Archaeological and digital restoration of straight-front robe of Mawangdui Han Dynasty Tomb based on 3D reverse engineering and man-machine interactive technologies

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ABSTRACT – REZUMAT

Archaeological and digital restoration of straight-front robe of Mawangdui Han Dynasty Tomb based on 3D reverse engineering and man-machine interactive technologies

Based on 3D reverse engineering and man-machine interactive technologies, this paper completed the pattern development of a straight-front robe of the Mawangdui Han Dynasty tomb and restored the straight-front robe by virtual simulation technology. Firstly, the garment contour was extracted from the straight-front robe image of the Mawangdui Han Dynasty tomb, and then the garment model was established in the 3D virtual environment. According to the style characteristics of the straight-front robe, the structural curves were drawn on the adjusted 3D robe surface, and the different curved surfaces formed by these curves were expanded to obtain 2D garment patterns. Finally, the unfolded patterns were stitched on the virtual human body to realize the digital restoration of the straight-front robe of the Mawangdui Han Dynasty tomb.

Compared with the current methods of garment restoration, the method proposed in this paper not only reduces the technical requirements of pattern-making for archaeologists but also for unearthed cultural relic garments, the final pattern can be obtained without consulting a lot of data and repetitive modification of pattern, to improve efficiency and save manpower. Our proposed technology provides a new practical method for costume archaeology and restoration.

Keywords: *reverse engineering, Han dynasty, straight-front robe, Mawangdui Tomb, virtual simulation, pattern-making, human-computer interaction*

Restaurarea arheologică și digitală a veșmântului de înmormântare frontal al mormântului dinastiei Han Mawangdui, bazată pe inginerie inversă 3D și tehnologii interactive om-mașină

Bazată pe inginerie inversă 3D și tehnologii interactive om-mașină, această lucrare a finalizat dezvoltarea tiparelor unui veșmânt de înmormântare frontal al mormântului dinastiei Han Mawangdui și a restaurat veșmântul prin tehnologia de simulare virtuală. În primul rând, conturul îmbrăcămintei a fost extras din imaginea veșmântului de înmormântare frontal al mormântului dinastiei Han Mawangdui, iar apoi modelul îmbrăcămintei a fost stabilit în mediul virtual 3D. În conformitate cu stilul veșmântului de înmormântare frontal, curbele structurale au fost desenate pe suprafața ajustată a veșmântului 3D, iar diferitele suprafețe curbate au fost extinse pentru a obține tiparele 2D. În cele din urmă, tiparele desfășurate au fost asamblate pe corpul uman virtual pentru a realiza restaurarea digitală a veșmântului de înmormântare frontal al mormântului dinastiei Han Mawangdui.

În comparație cu metodele actuale de restaurare a articolelor de îmbrăcăminte, metoda propusă în această lucrare nu numai că reduce cerințele tehnice ale modelării pentru arheologi, ci și cele impuse relicvelor culturale dezgropate, modelul final putând fi obținut fără consultarea multor date și modificarea repetitivă a tiparelor, astfel încât să îmbunătățească eficiența și să economisească forța de muncă. Tehnologia noastră propusă oferă o nouă metodă practică pentru arheologia și restaurarea costumelor.

Cuvinte-cheie*: inginerie inversă, dinastia Han, veșmânt frontal, mormântul Mawangdui, simulare virtuală, construcția tiparelor, interacțiune om-calculator*

INTRODUCTION

Mawangdui Han Dynasty tomb is the family cemetery of Li Cang, the prime minister and Marquis of Changsha in the early Western Han Dynasty (202 BC-8 AD). Among the three Han Dynasty tombs, Tomb No. 2 is Li Cang, the Prime Minister of Changsha in the early Han Dynasty; Tomb 1 is Li Cang's wife, and Tomb No. 3 is Li Cang's son [1]. More than 3000 precious cultural relics are unearthed from the three Han Dynasty Tombs of Mawangdui [2], most of which are well preserved. Among them, more than 500 pieces of various lacquerware are exquisitely made with gorgeous patterns and new lustre [3]. In addition, a large number of silk fabrics were unearthed from Tomb No. 1, which were well protected. There are many varieties, such as tough silk, figured woven silk material, silk with sparse texture, gauze and brocade [4]. There is a plain gauze garment, which is 1.28 meters long and has long sleeves. It weighs only 49 grams and has excellent weaving skills [4]. Han Dynasty is the heyday of the textile industry in the history of Chinese arts and crafts. The cultural relics unearthed from the Mawangdui Han Dynasty Tomb carry the unique aesthetic connotation of Han Dynasty costumes, reflecting the two characteristics of functional beauty and formal beauty. The tomb contains a large number of costume cultural relics and records about costumes. It is the largest number, the most complete variety and the most complete preserved costume cultural relics in China. These costume relics and related records complement each other with different kinds of wooden servants and figures in silk paintings in the tombs, which constitute a relatively complete set of costume materials in the early Han Dynasty, and truly and intuitively represent the splendid costume culture of the Han Dynasty, which is of the highest value in the field of Costume research. The research on the development and restoration of the straight-front robe pattern of the Mawangdui Han Dynasty tomb is a supplement to the research on Chinese traditional costume culture.

The most important step in costume Archaeology and restoration is to make a costume pattern. Garment pattern is an important intermediate link in garment design and production. It is the basis for cutting or sewing [5]. Garment pattern-making methods are mainly divided into traditional manual drawing and computer-aided design [6]. Manual pattern-making is drawing garment structure lines on kraft paper and then cutting along these structure lines to obtain the pieces of paper for cloth cutting. The automatic generation of computer patterns uses computer drawing software to establish the pattern library, we can find similar patterns in the pattern library and modify them to get the target pattern. This method is more likely to find similar patterns, and finally, get the final pattern by enlarging and reducing the key points of the pattern [7]. Both of these methods have three shortcomings: time-consuming, low production efficiency, and inability to meet individual needs.

In the process of Archaeology and restoration, archaeologists need to consult a large number of documents, constantly measure the objects, and repeatedly modify the pattern, to get a reasonable pattern. It largely depends on the personal experience of archaeologists, and repeated folding of cultural relics may cause physical damage. Emerging technologies, such as ergonomics, virtual simulation and reverse engineering, provide new methods for garment pattern-making. Many scholars try to use these new technologies to develop clothing patterns quickly and simply. These methods provide a new idea for the archaeological restoration of ancient costumes. For example, Xuyuan Tao et al. [8] directly conceived the virtual clothing on the human body model in the virtual space, taking into account the comfort margin between the human body and the clothing, which saves the production process of two-dimensional garment patterns. Wang et al. [9] proposed a garment pattern-making method based on fuzzy logic and artificial neural network knowledge to generate garment patterns quickly. Kaixuan Liu et al. [10–12] proposed parametric pattern-making and flat design methods based on human body size, which can generate garment patterns quickly by inputting some constraint parameter values. Haisang Liu et al. [13] established a warp knitted garment size prediction model by analysing the relationship between the size characteristics of warp knitted jacquard pattern and knitting process, and realized the automatic generation of garment pattern by using JavaScript and WebGL technology. Guangzhou Zhu et al. [14] established the Mass-Spring model by using regular mesh method to mesh the quadrilateral pattern and connecting the diagonal lines of the quadrilateral to get the triangular mesh. On this basis, the paper pattern design was completed by using the integral method. Haixia Li et al. [15] applied three-dimensional virtual reality technology to establish a three-dimensional model of human body, and then carried out the design, and then designed and optimized the pattern of Yoga suit. Yeonhee Jeong et al. [16] constructed a three-dimensional garment surface with triangular meshes. On the premise of keeping the original three-dimensional surface area unchanged, these triangular meshes were pieced together to obtain two-dimensional garment patterns. Jin Wang et al. [17] constructed an electronic human body model based on the digital information of human body features. By smoothing the human body surface, they obtained the deployable garment prototype surface attached to the human body surface, and then expanded the prototype surface to obtain the garment prototype patterns. Sun min Kim et al. [18–20] obtained human body data by non-contact three-dimensional scanner to construct a human body model, which was approximately expanded to automatically generate clothing pattern. Kaixuan Liu et al. [21] proposed a three-dimensional interactive garment pattern-making technology. Pattern makers can efficiently develop garment patterns in the way of "what you see is what you get" by their proposed technology in the way of "what you see is what you get". This technology was successfully applied to the pattern-making of riding clothes [22].

Based on the methods of previous studies, this paper proposed a method of ancient costume pattern-making and digital restoration based on 3D reverse engineering and man-machine interactive technologies, which was used to restore the straight-front robe of Mawangdui Han Dynasty tomb. Compared with the previous clothing Archaeology and restoration methods, 3D interactive clothing pattern-making technology doesn't require archaeologists to have pattern-making knowledge, which solves the problem of high requirements for operators in the process of traditional clothing archaeology, renovation and restoration. With the support of our proposed method, archaeologists can quickly recover the pattern of costume relics without manual pattern-making, and realize the costume relics according to the pattern.

METHODOLOGY

General scheme

The restoration process of straight-front robe of Mawangdui Han Dynasty tomb based on 3D reverse engineering and man-machine interactive technologies can be divided into seven steps: 2D garment outline pattern extraction, 3D garment model establishment, 3D garment model adjustment, 3D garment surface construction, 3D garment surface flattening, 2D garment pattern adjustment, 3D virtual simulation. The implementation process is shown in figure 1.

The pattern development process of the straight-front robe of Mawangdui Han Dynasty tomb adopts 3D interactive garment pattern-making technology, which mainly includes 2D to 3D garment modeling, 3D to 2D pattern flattening and 2D to 3D virtual simulation process. First of all, we extracted the contour pattern of the straight-front robe, and then established a 3D garment model in the virtual environment. The purpose of this process is to transform the 2D garment contour pattern into a 3D garment model. Secondly, we drew structural curves on the adjusted 3D garment surface according to the straight-front robe garment style, which divided the 3D garment surface into different adjacent surfaces. We unfolded the different 3D garment surface, adjusted the lines of the unfolded plane, and finally got the garment pattern of the straight-front robe. Finally, the feasibility of this method was verified by virtual fitting technology, and the virtual simulation restoration garment of the straight-front robe was obtained.

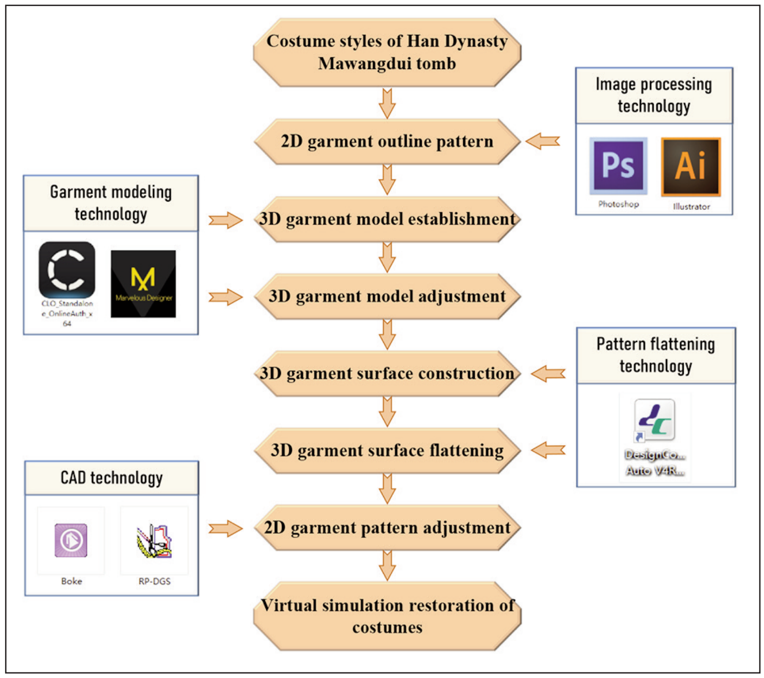

Fig. 1. General scheme

Object analysis

The costumes of Han Dynasty mainly include Shenyi, Robes, Danyi, Ru, and so on. Shenyi is still used as court clothes in the Han Dynasty, and its shape is still the Zhou Dynasty (1046 BC – 256 BC) model of cross collar, the right lapel, curving-front robe and top and bottom, but the sleeves are obviously longer and wider than those of the Zhou Dynasty. Shenyi style robe of Han Dynasty (202 BC – 220 AD) follows the old system of Qin Dynasty (1636 AD – 1912 AD). On the basis of the cross shaped plane structure of the upper and lower garments, it adds a lot of techniques of straight cutting and oblique splicing, and projects a prosperous imperial atmosphere. The clothes unearthed from Mawangdui Han Dynasty tomb No.1 are basically well preserved. There are 11 robes, including 8 curving-front robe and 3 straight-front robe, all of which are in the style of cross collar and right lapel. The data information of relevant robes is shown in table 1 [23].

There are mainly two types of robes, namely “curving-front robe” and “straight-front robe”. The skirt of curving-front robe extends in a triangular shape to one side. When wearing a curving-front robe, the triangle part of the skirt is wrapped around the back from the armpit, and then tied with a rope to cover the back. The curving-front robe is mainly used for formal dress. The “Zhuhong Luoqi cotton robe” unearthed from the Mawangdui Tomb No.1 is the Han Dynasty formal dress of curving-front robe style (figure 2, *a*). The straight-front robe is slightly different from the curving-front robe. Its shape is that the lapels intersect to the back of the left chest and fall vertically until the hem. When wearing, the inner lapel is covered under the left armpit, the outer lapel is around the right side, and the bottom is slightly curved.

Table 1

THE SIZE DATA OF CURVING-FRONT ROBE AND STRAIGHT-FRONT ROBE UNEARTHED OF MAWANGDUI HAN DYNASTY TOMB NO.1 [23]

Items	Length (cm)	Long sleeve length (cm)	Sleeve width (cm)	Cuff width (cm)	Waist width (cm)	Hem width (cm)	Collar edge width (cm)	Sleeve edge width (cm)	Swing edge width (cm)
Curving-front robe	130~155	232~250	30~39	24~28	52~63	58~80	20~28	26~35	28~31
Straight-front robe	130~132	228~250	38~41	25~30	48~54	57~66	10~20	29~44	37~38

Fig. 2. Zhuhong Luoqi cotton robe and printed crimson silk robe [24]

Straight-front robe is a kind of casual clothes, which cannot be worn on important occasions.

The "Printed crimson silk robe" unearthed from the Tomb No.1 of Mawangdui is a straight-front robe silk robe (figure 2, *b*).

The upper part of straight-front robe with the printed crimson silk cotton is spliced with four pieces, and the lower part of the straight-front robe is spliced with three pieces. Both the upper and lower parts of the robe are cut straight. Outer placket and inner placket are spliced form a certain amount of overlap. With the wide collar and swing edge, the inner and outer placket can be covered to a slightly backward position. The robe is made of printed crimson yarn and plain yarn. The pattern on the garment surface consists of branches and leaves, buds, stamens and flower spikes. The branches are printed in Yangwen version, which is called "Yinhua", while the rest are painted manually, namely "Fucai".

Garment size determination

The pattern development of straight-front robe of Mawangdui Han Dynasty tomb is based on 3D reverse engineering and man-machine interactive technologies in this paper. We take the printed crimson silk robe of Mawangdui No.1 Han Dynasty tomb as an example of pattern-making and restoration. The length of the straight-front robe is 130 cm, and the length of the through sleeve is 236 cm [23]. As shown in figure 3, the front placket of the straight-front robe intersects left and right, the upper part of the robe is four pieces of stitching, and the lower part of the robe is three pieces of stitching. The upper and lower parts of the robe are cut straight, and the back is sewed together. The upper part of the straight-front robe is cut straight, and the lower part, collar edge, sleeve edge and swing edge are cut obliquely.

Among them, the oblique cutting of sleeve edge is the most characteristic in the use of fabric. The sleeve edge of straight-front robe is "obliquely rolled into a tube shape with half a piece of white yarn straight strip, and folded inward into two layers, so the cuff is seamless" (figure 4). The structure of the inclined cut and inclined roll gives the cuffs good scalability. From the perspective of the wide cuff size (the width of the cuff is 25–30 cm), the scalability of the cuffs exceeds the practical purposes such as warmth preservation, convenient to wear and take off, and convenient for activities. On the one hand, the phenomenon above reflects the economic richness, on the other hand, it indicates the social status of the wearer. This kind of structure in the use of fabric performance technology has reached the peak which cannot be achieved in the future. The edge of the slant cut is slanted at the side seam, so that the hem is slightly stretched, which not only increases the beauty of the train skirt, but also makes the road convenient.

2D garment contour pattern extraction

The acquisition of 2D garment contour pattern is the basis of 3D garment modeling. According to the

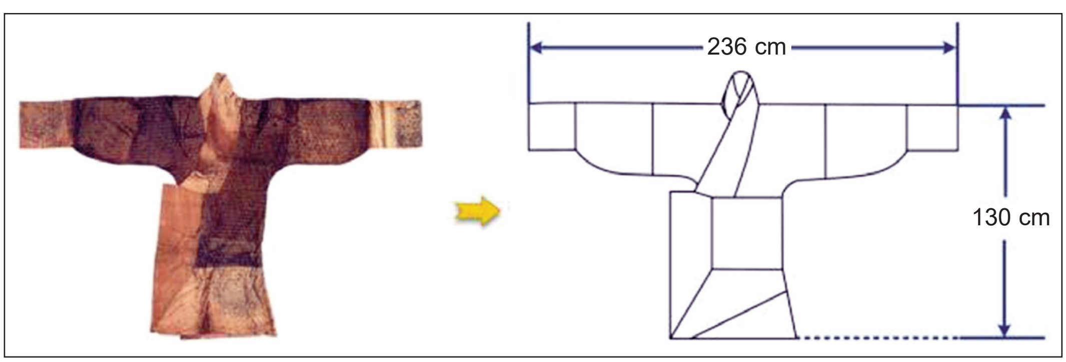

Fig. 3. The straight-front robe's size at Mawangdui Han Dynasty Tomb

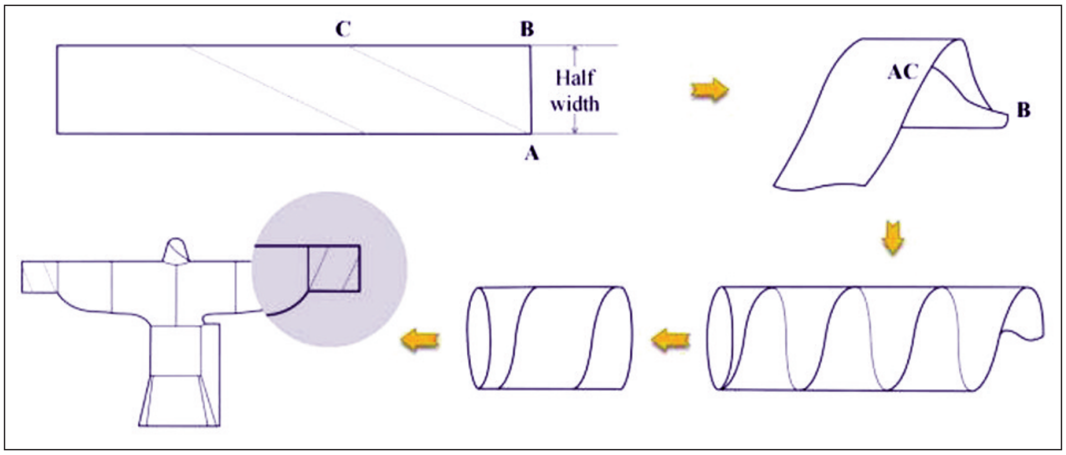

Fig. 4. The oblique cutting diagram of Mawangdui straight-front robe's sleeve edge [23]

straight-front robe pattern in the Mawangdui tomb, the line drawing of garment was directly extracted in CAD drawing software (figure 5, *a*), and then the front and rear contour paper of garment was drawn combined with the determined length of garment and sleeve length (figure 5, *b*). This process is only for obtaining the contour pattern of the robe and does not require accurate pattern size, so there is no requirement for the operator's garment pattern-making skills.

3D garment model establishment

After getting the 2D garment pattern, we needed to build the 3D garment model on the mannequin. At present, the existing modeling methods are mainly start from the perspective of 3D scanning human

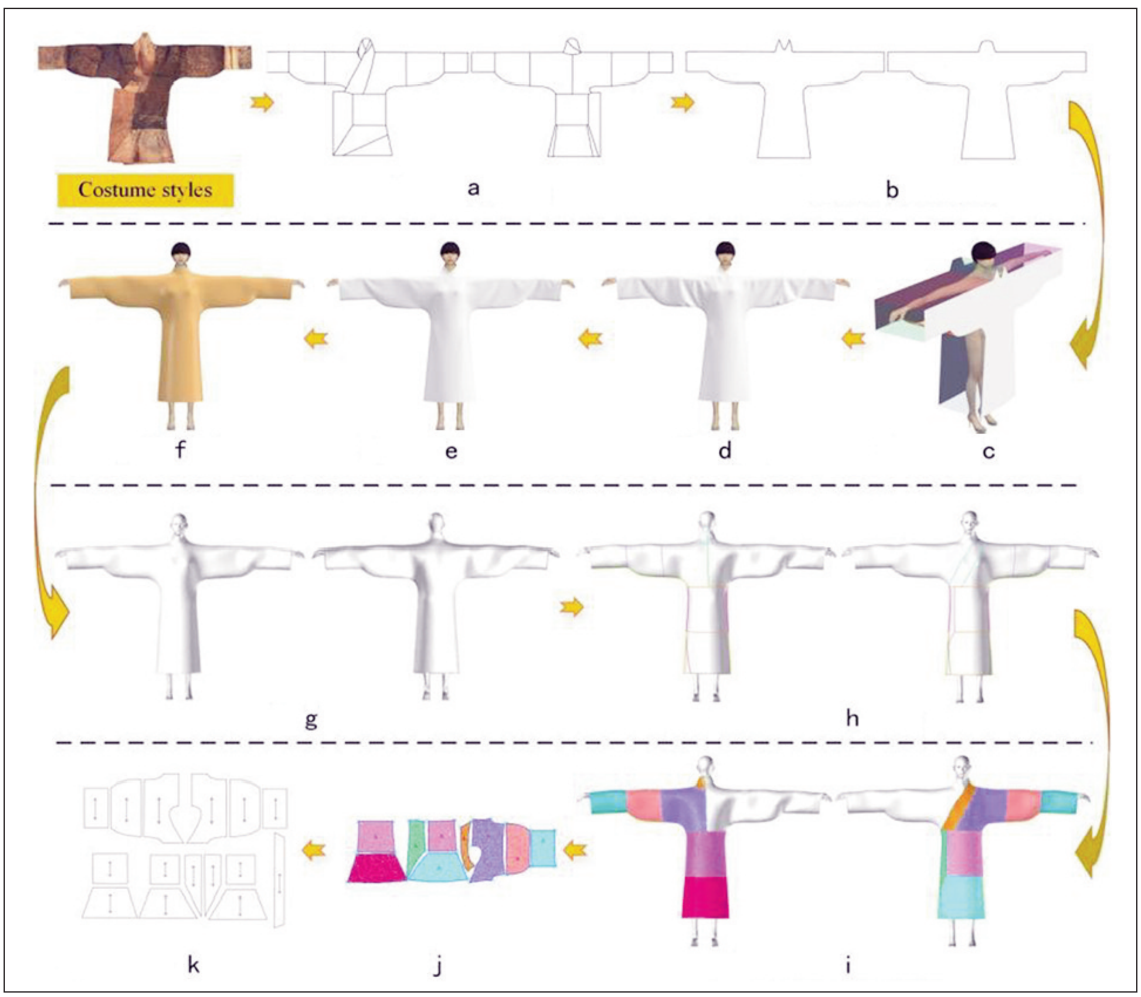

Fig. 5. Interactive pattern-making of the straight-front robe of Mawangdui Han Dynasty Tomb: *a* – line drawing; *b* – contour extraction; *c* – arrangement; *d* – try-on; *e* – adjustment; *f* – hardening; *g* – freeze; *h* – draw curves; *i* – generating surfaces; *j* – 3D→2D unfolding; *k* – pattern post-processing

body. At present, the main modeling method is to use 3D human body scanning to build 3D human body model based on feature information, and then expand the surface of 3D garment model to get 2D pattern [25]. In addition, there are many methods for garment modeling, such as garment modeling based on 2D sketch [21, 26, 27], garment modeling based on 3D sketch [8, 28–37] and garment modeling based on image [38, 39]. According to the structural characteristics of Mawangdui Han Dynasty tomb straight-front robe garment, this paper adopted the method of combining geometric modeling and image modeling. The development of Mawangdui Han Dynasty tomb straight-front robe pattern was based on the real image, so its 3D model was directly stitched by 2D garment pattern in the virtual environment using virtual try on technology (figure 5, *c* and *d*).

3D garment model adjustment

In the above two steps, we extracted the two-dimensional outline patterns of the straight-front robe of Mawangdui Han Dynasty tomb, and then the outline patterns were virtual stitched to get the three-dimensional clothing model. Because the two-dimensional contour pattern is not a real garment pattern, the garment model cannot fully meet the simulation requirements. Moreover, there may be some problems in the model, such as the model's surface is not smooth enough, and the details are creased or wrinkled. The existence of these creases and folds affects the accuracy of the structural curve drawn on the model's surface.

In order to avoid the above uncertainty, we adjusted the three-dimensional model of the straight-front robe of Mawangdui Han Dynasty tomb properly, and then unfolded the surface without changing the area and edge of any triangle mesh, so as to make the clothing model surface flatter and smoother (figure 5, *e*). Finally, we froze the stretched garment to maintain its shape (eliminating virtual gravity) (figure 5, *f*). In the process of 3D garment adjustment, we only need to ensure that the visual effect of 3D garment can meet the restoration requirements, and there are not too many restrictions on the shape and size of 2D garment outline pattern.

3D garment surface construction

The 3D garment model of the straight-front robe of Mawangdui Han Dynasty tomb was created based on the garment image. The 2D pattern obtained from the 3D garment model is more realistic. According to the analysis of the straight-front robe style, we used surface flattening technology to draw the structure curve on the surface of the 3D robe model after stretching and freezing (figure 5, *g* and *h*). Because the human body shape is irregular surface, we need to adjust and modify the curve repeatedly in order to get the most accurate pattern. These structural curves divided the 3D garment's surface into different small surfaces (figure 5, *i*).

3D garment surface flattening

There are three kinds of 2D flattening techniques for 3D garment modeling, which are geometric unfolding, mechanical unfolding and geometric unfolding combined with mechanics correction method. In this paper, the geometric expansion method was used to expand the different 3D garment areas subdivided in the previous section into 2D garment patterns using 3D surface unfolding technology (figure 5, *j*). In this process, we should minimize the changes of triangle mesh edge on 3D garment surface and the corresponding changes of 2D pattern in combination with the previous steps.

2D garment pattern adjustment

Generally speaking, the expanded boundary triangles of 2D garment patterns are irregular, so we need to Delaunay triangulation again. The process must maintain the pattern's boundaries and also maintained characteristic areas such as "holes" that may exist in the pattern. The vertex of the re-triangulated mesh only contains the information of the 2D plane domain, so it needs to be mapped to the 3D space domain in order to obtain the exact position of the mesh in the 3D space and complete the stitching of garment. According to the principle of topological invariance, the 3D positions of the vertices can be obtained by using the relationship between the barycentric coordinates of the triangle and the coordinates of the vertices [40]. In addition, we needed to smooth the edge of the straight-front robe patterns using pattern-making CAD (figure 5, *k*).

RESULT

3D virtual simulation restoration

Using 3D interactive pattern making technology, we have completed the pattern development of the straight-front robe of Mawangdui Han Dynasty tomb. In order to verify the feasibility of this method, we needed to check and modify the adjusted pattern, and sewed the 2D pattern back to the virtual human body in the 3D virtual environment. First, we imported the 2D garment pattern into the 3D virtual simulation software, the pattern in the form of plane can be seen in the 2D and 3D visualization interface. Through the arranged points that have been set, the pattern can be accurately matched and attached to the corresponding body parts. Next, we performed virtual stitching in the way of actual garment stitching. Before stitching, the number of pattern layers was set according to the garment style. In this way, we tried to avoid the phenomenon of disordered stitching due to overlapping and cross-stitching during stitching. Moreover, the pattern must be placed in the 3D window according to the requirements of being close to the human body and meeting the suture position. Then, we set the pattern, technology, color, thickness, elasticity, hardness and other properties of the fabric in the physical window. Finally, the virtual garment was tried on and displayed, and the virtual simulation of the straight-front robe of Mawangdui Han

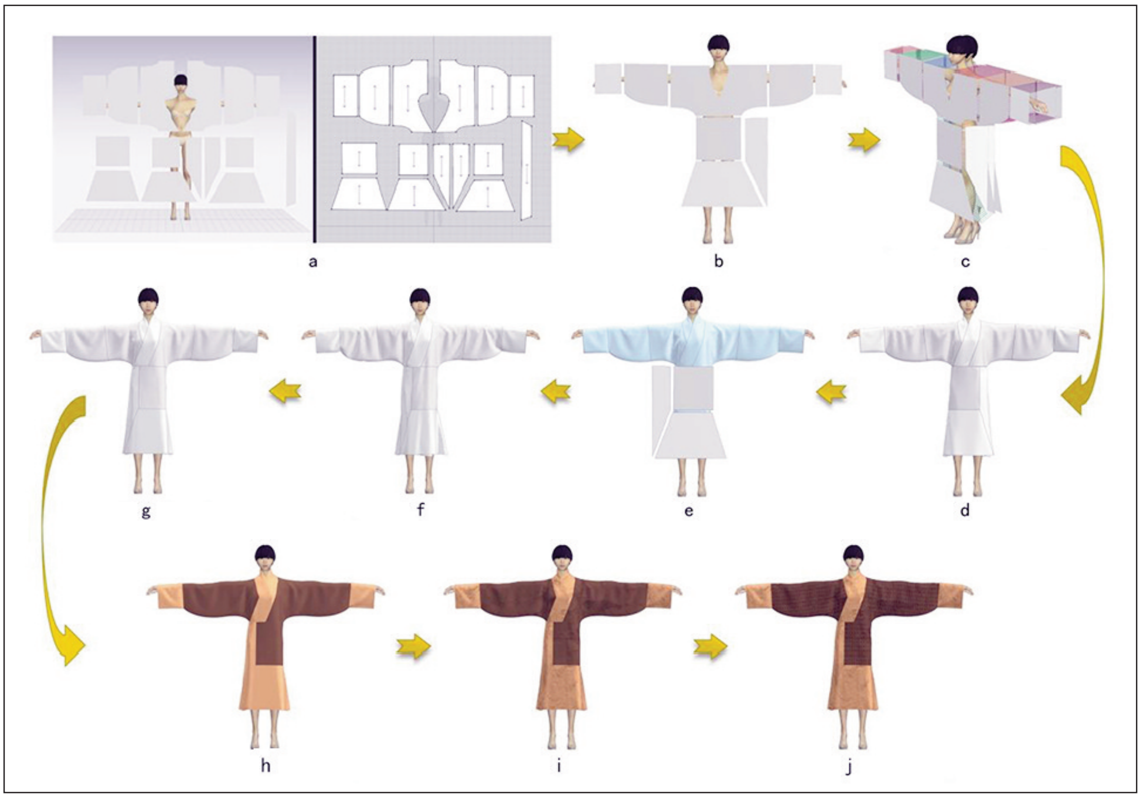

Fig. 6. The virtual simulation restoration of the straight-front robe of Mawangdui Han Dynasty tomb: *a* – pattern import; *b* – pattern arrangement I; *c* – sewing thread setting; *d* – virtual suture I; *e* – pattern arrangement II; *f* – virtual suture II; *g* – adjustment; *j* – pattern attribute settings; *I* – texture attribute settings; *h* – colour attribute settings

Dynasty tomb was adjusted to meet the restoration requirements (figure 6).

We compared the real straight-front robe with the simulated straight-front robe. As shown in figure 7, the upper left corner of the figure is the real photo of the unearthed straight-front robe, the upper right corner is the simulation picture of the tiled straight-front robe, the lower left corner is the front view of the 3D simulation restoration of the straight-front robe, and the lower right corner is the back view of the 3D simulation restoration of the straight-front robe. Through the comparison, we find that the restoration technology we proposed reflects a higher fidelity, and it can be used as a new attempt and method for costume Archaeology and restoration.

Evaluation of garment virtual restoration effect

After completing the virtual restoration of straight-front robe of Mawangdui Han Dynasty tomb, we use the hierarchical fuzzy comprehensive method to evaluate the effect of virtual restoration garment. Firstly, we determine the evaluation index of garment restoration effect $U = (u_1, u_2, u_3, u_4)$ = (overall shape, color pattern, fabric performance, detail structure). According to the restoration effect, a five-level evaluation standard $C = (c_1, c_2, c_3, c_4)$ = (very poor, poor, average, good, very good) is adopted. Then, we use the priority chart method to determine the weight of each item in the evaluation item set, and the evaluation group is composed of 8 teachers majoring in garment digital technology. They compare two of the four indicators respectively according to their professional experience. The weight of each index calculated according to the score is $A = (\alpha_1, \alpha_2, \alpha_3, \alpha_4) = (0.44, 0.16, 0.09, 0.31)$. The importance of each index can be obtained according to the degree of membership: overall shape > detail structure >

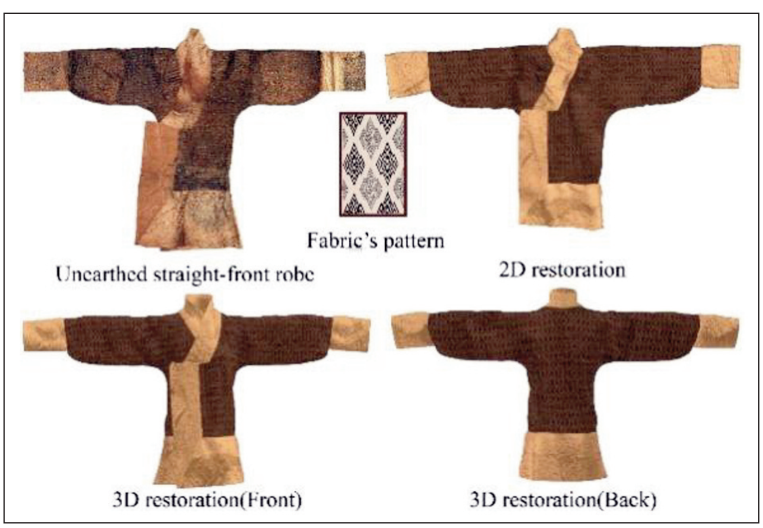

Fig. 7. Real unearthed straight-front robe and its simulated restoration picture

color pattern > fabric performance. We evaluate the recognition degree of virtual garment in the form of questionnaire. The respondents are college students who have a relevant understanding of virtual garment. According to the statistical results, we get the comprehensive evaluation matrix *E*:

$$E = \begin{bmatrix} 0 & 0 & 0.04 & 0.46 & 0.50 \\ 0 & 0 & 0.13 & 0.41 & 0.46 \\ 0 & 0 & 0.47 & 0.27 & 0.26 \\ 0 & 0 & 0.47 & 0.44 & 0.09 \end{bmatrix}$$

Finally, the comprehensive effect evaluation *B* can be obtained by synthesizing *E* with the corresponding evaluation item weight. 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 straight-front robe of Mawangdui Han Dynasty tomb is “good”.

DISCUSSION

At present, the research on the costumes at Mawangdui Han Dynasty tomb mainly focuses on the surface cultural characteristics such as shape, color, pattern, etc. The research from the perspective of garment structure is not detailed enough, and there is no complete garment pattern be formed. From the perspective of traditional costume restoration, it is mainly realized by means of reality restoration. Due to the limitation of technical conditions, it is difficult to preserve the real objects obtained from reality restoration, which is not conducive to the spread of culture. Drawing on the concept of 3D reverse engineering, this paper used 3D interactive garment pattern-making technology without professional knowledge to complete the pattern development of straight-front robe of Mawangdui Han Dynasty tomb. This paper introduced the automatic generation of garment pattern through 2D to 3D garment modeling and 3D to 2D pattern flattening. Finally, the garment was dynamically adjusted in 2D and 3D garment visualization space, and the virtual simulation of the straight-front robe of Mawangdui Han Dynasty tomb was obtained. Our proposed method highlights the advantages of improving efficiency, saving manpower, and lower professional requirements for operators. It shows that it is a feasible and effective way to develop the pattern of unearthed costume relics by using 3D reverse engineering and man-machine interactive technologies.

The smooth and coherent garment style characteristics of Mawangdui Han Dynasty tomb reflect the high unity of aesthetic and functional. Taking the straight-front robe of Mawangdui Han Dynasty Tombs as an example, the paper pattern development makes up for the lack of complete records of Mawangdui Han Dynasty Tombs garment pattern, further improves and enriches the research content in this field, and provides a useful exploration for the study of Han Dynasty garment modeling structure. At the same time, it provides a direction for deepening and expanding the research of this major, and also provides a reference for the follow-up research of this kind of garment, which has certain practical and guiding significance. However, the human-computer interactive garment pattern-making technology based on 3D reverse engineering is not perfect. Due to the thickness of garment fabric itself, the pattern contour extracted from garment image may have slight deviation from the actual garment, which is a problem we need to solve in the future.

CONCLUSION

In this paper, reverse engineering, virtual simulation, human-computer interaction and other technologies are used to complete the digital restoration of straight-front robe of Mawangdui Han Dynasty Tomb. Compared with the existing technical methods of costume restoration, this method has obvious advantages. First of all, it reduces the technical requirements for operators in the traditional pattern making process when obtaining the garment pattern. Secondly, the pattern can be made without consulting a large number of materials and repetitive modification, which solves the problem of time-consuming and laborious, low efficiency and damage to unearthed cultural relics. Our proposed method provides a feasible new method for costume archaeology and digital restoration. It can be recommended for reconstruction of partly destroyed historical textiles. The restored garment does not need to be preserved on the spot, which eliminates the constraints of time and geographical conditions on the transmission of ancient garment culture. It also provides a new way to inherit and develop clothing culture. The combination of technology and traditional costume archaeology is one of the directions of future archaeology.

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