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Study and Digital Restoration of Costumes Unearthed from the Tomb of Zhao Boyun

Geheng Feng[1], Kaixia Li[2], Ziyi Xie[1], Fandong Kong[3]*

[1] *School of Fashion Design & Engineering, Zhejiang Sci-Tech University, No.2 Street, Xiasha Higher Educational Park, Hangzhou P.R., 310018, China; 956989621@qq.com*
[2] *CHINA CERTIFICATION &INSPECTION GROUP ZHEJIANG Co.,LTD. 310018, China; 312724374@qq.com*
[3] *International Institute of Fashion Technology, Zhejiang Sci-Tech University, No.2 Street, Xiasha Higher Educational Park, Hangzhou P.R., 310018, China*
* *Corresponding author. E-mail: kongfandong@126.com*

Abstract
Ancient costumes are a valuable historical heritage of Chinese civilization, and the preservation of traditional culture is an essential contemporary research topic. However, exhibiting precious cultural relics will risk damage, but digitizing traditional costumes can effectively solve this problem through virtual exhibition, and help traditional costume culture spread more widely with the help of technology. The article took sixteen costumes worn by the owner of the tomb of Zhao Boyun of the Southern Song Dynasty in Huangyan as the object of study, analyzed their structural dimensions and fabric patterns, and digitally restored them using the style3D software system. Finally, the fuzzy analytic hierarchy process evaluated the garment restoration effect. This approach effectively combines the conservation of cultural relics and cultural inheritance with information technology and digitalization, which provides new ideas for disseminating traditional costumes and promotes the heritage and development of ancient Chinese costumes.

Keywords
The tomb of Zhao Boyun, men's costumes of the Song dynasty, digital restoration.

1. Introduction

In May 2016, a more than 800-year-old Southern Song Dynasty tomb owned by Zhao Boyun was excavated in Huangyan District, Taizhou City, Zhejiang Province, and a total of 76 costume artifacts were unearthed, covering clothing, pants, shoes, socks, and hats, and containing a variety of silk categories. Its rich form, exquisite weaving techniques, and various motifs reflect the high silk weaving technology at that time, which is why it is called "the crown of Song clothing." These precious cultural relics are of great significance to the study of the cultural history of the Southern Song Dynasty, as well as the history of costume, art history, economic history, etc. It is another significant discovery in silk cultural relics.

Before this, Zhejiang, where the capital of the Southern Song Dynasty is located, had had a few Southern Song Dynasty silks unearthed. In the Southern Song tombs that have been unearthed, the silk artifacts are either poorly preserved or damaged by theft, making it difficult to see the full extent of Southern Song silk clothing. The appearance of Zhao Boyun's tomb has changed this situation. Not only is it undisturbed by tomb robbers, but the preservation of its silk products is relatively intact. This matter opened a door for the study of Zhejiang silk, especially that of Zhejiang Southern Song silk, so it is necessary to study the silk clothing excavated from Zhao Boyun's tomb.

However, most modern archaeological excavations are incredibly fragile, and over time, silk artifacts in tombs often break and become mutilated. Although restored by modern people, it is impossible to ensure that the artifacts are not damaged during exhibition. And the exhibition of physical relics is often limited by time and space, which could be not conducive to the wide dissemination of ancient Chinese costume culture. In this context, a new approach to the conservation and dissemination of silk costumes of the Southern Song Dynasty in Zhejiang is urgently needed. Fortunately, since the 1990s, with the rapid development of computer technology, 3D technology, including data acquisition, 3D scanning, digital modeling, and other technologies, have gradually matured. At the same time, 3D technology is gradually being applied to the restoration, conservation, research, repository, and dissemination of cultural heritage. Its excellent mechanism and easy operation are very suitable for the above five projects.[1]

In the conservation, restoration, and study of cultural artifacts, the use of 3D technology allows for contactless examination of the interior and exterior of objects without destroying the physical integrity of the artifact. Peter Reischig et al.[2] conducted visualization of a prayer nut by computerized X-ray tomography. Anton Du Plessis et al.[3] combined high-resolution computed tomography with rapid prototyping techniques for the production of an accurate 1-to-1 model of an object obscured by an envelope. In addition, virtual simulation technology allows for easy and quick detailed restoration of artifacts, providing a powerful digital solution for costume artifacts that are not easily preserved. In this way, Victor Kuzmichev et al.[4] conducted a study on the re-patterning and 3D virtual simulation of 19thcentury menswear. Aleksei Moskvin et al.[5] conducted a three-dimensional reconstruction of a caged petticoat from the late 1950s and 1960s using CG modeling techniques to digitally recover Germanic warriors' equipment and study its fit and comfort. Maria Cybulska's conducted restoration of archaeological textiles using CG modeling techniques[6]. Liu Kaixuan et al.[7] digitally restored a plain unlined silk robe excavated from the Mawangdui Han tomb in Changsha, Hunan, China. They judged the restoration effect using hierarchical analysis and the fuzzy comprehensive evaluation method. The case shows that digital restoration of ancient costumes using 3D modeling technology facilitates the restoration study of artifacts and enables a more diverse and detailed study of ancient costumes more efficiently.

In this context, we tried to use 3D virtual fitting technology to digitally recover typical cases of costumes excavated from the tomb of Zhao Boyun of the Southern Song Dynasty in Huangyan to provide a new approach to the inheritance and development of Song charm menswear culture and Zhejiang silk culture. The digital restoration not only demonstrates the charm of Song culture and Zhejiang silk culture but also fills the academic gap in the digital restoration of Song men's costumes.

2. Research aim

This paper digitally restored 16 costumes on the body of the tomb owner excavated from the tomb of Zhao Boyun of the Southern Song Dynasty in Huangyan, based on physical materials and supplemented by documentary and pictorial materials. Complete costume relics are a valuable heritage of Chinese costume culture, which allows us to learn important information about the social, economic, political, cultural and living conditions as well as spiritual beliefs of people thousands of years ago. Using digital technology to restore and display costume relics not only avoids secondary damage to valuable relics in the process of research and display but also makes it easier to exhibit and promote. This allows the audience to understand the characteristics and charm of ancient costumes more intuitively and facilitates the construction of a digital museum of ancient costumes.

3. Material and methods

3.1 General Scheme

The approach of this paper was to gradually complete the 3D virtual modeling restoration of 16 costumes on the corpse of the tomb owner of Zhao Boyun in the Southern Song Dynasty, based on the physical objects combined with documentary and image materials. Then, a fuzzy evaluation system was established on this basis, and the Fuzzy analytic hierarchy process and fuzzy comprehensive evaluation method were used to judge the overall recovery effect. The study is divided into three main parts, as shown in Figure 1:

- The 16 costumes on the body of the tomb owner of Zhao Boyun were analyzed through five aspects: size, structure, color, pattern, and fabric.
- The paper pattern was drawn separately according to each garment's specific structure and size, and the materials prepared were put into a 3D environment for digital modeling in conjunction with the prep work.
- The effect presented by the combined virtual simulation model was adjusted to achieve the best recovery effect.
- T Fuzzy hierarchical analysis and the fuzzy comprehensive evaluation method were used to evaluate the recovery effect and verify the completion of recovery.

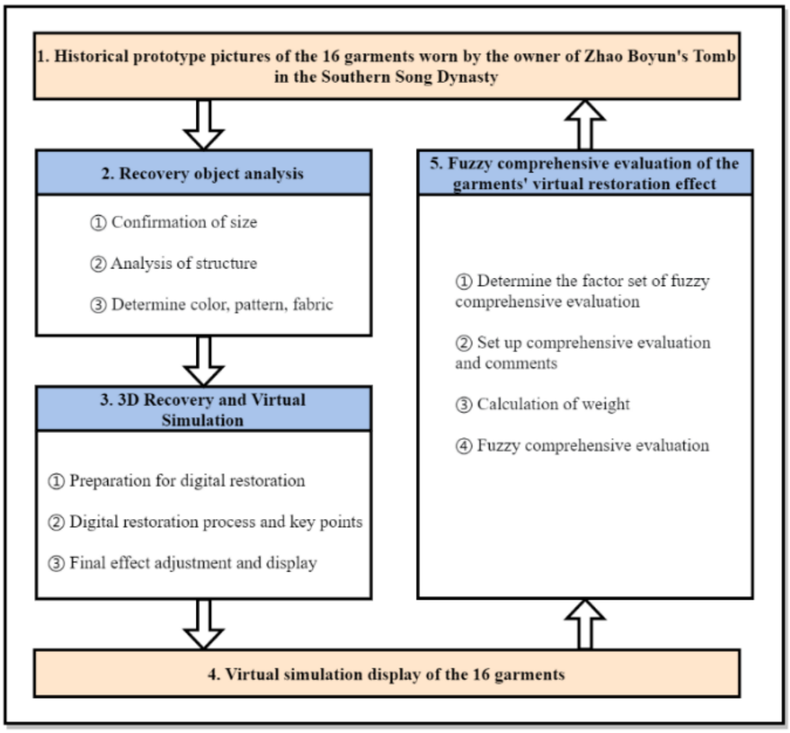


Fig. 1. Digital restoration process

3.1. Recovery Object Analysis

3.1.1. Size confirmation of the costume worn by Zhao Boyun

Zhao Boyun (1155-1216), the seventh-generation descendant of Song Taizu Zhao Kuangyin, was buried at the rank of an eighth-rank official after his death. The study found that Zhao Boyun wore sixteen pieces of clothing at the time of his burial, divided into eight layers and worn in various forms. Tops include cross-collar shirts, symmetrical front jackets, and round-collar robes; pants include closed-crotch pants, open-crotch pants, and shin guards; collar types include closed-collar, cross-collar, round-collar and plate collar, and sleeves include wide sleeves, oversized sleeves, and narrow sleeves.

Based on the physical measurements and data review, it can be seen that most of the tops only have slight differences in the details, and the overall structure is in accordance with the "cross-shaped" planar structure of Han Chinese traditional clothing. Among Zhao Boyun's series of costumes, the round collar plain big sleeved robe shirt worn on the outermost layer belongs to the most generous official costume, as shown in Table 1. The rest are loose-fitting pairs of symmetrical front jacket or cross-collar shirts, which belong to daily wear. Pants can be divided into two types open-crotch pants and closed-crotch pants. Most closed-crotch pants are sewn together in two pieces at the front and back, attached to the waist, with a triangular cutout sewn at the crotch and an opening at the middle back or left side of the waistband. The open-crotch pants are sewn together at the front and back of the trouser legs, with a waistband attached to the top, two small triangular cut pieces stitched together on the inside of the pants without sewing, an open waist at the back, and ties at the sides. The second layer of these silk closed-crotch sandwich pants, which are not sewn on the outside and have openings, are worn with both legs sticking out from the unstitched sides of the pants. The third layer of open-crotch brocade trousers has no waist and crotch, with only two trouser cylinders, similar to shin guards.

3.1.2. Structural analysis of the costume worn by Zhao Boyun

Although each of the 16 costumes has its own characteristics, it is possible to find patterns in them. Therefore, we selected a few of the distinctive dresses to draw a structure diagram and used it as the basis to create a paper pattern of the dress on a computer. The structure diagram drawn is shown in Figure 2. Where a) is the symmetrical front jacket, b) the round-collar big sleeved robe, c) the round-collar sandwich robe, d) the crossed-collar coat, e) the round-collar sandwich robe, f) the closed crotch sandwich pants, g) the shin guards, and h) is the open-crotch pants.

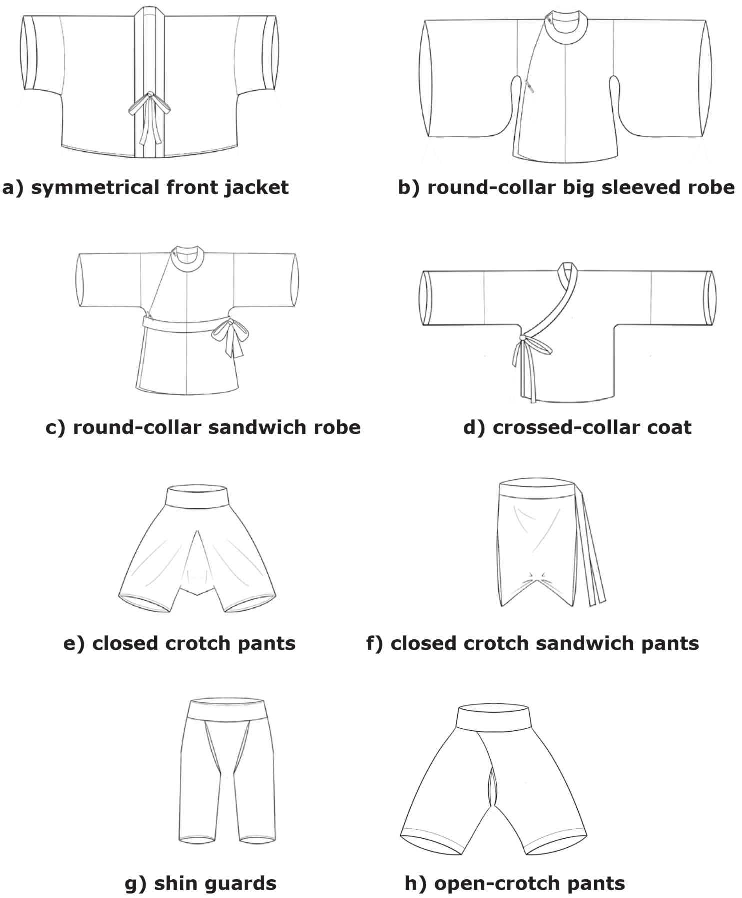


Fig. 2. Structure diagrams

3.1.3. Fabric, color, and pattern analysis

In the history of Chinese costume culture, the costume culture of the Song Dynasty has distinctive characteristics of freshness, elegance, leisure, and nature. The silk weaving industry in the Song Dynasty was well developed, and the institutions managing silk weaving and dyeing production were massive, with an excellent division of labor. The silk fabrics of the Song Dynasty were light and breathable, showing a translucent effect. In addition to the high level of weaving technology at that time, another reason was that the silkworms that people raised at that time gave out finer and tougher silk, and the silk thread itself had a small gram weight.

Clothing fabrics included gloss, color shades, fabric thickness, and other details according to the characteristics of different fabrics, such as thick but loosely woven silk, damask, brocade, and yarn to adjust the display effect one by one so that the modeling presented the physical state as far as possible.

According to the "Huangyan Xiqiao Zhao clan tree," Zhao Boyun was the seventh-generation descendant of Song Taizu Zhao Kuangyin, born in the 25th year of Shaoxing (1155) and died in the 9th year of Jiading (1216). After his death, he was given the title of "General Counselor" because he was a descendant of the royal family, which should have been a fourth-ranking official title. However, he was still enshrined at the original eighth-ranking official level. Experts in literature and history believe that the title was not a reflection of actual blessings but only a nominal blessing. According to the costume color specification of the Song Dynasty, the color of the costume worn by Zhao Boyun should be cyan.

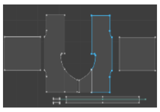
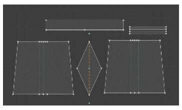
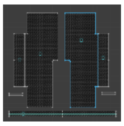
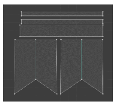
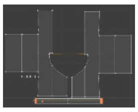
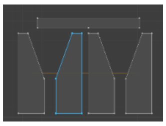
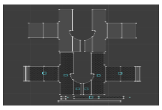
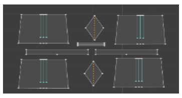
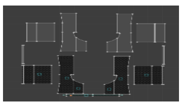
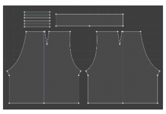
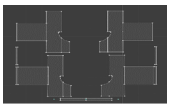
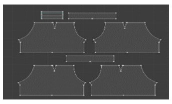
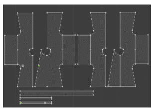
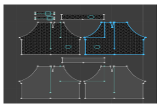
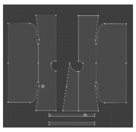
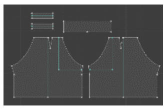
Level and Name	Illustration	paper pattern	Structural features	Size
The first layer (innermost layer) top: cross-collar silk single coat			Straight collar, straight lapel right, left and right slit	Through-sleeve length 262cm, sleeve width 39cm, hem width 85cm, neckline width 17cm, collar width 6cm
The first layer (innermost layer) trousers: silk closed crotch single pants			Closed crotch, Trousers with wide opening, live pleats on both sides	Trousers length 65cm, waist width 48cm, waist band 12cm, crotch depth 43cm, trouser width 48cm, belt length 45cm
The second layer top: wrapped grape pattern silk symmetrical front jacket			Straight collar, wide sleeves	Through-sleeve length 150cm, sleeve width 59cm, hem width 117cm, neckline width 23cm, collar width 5.5cm
The second layer trousers: silk closed crotch sandwich pants			Closed crotch, left and right slit, tied on the left side	Trouser length 67cm, waist width 51cm, waist band 14cm, crotch depth 49cm,trousers width 26cm, belt length 80cm
The third layer top: embroidered ball and plum blossom damask cross-collar coat			Straight collar, straight lapel right, left and right slit	Through-sleeve length 270cm, sleeve width 54cm, hem width 85cm, neckline width 18cm, collar width 6cm
The third layer trousers: open-crotch brocade trousers			Crotchless, similar to shin guards	Trouser length 83cm, waist band 10cm, crotch depth 47cm, trousers width 27cm, belt length 53cm
The fourth layer top: flame pattern silk crossed-collar coat +plum pattern ribbon			Right overlapping collar, narrow sleeves, with a ribbon around the waist	Through-sleeve length 292cm, clothing length 125cm
The fourth layer trousers: silk closed crotch sandwich pants			Closed crotch, pleats on both sides of the front, tied on the left side	Trouser length 82cm, waist width 52cm, trouser width 40cm, waist band 13.5cm, belt width 5cm, crotch depth 45cm
The fifth layer top: camellia print silk cross-collar sandwich shirt			Right overlapping collar, narrow sleeves	Through-sleeve length 290cm, clothing length 142cm
The fifth layer trousers: scrolling dragon pattern silk open crotch sandwich pants			Crotch opening, rear center tie	Trouser length 85cm, waist width 59cm, waist band 14cm, crotch depth 47cm, trouser width 41cm, belt length 63cm
The sixth layer top: cross-collar silk sandwich jacket with floral and Ruyi pattern			Right overlapping collar, narrow sleeves	Through-sleeve length 289cm, sleeve width 54cm, hem width 95cm, width neckline 17cm, collar width 6cm

Table 1. Name, features and size of each layer

Level and Name	Illustration	paper pattern	Structural features	Size
The sixth layer trousers: sesame brocade open-crotch sandwich pants			Crotch opening, rear center tie	Trousers length 79cm, waist width 47cm, waist band 15cm, crotch depth 45cm,trouser width 45cm, belt length 100cm
The seventh layer top: round-collar plum print sandwich robe			Crew neck, large lapel right, large sleeves, with a ribbon around the waist	Through-sleeve length 194cm, sleeve width 50cm, clothing length 127cm, belt width 14cm, belt length 254cm, wide hem 106cm
The seventh layer trousers: grapevine print silk open-crotch sandwich pants			Crotch opening, rear center tie	Trouser length 79cm, waist width 47cm, waist band 15cm, crotch depth 45cm, trouser width 45cm, belt length 100cm
The eighth layer top: round-collar plain big sleeve robe			Crew neck, large lapel with right hand, large sleeves	Through-sleeve length 230cm, sleeve width 95cm, clothing length 115cm, sleeve root width46cm, chest width 72cm, hem width 96cm
The eighth layer trousers: diamond lattice flower pattern pants			Crotch opening□rear center tie	Trouser length 84cm, waist width 52cm, waist band 14cm, crotch depth 40cm, trouser width 48cm

Continued *Table 1. Name, features and size of each layer*

The clothing worn by Zhao Boyun is richly patterned, elegant, and delicate, with natural flowers and birds as the main content. There are the wrapped grape pattern, the embroidered ball plum pattern, the flame pattern, the camellia pattern, the floral square winning ruyi pattern, the scrolling dragon pattern, and the diamond lattice flower pattern. Among them, the wrapped grape pattern has realistic characteristics, with curved and twisted vines and rounded and full fruits, making the pattern full of composition, delicate and neat, but also lively and dynamic. The continuous structure of the grapes implies a wish for long life, and the fruitfulness of the grapes is also a metaphor for many children and many blessings, as shown in Figure 3(a-2). The floral square winning ruyi pattern is a typical square skeleton pattern, decorated with fine bouquets on all sides and filled with regimented geometric patterns inside the square Sheng, the overall structure is tight and presents an exotic atmosphere, as shown in Figure 3(b). The flame pattern has the characteristics of geometrized patterns typical of the Southern Song Dynasty, with freshness, elegance, lightness, and simplicity, as shown in Figure 3(c). The camellia pattern is based on the camellia flower, as shown in Figure 3(d). The camellia flower blooms in the cold of winter, but it does not affect its noble beauty, symbolizing the tough and modest character of the wearer. These patterns demonstrate the scholarly class's elegant aesthetic sensibilities and incorporate the people's good wishes for good fortune, longevity, and peace.

3.2. Process of 3D Recovery and Virtual Simulation

3.2.1. Preparation before 3D Recovery

The modeling software currently available on the market for cultural relic restoration can be divided into two categories: one is CG modeling software, such as blender, 3ds max, Maya, etc. This modeling software is more suitable for the recovery of hard material relics. The other is specialized in clothing modeling, such as CLO 3D, Marvelous Designer, Style 3D, etc., more suitable for recovering ancient clothing modeling. Thanks to the large library of styles and fabrics, this article used Style 3D software from a Chinese company to carry out the restoration modeling.

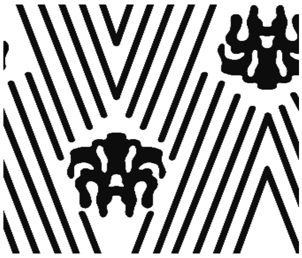
Based on the analysis of the dress shape and size in the previous section, we proceeded with drawing the paper pattern. The paper pattern was drawn after referring to the graphic materials and physical dimensions. The lapel shirt, cross collar shirt, and round collar shirt were the three most basic forms of the eight sets of clothing worn by Zhao Boyun at the time of his funeral. After drawing these three paper patterns, we changed the size and details to draw the

a-1) actual pattern

a-2) restored pattern

a) Wrapped grape pattern: a comparison between the actual pattern and the restored pattern

b) Floral square winning ruyi pattern



c) flame pattern

d) camellia pattern

Fig. 3. Pattern recovery

rest of the costumes. Pants, on the other hand, are available in open-crotch pants, shin guards, and closed-crotch library, and we also drew paper patterns by looking for patterns.

In addition to the garment's paper pattern, the pattern's preparation was completed before the digital restoration. For example, as shown in Figure 3(a), the four-sided continuous pattern of the wrapped grape pattern is drawn against the excavated costume and exported as a transparent background image in png format for easy use. When making a garment, we can use the pattern continuity function in the software to make the pattern fill the fabric by four-sided continuity.

3.2.2. Virtual fitting recovery process and key points

3.3.2.1 Recovery process

After archaeologists examined Zhao Boyun's corpse, they judged his height to be around 1.7 meters. Before proceeding with the garment, a mannequin of similar height was set up in the style3D software system for the subsequent steps. After setting up the mannequin, we placed the paper pattern in the corresponding position around the virtual model. The specific steps are shown in Figure 4.

3.3.2.2 Production points

Fitting the costume on the mannequin is only the beginning of the digital restoration step, after which a series of detailed adjustments need to be made. First of all, if the garment does not fit well on the mannequin, you can use the stress display function to see the stress on each part of the garment and improve and optimize the paper pattern according to the situation. Generally, we need to pay special attention to the collar, cuffs and other details. Next, since the sleeves of the costume worn by Zhao Boyun were extremely wide, the costume would sag due to gravity when the simulation is performed without intervention. The sleeves would hang down far beyond the arms of the human model, while the fingers of the virtual model would appear to penetrate the garment easily. To solve this problem, the sleeves need to be put on the arms of the human model in the state of small pleats stacked by drawing, mimicking the form of the garment when the person wears it normally.

In addition, Zhao Boyun wears a lot of clothing with the warm function of a double-layer fabric jacket. If only a single layer of fabric is used without modification, the overall effect is slightly thin. In order to simulate this effect more realistically, this paper innovatively adopted the "double-layer fabric filling method." In order to simulate the effect of silk filling, first of all, we should set a lining layer of fabric and set a force between the double-layer fabric to make the fabric bulge, about 0.5-1g/mm/s2, so as to create the effect of filling inside the garment.

3.2.3. Optimization of the final display

Zhao Boyun was sixty-two years old at the time of the burial, so a realistic restoration effect was needed for the model. We exported the model's face mapping and aged it with image processing software. At the same time, we used fabric modeling to simulate the hat and to create the shoes so as to restore the form of the tomb owner when he was buried. In order to better display the details of the restored clothes, in addition to the most basic virtual model fitting display, a flat display and a total of eight layers of clothing in a wearing effect display were also created. The overall recovery effect is shown in Figure 5. The overlay effect is shown in Figure 6.

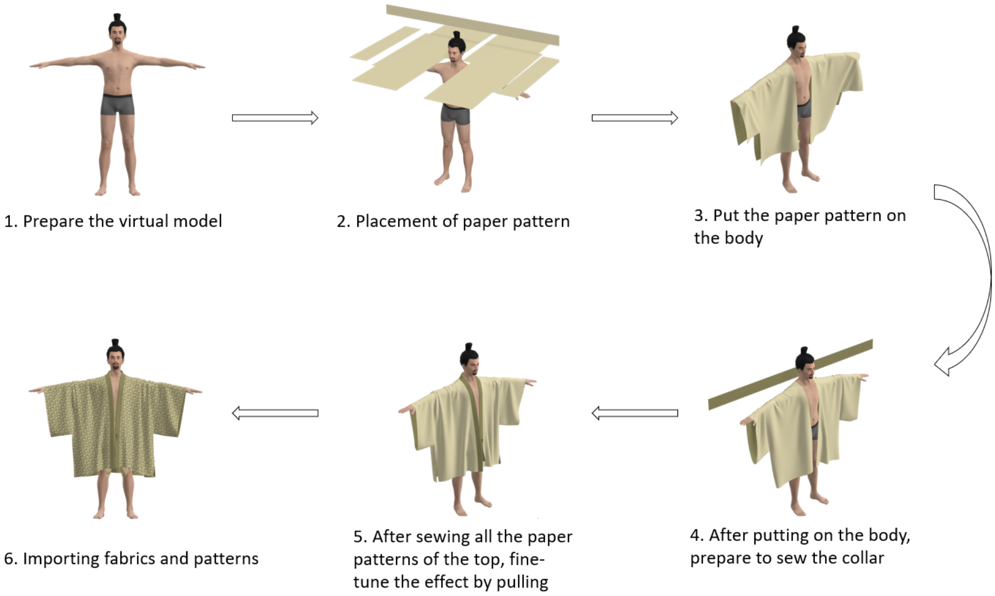


Fig. 4. Virtual fitting recovery steps

Fig. 5. Recovery effect show

Fig. 6. Clothing overlay simulation effect

First level indicator	Second level indicators	Three level indicators
Digital restoration effect of the first layer: cross-collar silk single coat **U**	Form$\mathbf{U}_1$	Clothing silhouette$\mathbf{U}_{11}$ Clothing style$\mathbf{U}_{12}$
	Structure$\mathbf{U}_2$	Body (trouser) structure$\mathbf{U}_{21}$ Collar (trouser waist) structure$\mathbf{U}_{22}$ Sleeve (trouser leg) structure$\mathbf{U}_{23}$ Garment hem (crotch) structure$\mathbf{U}_{24}$
	fabrics$\mathbf{U}_3$	Color$\mathbf{U}_{31}$ Fabric texture$\mathbf{U}_{32}$ Drapability$\mathbf{U}_{33}$

Table 2. Digital recovery effect evaluation index system

4. Assessing the recovery effect of clothing in virtual simulations by means of calculation

Since the evaluation of the costume restoration effect is too subjective and fuzzy, a quantifiable data analysis method was needed to evaluate the scientific restoration effect of the digital restoration of the excavated costumes of Zhao Boyun's tomb. In this paper, we used the Fuzzy analytic hierarchy process (FAHP) [8] method, which is a mature method, to analyze and evaluate the restored costumes.

4.1. Establishing the evaluation index system

Using the operational idea of the fuzzy analytic hierarchy process, the first thing to determine is a set of fuzzy evaluation indicators of the evaluation object: **u**= {$\mathbf{u}_1$, $\mathbf{u}_2$, **…**, $\mathbf{u}_m$}, which means that the evaluation object can be effectively evaluated from **m** aspects, and also means that the evaluated object contains **m** secondary indicators. The sub-indicators of each secondary indicator can be $\mathbf{u}_1$= {$\mathbf{u}_{11}$, $\mathbf{u}_{12}$, **…**, $\mathbf{u}_{1r}$}, $\mathbf{u}_2$= {$\mathbf{u}_{21}$, $\mathbf{u}_{22}$, **…**, $\mathbf{u}_{2r}$}, **……**, $\mathbf{u}_m$= {$\mathbf{u}_{m1}$, $\mathbf{u}_{m2}$, **…**, $\mathbf{u}_{mr}$}, indicating that they can be evaluated from the above perspectives. In this paper, the first layer of apparel is used as an example for the establishment of the evaluation index system, as shown in Table 2. The first level is indicator **U**, the second level - indicators **U**= {$\mathbf{U}_1$, $\mathbf{U}_2$, $\mathbf{U}_3$}, and the third level - indicators $\mathbf{U}_1$= {$\mathbf{U}_{11}$, $\mathbf{U}_{12}$, $\mathbf{U}_{13}$}, $\mathbf{U}_2$= {$\mathbf{U}_{21}$, $\mathbf{U}_{22}$, $\mathbf{U}_{23}$}, $\mathbf{U}_3$= {$\mathbf{U}_{31}$, $\mathbf{U}_{32}$, $\mathbf{U}_{33}$}.

4.2. Establish a rubric set for evaluation indicators

A rubric set is a collection of rubrics. Generally, the set of comments is denoted by **V**: **V** = {$\mathbf{V}_1$, $\mathbf{V}_2$, **…**, $\mathbf{V}_t$}. In this paper, the rubric set is designed as follows: excellent; good; normal; poor; very poor, assigned h values from 0 to 100, and divided into levels according to the status of the superiority and inferiority of the indicators.

4.3. Determine the weight of each indicator

Indicator weights refer to the relative importance of different indicators in the same hierarchy and require a specific score determined by means of an expert questionnaire. The weights can have a great impact on the final evaluation results.

①FAHP score quantitative table. The scale method of **0.1~0.9** is used to compare two factors. It is stipulated that **0.1~0.9** indicates that factor **i** is more important than factor **j**, from absolutely unimportant to absolutely important. If element $\mathbf{a}_i$ is compared with element $\mathbf{a}_j$ to get the judgment $\mathbf{r}_{ij}$, then element $\mathbf{a}_j$ is compared with element ai to get the judgment $\mathbf{r}_{ji}$ = **1 -** $\mathbf{r}_{ij}$.

②Establishing the judgment matrix. Using the above **0.1~0.9** scaling method, the FAHP Judgment Matrix ***A*** was obtained by a two-by-two comparison of each evaluation factor by means of an expert questionnaire, shown in Equation (1) below. Matrix ***A*** satisfies the fuzzy complementary matrix, i.e., 0 < aij < 1; aij + aji = 1; aij = 0.5 (i = j).

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

③Matrix A is summed by rows, as shown in Equation (2).

$$a_i = \sum_{k=1}^{n} a_{ik}, (i, k = 1,2, \dots, n) \quad (2)$$

④Find the weight matrix ***WI***, as shown in Equations (3) and (4), with **n** denoting the number of indicators at the current level.

$$w_i = \frac{1}{n} - \frac{1}{2\alpha} + \frac{a_i}{n\alpha}, \alpha = \frac{n-1}{2} \quad (3)$$

$$\boldsymbol{WI} = [w_1 \ w_2 \ \cdots \ w_n]^{\tau} \quad (4)$$

⑤Consistency ***CI*** checking. The weight matrix ***W*** is constructed as shown in Eqs. (5) and (6), and the ***CI*** value is shown in Eq. (7.) The smaller the ***CI*** value, the better the consistency, and the general convention is that a ***CI*** < 0.1 indicates that the consistency requirement is satisfied.

$$w_{ij} = \alpha(w_i - w_j) + 0.5 \quad (5)$$

$$\boldsymbol{W} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{bmatrix} \quad (6)$$

$$\boldsymbol{CI}(\boldsymbol{A}, \boldsymbol{W}) = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|w_{ij} - a_{ij}|}{\boldsymbol{n}^2} \quad (7)$$

After 10 expert questionnaires were collected, the weight of the evaluation indicators of digital recovery effectiveness was finally determined by the above process, shown in Table 3.

First level indicator	Second level indicators	weight	CI	Three level indicators	weight	CI	Combined weights
U	U_1	0.387	0.0178	U_{11}	0.600	0.05	0.232
				U_{12}	0.400		0.155
	U_2	0.363		U_{21}	0.260	0.015	0.094
				U_{22}	0.297		0.108
				U_{23}	0.247		0.090
				U_{24}	0.197		0.071
	U_3	0.250		U_{31}	0.390	0.0267	0.098
				U_{32}	0.337		0.084
				U_{33}	0.273		0.068

Table 3. Weights of digital recovery effect evaluation indicators

Layers	Excellent	Good	Normal	Poor	Very Poor	Final Score
1	0.6018	0.3254	0.0617	0.0112	0	87.95
2	0.6666	0.2677	0.0624	0.0024	0.0010	89.91
3	0.7057	0.2460	0.0449	0.0035	0.0000	91.35
4	0.7142	0.2371	0.0466	0.0021	0.0000	91.59
5	0.7004	0.2396	0.0566	0.0024	0.0010	90.90
6	0.7129	0.2202	0.0570	0.0100	0.0000	90.90
7	0.7006	0.2385	0.0549	0.0060	0.0000	90.85
8	0.7089	0.2262	0.0580	0.0069	0.0000	90.93

Table 4. Fuzzy comprehensive evaluation results

4.4. Determine the scoring matrix

According to the results of 66 questionnaires filled in by related practitioners, their scores for each indicator were compiled and counted, which is the specific score of the evaluation object in each indicator, and can be expressed as $\mathbf{p_i = \{p_{i1}, p_{i2}, ..., p_{it}\}}$ $\mathbf{(i = 1,2,...,m)}$. Where **m** refers to the number of indicators at that level, **t** to the number of elements in the rubric set, and $\mathbf{p_i}$ to the scoring set of the **i**th indicator. Combining the scoring sets of each index leads to the fuzzy comprehensive evaluation scoring statistical matrix P_{ij}.

4.5. Fuzzy comprehensive evaluation

According to the fuzzy comprehensive evaluation method, the model is shown in Equation (8). where matrix ***WI*** represents the weight matrix, matrix ***P*** the scoring statistics matrix, and matrix ***B*** the final score of the item under each rubric level. The final matrix ***B*** is then multiplied with the rubric set **V** to give the final score for each level.

$$B = WI \cdot P \tag{8}$$

5. Results

Combining the above calculation principles and data statistics, the final score of the costume restoration effect of each layer was calculated, the results of which are shown in Table 4. It can be seen that in the composite score of the restoration effect of the first layer of clothing, excellent accounted for 0.6018, good for 0.3254, normal for 0.0617, poor for 0.0112, and very poor 0. The final composite score was 87.95, and the restoration effect was good. The rest of the levels also have good overall recovery scores.

6. Discussion

The style of Song Dynasty costumes fully reflected the frugal and elegant social trend of the Song Dynasty as well as the living habits and cultural thoughts of the people in the Song Dynasty. The costumes excavated from the tomb of Zhao Boyun of the Southern Song Dynasty of Huangyan show the characteristics of the costumes of scholars in the Song Dynasty, containing a rich cultural connotation.

The difficulty of preserving silk fabrics limits the current study of Southern Song silk costumes, and most of the objects excavated are in a state of disrepair. Therefore, it is necessary to study the restoration of Southern Song Dynasty silk costumes. In this paper, we used computerized 3D costume modeling software to digitally restore the excavated costumes, which is a more cost-effective method than realistic restoration. During the recovery process, the garment coiuld be adjusted more quickly to achieve a better recovery effect.

Finally, through the FAHP method, the restoration of the garment was evaluated objectively so that the restoration results are more convincing. At the same time, we could improve the restoration effect accordingly by this method.

7. Conclusions

This paper took the eight layers of a total of sixteen garments worn by the tomb owner at the time of the excavation of Zhao Boyun's tomb of the Southern Song Dynasty in Huangyan as the object of study, analyzed their structure, size, fabric, and pattern, and digitally restored them using the style3D software system. The digital display of traditional costumes with 3D modeling can avoid the problem of damage during the exhibition of physical relics. At the same time, the FAHP method was used to evaluate the restoration effect, which transforms the subjective issue of the restoration effect into a quantitative data analysis and makes the evaluation results more convincing. The combination of heritage conservation and cultural heritage with information technology and digitalization is a major trend nowadays. Observing the appearance of ancient costumes through multiple perspectives or dynamic displays allows the viewers to feel the charm of Song Dynasty costumes more deeply and intuitively. This provides new ideas to promote the dissemination of traditional costumes, which is conducive to the heritage and development of ancient Chinese costumes.

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