 of the garment structure restoration according to the proportional relation $n/n_1 = m/m_1$, as shown in Figure 10.

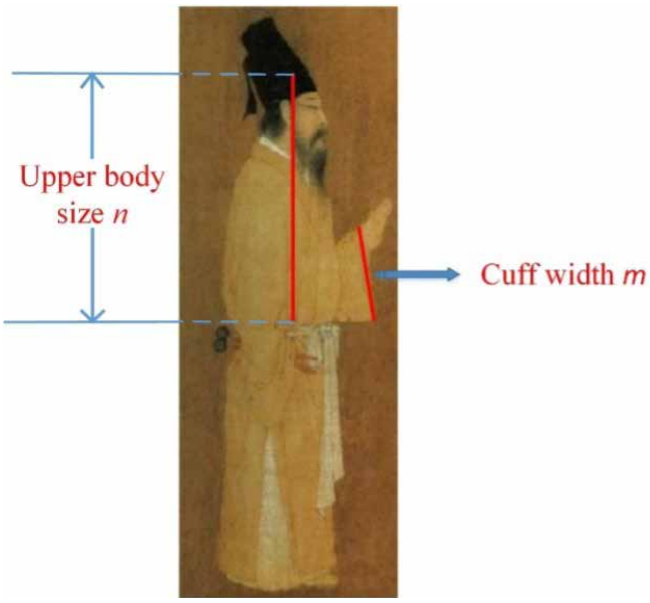

Figure 10. Determination of garment size data by human body proportions.

The garment size obtained by consulting relevant literature and combining human body basis and human body proportion is shown in Table 1. After determining the size of the main parts of garment, we make pattern for different types of garment by using CAD and other pattern making software according to the garment size. This process can achieve the expected effect by changing the size and style of the paper pattern, as shown in Figure 11.

2.6 3D virtual simulation restoration

Through the steps above, we have completed the archaeology and pattern making of the character costumes in the Han Xizai Banquet painting; next, the virtual simulation restoration of the characters costumes in the painting is carried out. At present, 3D software mainly includes two categories. One focuses on modeling and rendering, such as 3D Max, Maya, etc., which is mostly used in game environments, film and television, and 3D animation. The other category is dedicated to garment design and virtual display. This kind of software pays more attention to garment pattern making and fabric simulation, such as DC suite, marvelous designer, CLO 3D, etc. This software basically has the functions of model design and modification, model virtual try-on, dynamic virtual display, and so on, providing efficient, convenient, multi-dimensional and intuitive technical support for garment design and display. We chose CLO 3D software for 3D virtual simulation restoration. The reason we choose it is that the function of CLO 3D software is more humanized, it supports the import of template files in DFX format, and it also has relatively mature technologies in fabric simulation and dynamic 3D. We sew the 2D pattern to the virtual human body in the 3D virtual environment, and set the physical properties such as pattern, process, color, thickness, elasticity, and hardness of the fabric in the parameters according to the style of the characters' garments in the painting. Firstly, we select the character model in the 3D virtual system and set the human body parameters and then import the 2D garment pattern drawn in the 3D virtual simulation software. The patterns in the form of plane can be seen in the 2D and 3D visual interfaces, and the pattern can be accurately matched and attached to the corresponding body parts through the set arrangement points. Next, with the help of sewing tools, the virtual sewing of patterns is carried out in the same way as the actual garment pattern. In this process, one-to-one correspondence between pattern should be ensured. Different types of sewing tools are used under different sewing conditions, and timely adjustment should be made when sewing mistakes occur. After the stitching is completed, the virtual garments are displayed. Because the restored object wears a multi-level garment, the virtual stitching and fitting need to follow the principles from top to bottom and from inside to outside in the restoration process. Finally, the virtual human body is rotated to adjust the details of the 3D model to complete the virtual simulation restoration of the garment in the Han Xizai Banquet painting.

3. Fuzzy comprehensive evaluation of a garment's virtual restoration effect

3.1 Determine the set of evaluation items

The virtual restoration of garments is the reproduction of the original appearance based on pictures and documents. Therefore, it is necessary to restore the structure, style, color, pattern, and other information of clothing when we perform virtual restoration of garments. At present, there is no unified

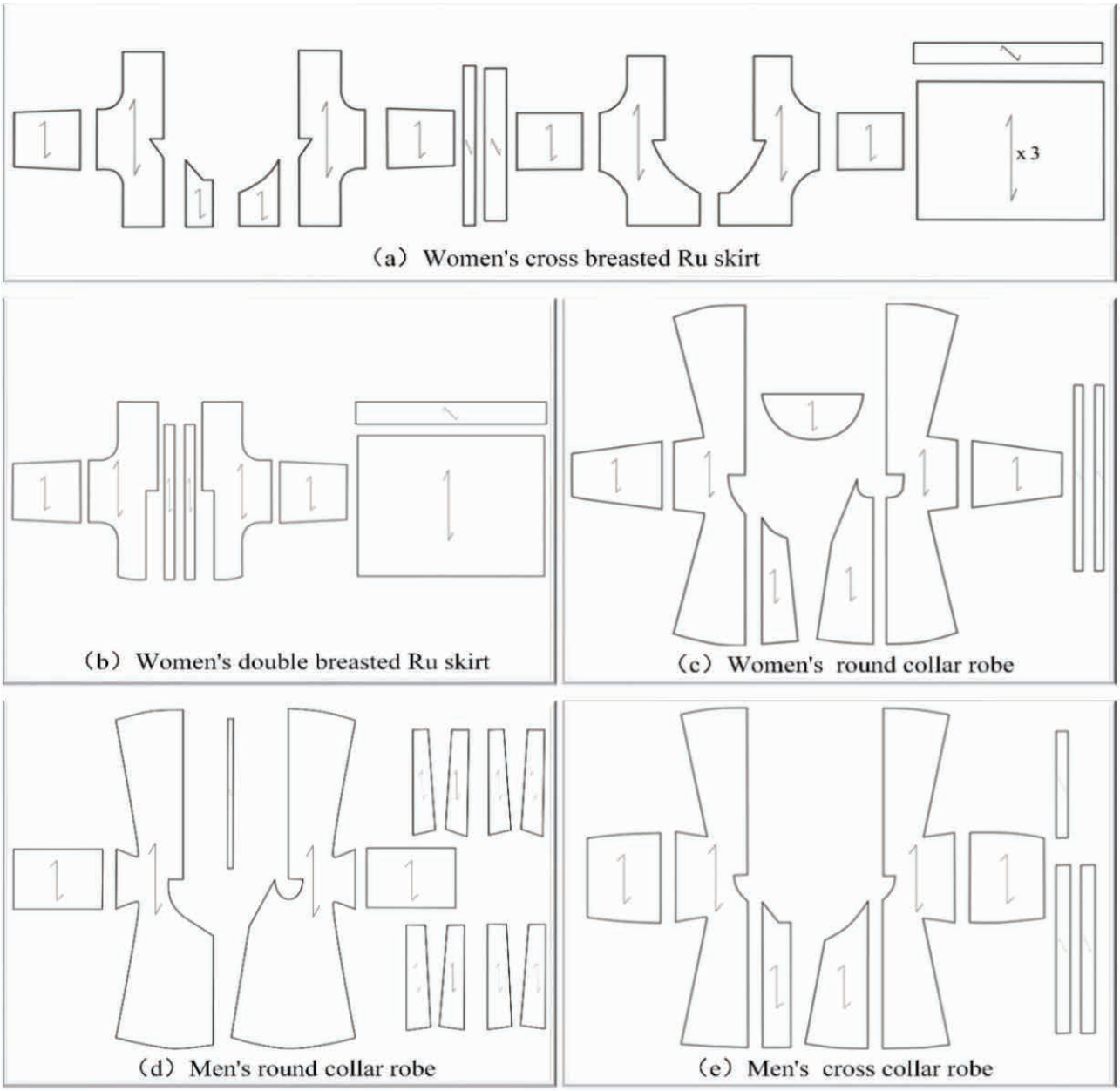

Figure 11. Different types of garment patterns.

evaluation standard for the effect standard of garment virtual restoration. After consulting relevant literature, we finally determine the evaluation index of the garment restoration effect U, $U = (u_1, u_2, u_3, u_4)$, where u_1 = overall shape, u_2 = color pattern, u_3 = fabric performance, u_4 = detail structure, that is to say, the evaluation index of garment restoration effect is U = (overall shape, color pattern, fabric performance, detail structure).

3.2 Determine the recovery effect evaluation set

Evaluation set is the set of evaluation results that evaluators can make for each factor, and the evaluation of different evaluation indicators is different. According to the restoration effect, a five-level evaluation standard $C = (c_1, c_2, c_3, c_4, c_5)$ is adopted, where c_1 = very poor, c_2 = poor, c_3 = average, c_4 = good, c_5 = very good, in other words, the evaluation standard of garment restoration effect is C = (very poor, poor, average, good, very good).

3.3 Determine the weight coefficient of each index

Different indicators have different effects on the evaluation of the virtual restoration effect, so it is very important to determine the weight of each indicator. We use the priority chart method to determine the weight of each item in the evaluation project set, and a jury group is composed of eight experts in the field of garment digital technology. They compare two of the four indicators according to their professional experience. If the index *Xi* is more important than the index *Xj*, *Xi* gets 1 point; if it is equally important, *Xi* gets 0.5 points; If the index *Xj* is more important than the index *Xi*, *Xi* will get 0 points, and the results are shown in Table 2.

According to the score, we calculate the importance weight of each influencing factor, so the calculated weight is as follows:

$$\alpha_i = R_i \Big/ \sum_{k=1}^{8} R_k \tag{1}$$

Table 1. Restore garment size (Unit: mm).

Category	Length	Ready to wear bust	Hem width	Cuff width	Arm length	Neckline width	Collar width
Women's cross-breasted Ru skirt	620	980	490	200	1,680	168	60
Women's double-breasted Ru skirt	680	1,000	560	200	1,680	166	70
Women's round collar robe	1,165	1,000	860	181	1,950	168	35
Men's round collar robe	1,460	1,100	1,020	257	2,250	180	35
Men's cross collar robe	1,235	1,080	820	205	1,810	180	75

The weight of each index calculated by equation (1) is $A = (\alpha_1, \alpha_2, \alpha_3, \alpha_4) = (0.41, 0.16, 0.09, 0.34)$. According to the degree of membership, we can see the corresponding weight of each index and get the importance of each index: overall shape > detail structure > color pattern > fabric performance.

3.4 Establish fuzzy evaluation matrix

After we have determined the evaluation items, evaluation scale, and evaluation item weight, the recognition degree of virtual garment is evaluated in the form of questionnaire survey. The survey objects are college students who have a relevant understanding of virtual garment. A total of 267 questionnaires were collected, including 255 valid questionnaires, with an effective rate of 95.5%. The survey statistical results are shown in Table 3.

According to the statistical results in Table 3, the comprehensive evaluation matrix, as follows:

$$E = \begin{bmatrix} 0 & 0 & 0.05 & 0.44 & 0.51 \\ 0 & 0 & 0.11 & 0.43 & 0.46 \\ 0 & 0 & 0.48 & 0.24 & 0.28 \\ 0 & 0 & 0.46 & 0.44 & 0.10 \end{bmatrix}$$

3.5 Fuzzy comprehensive effect evaluation

Each line in E_i indicates that in the evaluation of the effect of garment digital restoration, the subordinate degree of each item index is investigated from different factors, and the corresponding evaluation item weight is used to synthesize E_i. Finally, the comprehensive effect evaluation B can be obtained. We use formula $B \bullet A \bullet E$ to calculate B as follows:

Table 2. Restoration effect index importance ranking.

Sort	Overall shape	Color pattern	Fabric performance	Detail structure
R_1	1	0	0.5	0.5
R_2	0.5	0.5	0	1
R_3	1	0.5	0	0.5
R_4	1	0	0.5	0.5
R_5	1	0.5	0	0.5
R_6	0.5	0.5	0	1
R_7	1	0.5	0	0.5
R_8	0.5	0	0.5	1
Score (R_j)	6.5	2.5	1.5	5.5

Table 3. Statistical results of restoration effect recognition evaluation.

Evaluating indicator	Very poor	Poor	Average	Good	Very good
Overall shape	0	0	0.05	0.44	0.51
Color pattern	0	0	0.11	0.43	0.46
Fabric performance	0	0	0.48	0.24	0.28
Detail structure	0	0	0.46	0.44	0.10

$$B = [0.41 \quad 0.16 \quad 0.09 \quad 0.34] \bullet \begin{bmatrix} 0 & 0 & 0.05 & 0.44 & 0.51 \\ 0 & 0 & 0.11 & 0.43 & 0.46 \\ 0 & 0 & 0.48 & 0.24 & 0.28 \\ 0 & 0 & 0.46 & 0.44 & 0.10 \end{bmatrix} =$$

$$[0 \quad 0 \quad 0.24 \quad 0.42 \quad 0.34]$$

The comprehensive evaluation results show that 24% of the evaluators think the restoration effect is "general," 42% think the restoration effect is "good," and 34% think the restoration effect is "very good." According to the principle of maximum subordination, the restoration effect of character costumes in the Han Xizai evening banquet painting is "good."

4. Results and Discussion

The Five Dynasties inherited the glory and grandeur of the Tang Dynasty costumes and laid a foundation for the simple and slightly formal costumes of the Song Dynasty. In this paper, the archeological and digital restoration is carried out on the typical costumes in the Han Xizai Banquet painting, a figure painting of the Five Dynasties. First, different scenes and characters in the painting were analyzed from the perspective of archaeology. Second, from the contemporary and other image data, we inferred the style characteristics of each garment from the aspects of style, color, pattern, and fabric through the painting style of the portrait, the texture and drape of the garment, etc. Finally, image processing software and virtual fitting software were used to make pattern and virtual simulation restoration. The simulation restoration of the garments in the Han Xizai Banquet painting obtained by visual virtual fitting, as shown in Figure 12.

From the comprehensive evaluation results of fitting effects and restoration effects, the virtual garments restored by digital technology can basically restore the shape, structure, color, and pattern of the garments, and we can observe the wearing of the garments from multiple angles, which is conducive to the further research of related garments.

The Five Dynasties period is an important period in Chinese history from the Tang Dynasty to the Song Dynasty. In this period, society was turbulent and the political power existed for a short time. Therefore, there are relatively few historical records for this period, and the data that can reflect the garments at that time are scarce. Researchers can analyze and study these issues only with the help of literature or art works such as painting and sculpture. From the perspective of academic research, there are many works that comprehensively analyze and study the modeling characteristics of men's and women's costumes in the Han Xizai Banquet painting. However, the research existing in the academic circle is to analyze and discuss the costumes of the Han Xizai Banquet painting in the form of text expression, and no one has carried out virtual restoration of its costumes so far.

In terms of costume restoration, its research methods and practical application cases have appeared for a long time. Researchers mostly apply them to the physical reproduction of costume cultural relics, while the restoration of traditional costumes without physical preservation is rarely involved. Most of the researchers engaged in the history of garments and in the existing research results have limitations in the practical production of the experience and research methods that can be used for reference, and the restored objects are difficult to preserve for a long time. This situation cannot contribute to the dissemination of culture. After examining the literature related to this subject and the garment shape changes of the former and future generations of the Five Dynasties, we take men's and women's garments in the figure painting as the research focus and restore its garments with the help of the 3D virtual display system to obtain the restoration of the dynamic and static garments in the picture.

Through the restoration of the characters' costumes in the Han Xizai Banquet painting, this paper has played a certain role in the study of the men's and women's costumes of the Five Dynasties and Ten Kingdoms, and provided some help to the scholars studying the costumes in Han Xizai Banquet painting in the future. Using 3d virtual fitting technology for simulation restoration is beneficial to reflect the real garment pattern, fabric, and workmanship. In the process of restoring garments, we can find the problem of garment patterns earlier. Meanwhile, 3D garments can more intuitively reflect a lot of information, which can effectively improve work efficiency, greatly shorten the cycle of garment restoration, speed up the number of garments designed, and change the fabric and pattern of garments freely.

With the revival of traditional culture, traditional costumes began to go out of the museum and appear to the general public, so that an upsurge of wearing, displaying, and studying ancient traditional costumes quietly rose in the society. Some enthusiasts spontaneously formed "Han Fu" societies and other nongovernmental organizations. They held activities such as "Han Fu day" and "costume restoration" production, so as to promote the traditional costume culture to the public. At the same time, some historical films, television dramas, and games have shown all kinds of gorgeous and unrestrained ancient costumes. However, there are different degrees of deviations between these costumes and ancient costumes in history. Designers have added too much of modern aesthetics to the design process. It is more necessary for costume history researchers to correctly and scientifically guide the public to understand, wear, and make ancient traditional costumes. Using digital technology to restore ancient costumes can enrich research approaches; lead to understanding the wisdom and design essence of the ancients; make up for and improve the deficiencies in the design, style, and structure of traditional costumes, which can enlighten costume design nowadays; and correct the public's misunderstanding of traditional costumes to a certain extent, as the cornerstone of the inheritance and research of traditional costumes.

Figure 12. Virtual simulation restoration of costumes in the Han Xizai Banquet painting.

5. Conclusion

Using digital modeling and virtual display systems, this paper takes the costumes in the Han Xizai Banquet painting, a figure painting of Five Dynasties and Ten Kingdoms, as its research object and analyzes and studies the figures' costume characteristics of the five generations and ten countries in the works. On this basis, we have made a 3D virtual costume restoration of the costumes of this period.

(1) By analyzing the shape, fabric, pattern, and color of men's and women's garment in the Han Xizai Banquet painting of the

Five Dynasties and Ten Kingdoms, this paper fills in the content of garment culture of the Five Dynasties period and improves the research on garments in the Five Dynasties, which has a certain value and significance for the restoration of ancient Chinese characters' garments.

(2) The restored clothing does not need to be preserved on the spot, which breaks the constraints of time and space on the dissemination of ancient clothing culture and provides a new method for the digitization of historical and cultural heritage.

(3) The research on the male and female images in the Han Xizai Banquet painting and the restoration of costumes provide a new way to better carry forward ancient Chinese culture and restore ancient Chinese costumes. At the same time, it provides a reference for the design of artistic works such as character costumes in film and television and games.

(4) The digital restoration of the characters' costumes in these works is conducive to accelerating the construction of the Digital Museum of ancient costumes, so as to effectively enhance the interaction and participation between visitors and cultural relics, facilitate future generations' learning and observation, and create a new channel for the culture and inheritance of ancient costumes.

Acknowledgments

The work was financially supported by the China National Endowment for the Arts, China (No. 2018-A-05-(263)-0928); the Art science project of National Social Science Fund, China (No. 19EG211); the Social Science Fund Project of Shaanxi Province, China (No. 2018K32); the Innovation ability support plan of Shaanxi Province-young science and Technology Star Project, China (No. 2020KJXX-083); the National Natural Science Foundation of China, China (No. 61806161); the Shaanxi higher education teaching reform research project, China (No. 21BZ046); the Shaanxi higher education science research project, China (No. XGH21143); and The Youth Innovation Team of Shaanxi Universities, China (No. 21JP048).

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