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Preserving cultural heritage through virtual simulation design of traditional clothing styles: a study of Mazu clothing

Abstract

This study focuses on the virtual simulation design of Mazu clothing, a traditional Chinese style of clothing, using a combination of general design software, clothing CAD software, and clothing 3D design software. The study begins with an introduction to the development and shape of Mazu clothing and analyzes the design elements such as style, structure, color, and material of the clothing. Typical styles of Mazu clothing are then selected, and graphic designs for these styles are created using Corel Draw. The study then moves on to the virtual simulation design process, where the size and specifications of Mazu clothing are set based on the 160/84A standard female body data. Richpeace clothing CAD software is used to draw the pattern of Mazu clothing, completing the pattern design process. Finally, the plate file is imported into CLO 3D software to complete the 3D virtual stitching and simulation design of Mazu clothing. The study finds that the standard error and error probability after design were both below 5%, demonstrating the accuracy of the virtual simulation design method. The research plan presented in this study provides a fast and efficient way to achieve three-dimensional virtual simulation of Mazu clothing, which lays a foundation for the digital design and application of Mazu clothing. Overall, this study provides valuable insights and practical guidance for those interested in virtual simulation design for traditional clothing styles.

Keywords: Mazu clothing, digital technology, virtual reality, virtual showcase

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Introduction

Mazu is the goddess of escort at sea, and won the trust of coastal fishermen because she can escort fishermen to sea. With the migration of population and the spread of culture, Mazu beliefs spread to all parts of the world, and gradually formed Mazu culture internationally. Virtual simulation design first designs the flat pattern, then uses physical simulation or iterative optimization of the relevant parameters to stitch the flat pattern and obtain the desired 3D garment. To enable quick fitting of virtual clothing from one mannequin to another, some researchers have begun to focus on automated fitting solutions.

The inheritance and innovative design and application of traditional costumes have strong practical significance for mining excellent design resources and promoting traditional costume culture. This paper took the typical style of Mazu clothing as the research object, based on digital design technology, and comprehensively used design software such as Corel Draw, clothing CAD and CLO 3D to complete the 3D virtual simulation design of Mazu clothing.

This paper took the sea shirt and red and black trousers as the research object, through the analysis of the shape of the Mazu clothing, based on the digital design technology, and comprehensively applied Corel Draw, clothing CAD and CLO 3D to carry out the 3D virtual simulation design of the Mazu clothing. According to the key parts of the human body, a fabric simulation system that used the large-step implicit integration method to solve the equation of motion was proposed to deduce the size of the clothes. This digital design technology not only ensured the accuracy of virtual design but also improved design efficiency. Finally, the relocation of boundary nodes was constructed using clothing-specific clique features and cultural feature rules to accommodate virtual human bodies using fine-tuned auto-adjustment methods. The method automatically adjusted and maintained clothing styles on virtual human bodies with greatly different body proportions.

The contributions of this study are significant in several ways:

a. Firstly, it provides a detailed and systematic approach to the virtual simulation design of Mazu clothing, a traditional Chinese style of clothing. This approach includes a combination of general design software, clothing CAD software, and clothing 3D design software, which can be applied to other traditional clothing styles as well.

b. Secondly, the study highlights the importance of analyzing the design elements of traditional clothing styles, such as style, structure, color, and material, in the virtual simulation design process. This can help to ensure that the virtual simulation designs are accurate and authentic representations of the traditional clothing styles.

c. Thirdly, the study demonstrates the accuracy of the virtual simulation design method, with a standard error and error probability below 5%. This validates the effectiveness of the approach and provides confidence in the accuracy of the virtual simulation designs.

d. Finally, the study provides practical guidance for those interested in virtual simulation design for traditional clothing styles, laying a foundation for the digital design and application of Mazu clothing. This can contribute to the preservation and promotion of traditional clothing styles and cultural heritage.

Materials and methods

Digital model construction of Mazu clothing

Since the Northern Song Dynasty, Mazu costumes have experienced thousands of years of inheritance and development, forming a Mazu costume culture characterized by “sailboat head, sea shirt, red and black pants”. At present, there are three main types of Mazu clothing

styles: the first is the traditional Mazu clothing, which is also the most typical Mazu clothing. The top is a navy blue right-sided cardigan, and the bottom is two-color trousers with red and black stitching.[1] There is almost no decoration or only a small amount of striped trim with uneven thickness on the cuffs and trousers. It is mainly made of natural cotton and linen fabrics. This type is occasionally seen in elderly Meizhou women. The second is the improved Mazu clothing, which is currently the most common Mazu clothing. On the basis of the traditional Mazu clothing system, certain improvements have been made to the silhouette, structure, craftsmanship and materials. In particular, young Meizhou women who work as tour guides have improved Mazu clothes into work clothes, forming a beautiful landscape.[2] The third is the creative Mazu clothing, which mainly appears in the form of stage performances and design competitions. On the basis of the first two kinds of Mazu clothes, further innovative designs are carried out, and fashion elements, new fabrics and modern craftsmanship are integrated into them. The basic characteristics of the three Mazu clothes are shown in Table 1.

Table 1 Basic characteristics of Mazu clothing

Type	Style	Structural technology	Color	Fabric
Traditional Mazu clothes	Sea shirt, red and black pants	Loose, no province, with occasional lace	blue, black, red	cotton, linen
Improved Mazu clothing	Sea shirt, red and black pants	Fitting, waist dart, dividing, slanting; lace, trim, embroidery, decorative seam, etc.	blue, black, red; print	Cotton, linen, silk, etc.
Creative Mazu clothing	Big sea shirt, red and black pants or other	Diverse and modern	Mainly blue, black and red, supplemented by other bright colors	Cotton, linen, silk, lace, leather, etc.

Mazu clothes are mainly composed of tops and trousers. The tops are mainly in sea blue, and the style is Chinese-style cardigans, also known as sea shirts.[3] Because they are in the sea all the year round, the trouser legs are often wet by the sea water, so the bottom half of the trousers looks black from a distance, thus forming two-color trousers with red on the top and black on the bottom. Meizhou women follow Mazu and wear red and black trousers. There is also another legend that Mazu is a god in the sky and can wear all red, while ordinary people can't wear all red, and only take a section of it. Red represents the loyalty of the local women to their husbands who go out to sea to fish for a living, and black represents their longing for their husbands.

Mazu clothing style structure design

In this paper, an improved Mazu suit is selected for style structure analysis. Among them, the big shirt is a big cardigan with a stand-up collar and a right hem, and the front and rear pieces are set with waist darts to form a fit structure.[4] The right shoulder, big placket, back shoulder, left front lower side, cuffs, etc. are stitched with printed fabrics, and the stitching, neckline, and hem are provided with molding decorative seams; the closure of the placket is provided with black Chinese-style disk buttons.[5] The red and black trousers are improved to three-section stitching, maintaining a loose shape, with red and black as the main colors, and the trousers are stitched with the same printed fabric as the sea shirt to form an overall echo.

According to the numerical integration of the initial state of the fabric model, and calculating the position of the vertex of the triangular mesh in each time step, the simulation of virtual fabric can be realized.[6] According to the principles and methods of clothing structure design, Richpeace clothing CAD V8.0 is used to complete the pattern drawing of this Mazu clothing.[7] According to the structural relationship of the sea shirt and red and black trousers, the pattern structure is decomposed into pieces to complete the version design of the sea shirt and red and black pants. For the convenience of subsequent 3D stitching and virtual simulation, the pattern file is stored in "*.dxf" format through "Export ASTM file".

The fabric simulation system using the large step implicit integration method to solve the equation of motion achieves the ideal conjugate iteration of the fabric shape effect.[8] There are two types of numerical integration methods: explicit integration and implicit integration. Derivative recurrence relation in closed simulation due to derivative recurrence:

$$P'(i) = Q(i) \tag{1}$$

$$T'(i) = V(i) \tag{2}$$

$$V(i) = R(i)/\mathrm{n} \tag{3}$$

The display Euler numerical integration method uses the forward difference quotient to approximate the derivative, so the calculation equation of the display Euler method is expressed as follows:

$$f(i + \Delta i) = f(i) + f'(i)\Delta i \tag{4}$$

$$P(i + \Delta i) = P(i) + T(i)\Delta i \tag{5}$$

$$P(i + \Delta i) = P(i) + V(i)\Delta i \tag{6}$$

It follows from this that employing Euler integration in one time step would involve two explicit Euler calculations.[9] From the point of view of parallelism, because the state of each particle in Euler integration is calculated independently, the overall parallel performance is better.[10] From the perspective of operational efficiency, although the computational complexity of each step in the explicit Euler integration is not high, the explicit Euler integration is taken from the first two terms of the Taylor series expansion. So the use of explicit Euler integration requires smaller time steps. However, if the value of Δi is too small, the number of numerical integrations per unit time will be increased accordingly, which will increase the load of the system operation and affect the overall efficiency.[11] Therefore, it is necessary to improve the Euler integral to increase its accuracy and improve the stability of the system.

The implicit integration method belongs to the backward Euler integration method and is generally used to solve the rigid problem of the equation.[12] It allows a larger time step to be chosen, and the result of the operation is stable. But the implicit result still suffers from Taylor series truncation error.[13] For the entire particle system, the implicit differential equation of motion can be abbreviated as:

$$P'' = W^{-1}F(P, P') \tag{7}$$

If the implicit Euler method is used, the approximate value of time $i_0 + \Delta i$ is:

$$(W - \Delta \mathrm{i}\frac{\ell F}{\ell V} - \Delta \mathrm{i}^2\frac{\ell F}{\ell \mathrm{s}})\Delta v = \Delta \mathrm{i}(\mathrm{F}(\mathrm{a}_0) + \Delta \mathrm{i}\frac{\ell F}{\ell \mathrm{s}}v_0) \tag{8}$$

The Verlet integration method is the solution of particle motion trajectory, which was first used in molecular dynamics simulation.

This method is a kind of linear differential and integral method, which is derived from Taylor's equation of motion.

$$a(i_0 + \Delta i) = a(i_0) + \Delta i a(i_0) = \frac{1}{2}\Delta i^2 a^n(i_0) + \frac{1}{6}\Delta i^3 a^n(i_0) + O(\Delta i^4) \quad (9)$$

$$a(i_0 - \Delta i) = a(i_0) + \Delta i a(i_0) = \frac{1}{2}\Delta i^2 a^n(i_0) - \frac{1}{6}\Delta i^3 a^n(i_0) + O(\Delta i^4) \quad (10)$$

$$a(i_0 + \Delta i) = 2a(i_0) - a(i_0 - \Delta i) + \Delta i^2 a^n(i_0) + O(\Delta i^4) \quad (11)$$

In the Verlet integration, the time step is taken as a fixed value, and the equation for the current particle velocity is:

$$a'(i_0) = v(i_0) = \frac{a(i_0 + \Delta i) - a(i_0 - \Delta i)}{2\Delta i} + O(\Delta i^2) \quad (12)$$

It can be seen that the Verlet integration method does not need to calculate the velocity of the particle, but solves the entire differential equation through the current position of the particle and the position of the previous moment, combined with the force of the particle. The result can be obtained with only one solution process during the calculation.[14] Because the Verlet method reduces one step of the explicit Euler integration operation, it is computationally more accurate and faster than the explicit integration method.

3D virtual display of Mazu clothing

Most algorithms for surface unfolding work by constructing a developable surface and then unfolding it. For a surface to be expandable, it needs to be able to fully expand in a 2D plane without tearing, folding, or stretching. This characteristic makes developable surfaces widely used in many fields such as clothing design and manufacturing engineering.[15] There are three basic types of developable surfaces, including cylindrical surfaces, conical surfaces, and tangent surfaces of spatial curves, but most of them are complex surfaces in practical applications. Obviously, these three basic types of developable surfaces cannot meet the requirements. When the splicing curve is a straight generatrix of two developable surfaces, the combined surface formed by splicing will still be a developable surface.[16] The commonly used methods for constructing developable surfaces can be roughly divided into two categories: point geometry method and line and surface geometry method.[17] The point geometry method regards the developable surface as a ruled surface, and then realizes the construction of the developable surface by adding certain constraints to the equation of the ruled surface. The line and surface geometry method constructs the fitting curve in the dual space, and then constructs the developable surface according to the property that the developable surface is the envelope of a set of planes. In computer graphics, a triangular mesh model is usually used to represent the surface of a 3D object. Generally, these triangular meshes are obtained by performing surface reconstruction by interpolating or approximating a set of given points through mathematical description.

However, the development of a developable surface by constructing a developable surface has great limitations in the development of complex surfaces, and even if a developable surface is constructed, the fit of the surface to the human body is not necessarily very good. The surface expansion algorithm is inspired by the method of reconstructing the developable surface model based on the scanned paper data with creases. It breaks away from the traditional method of constructing the developable surface for surface expansion. It does not need to calculate the Gaussian curvature of the surface, and only needs to construct the surface of the surface. Two boundary curves, and then by sampling the two boundary curves at equal intervals, the sampling points are connected in an orderly manner to construct a triangular mesh surface. Therefore, the constructed surface has the characteristic that all the vertices of the triangular mesh are on the two constructed boundary curves. The expansion of the surface is also very simple, and it only needs to undergo basic geometric transformations such as translation and rotation.[18] The Gaussian curve represents the general degree of surface curvature. Using the positive and negative properties of Gaussian curvature, the structural characteristics of the surface formed by a point and its adjacent points can be revealed. Then the calculation equation of its Gaussian curvature is as follows:

$$Q = t_1 t_2 = \frac{LN - M^2}{EG - C^2} \quad (13)$$

A necessary and sufficient condition for a surface to be developable is that the surface is the envelope of a single-parameter plane family. Generalized to the discrete form, the Gaussian curvature of any point on the surface of the triangular mesh is:

$$T = \left(\frac{2\pi - \sum_y \alpha_y}{\sum_y P_y / 3}\right) \quad (14)$$

In this equation, α_y, P_y are the angles and areas corresponding to all neighboring triangles of the point, respectively. It is shown in Figure 1:

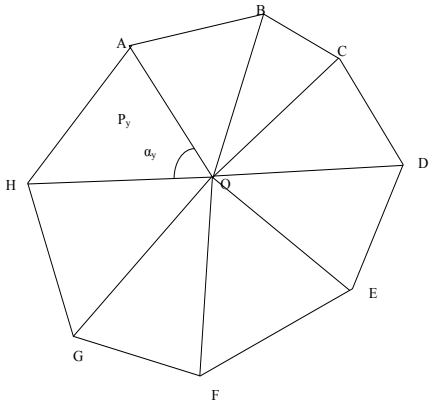

Figure 1 Gaussian curvature of triangulated surface.

By solving the calculation formula of the Gaussian curvature of the triangulated mesh surface, it can be known that to solve the Gaussian curvature of any point, it is necessary to calculate the angle and the area of the triangular mesh associated with the point. However, it is an essential work to solve the Gaussian curvature of the surface in all related algorithms for surface expansion by constructing a developable surface, so this expansion method requires a large amount of calculation. As is shown in Figure 5, a point O on the surface, after adding the deviation value r, the new coordinate Y remains unchanged, and the values of X and Z are:

$$x = OA \times \cos\alpha \quad (15)$$

$$Z = OA \times \sin\alpha \quad (16)$$

The coordinates are expressed as:

$$x = (r + \sqrt{x_0^2 + Z_0^2}) \frac{x_0}{\sqrt{x_0^2 + Z_0^2}} \quad (17)$$

$$Z = (r + \sqrt{x_0^2 + Z_0^2}) \frac{Z_0}{\sqrt{x_0^2 + Z_0^2}} \quad (18)$$

According to the formula calculation, the original modeling points of the clothing can be obtained, and then the uniform grid points of the clothing pieces can be interpolated to obtain the clothing modeling points. The three-dimensional virtual simulation design of Mazu clothing is processed in the three-dimensional clothing design software CLO 3D according to the following steps. First, the 3D mannequin that comes with the system is retrieved, and the size of the mannequin is edited through the "Virtual Model Editor", and the size is edited according to the 160/84A standard female human body size to generate a 3D virtual mannequin that conforms to the size of Mazu's clothes. Secondly, the pattern file of the big shirt is imported through "Import DXF (AAMA/ASTM)", the pattern position is adjusted in the 2D window, the pattern is filled, the internal lines are outlined, etc., in the 3D window according to the pattern and the human body. The three-dimensional positions of the corresponding patterns are arranged, and the hierarchical relationship of each pattern is noted. Third, the sewing thread tools (thread sewing and free sewing) are comprehensively applied, and the corresponding sewing lines of each pattern are set according to the sewing relationship between the various pieces of the big shirt. Simultaneously viewing the sewing line in the 3D viewport, it needs to be careful not to have wrong seams, cross seams, leakage seams, etc., as is shown in Figure 2.

Figure 2 3D virtual stitching of the sea shirt.

Fourth, the clothing fabric properties are set, the main material is cotton, the main color is blue, and the texture map corresponding to the pattern is selected for the lace. Fifth, "Simulation" is selected, and the static simulation effect of the big shirt can be viewed from multiple perspectives by rotating, panning, zooming, etc. in the 3D window; compared with Figure 2, the 3D virtual simulation effect of the big shirt can be adjusted through 2D and 3D linkage. Sixth, according to the above method, the 3D virtual simulation design of red and black pants is completed. It is noted that cotton is selected as the main material, red and black are selected as the main color, and the lace of the trousers and the sea shirt are set homogeneously. Seventh, the big shirt is saved as "clothing" and saved as "*.Zpac" file. The red and black pants file is opened, and the sea shirt clothing file is imported through "Add - Clothing", and the layer of the sea shirt is set to 1, and the combination of the sea shirt and the red and black pants is simulated.

After completing the three-dimensional virtual stitching and simulation of Mazu clothes, the three-dimensional dynamic and static display of Mazu clothes can be performed, which is also one of the advantages of digital virtual simulation. First of all, the posture of the model is adjusted, and the Mazu clothing can be displayed statically from multiple angles, and it can also display local details from multiple angles and 360-degree rotating display. Secondly, the CLO 3D "color matching" function is applied to design the color matching of Mazu clothes to realize a multi-color 3D virtual display.

Third, the "animation" function is applied to complete the 3D virtual T-stage show by adding stages, setting model movements, and video recording, etc., to realize the 3D virtual dynamic display of Mazu clothes.

Analysis and results

Mannequin selection

The mannequin selected for the dress simulation is a woman with a height of 161cm, a weight of 55kg, and an age of 45 years. The situation is shown in Table 2. Before carrying out the dress simulation, it is necessary to set various parameters of the mass spring model for force analysis, including the mass of the particles, the elastic coefficient and other parameters. The quality of fabrics of different materials is also different. In order to facilitate the simulation, the gravity parameter of the particles is set to a fixed value of 0.5. Based on the fact that the elastic deformation of the fabric will not exceed 10%, this paper will only consider the elastic coefficient and damping coefficient of the spring coefficients.

Table 2 Basic information of mannequins

Gender	Female
Age	45
Weight	55kg
Height	160cm

Virtual design results of Mazu clothing

By dividing the surface of the human body model, many sub-surfaces are obtained, and each sub-surface is called a garment piece. Therefore, the generation design of the parts mainly includes: shoulder parts, chest parts, chest side parts, waist parts, etc. Each panel area is defined by four control points. The triangular mesh formed by the discrete points of the two space curves obtained by the four control points according to a certain connection sequence is expressed as a surface similar to the human body. However, the obtained uniformly distributed discrete intersection points are only an ideal state. Since the number of points on the human body model may be small in this plane, it is necessary to obtain the curve equation of the intersection line through curve fitting. Since the number of points obtained above to obtain the intersection point is too small, the curve fitting will cause the problem of under-fitting, so it is necessary to obtain enough points to avoid the problem of curve fitting. Two boundary curves are constructed from feature points, which are the values at the endpoints of the boundary curves. The discrete points obtained from it are projected to the 2D plane, and then the curve fitting is performed on the 2D plane based on the 6th degree polynomial least squares method to obtain the curve equation. Equally spaced discrete sampling is performed between the maximum and minimum values of the X-axis on the curve, and n discrete sampling points including both end points are obtained to obtain all discrete intersection points between the plane and the human body model.

Through the obtained discrete points, the points on the upper and lower curves in sequence are connected to construct a triangular mesh. The interval value of discrete points should not be too large, otherwise it will cause under-fitting, and it should not be too small. If it is too small, it may not only cause over-fitting, but also increase the unnecessary computational burden. The only difference between the construction methods of different parts is the way of generating the boundary curve, and its essence lies in the relative positions of the feature points. It is roughly divided into two cases, when the two feature points are located directly above the human body, such as the two features points SP and SNP required when constructing the shoulder curve. When the control points are located around the body, such as the configuration of the lateral chest curve, there are differences in the configuration of the shoulder curve, but the configuration principle of the curve is the same anyway. Figure 3 shows a virtual model wearing

a Mazu Clothing design walking down a runway. Figure 4 illustrates Mazu Clothing design in different lighting conditions, such as natural light, artificial light, and low light. This can help demonstrate how the color and texture of the fabric change in different contexts. Figure 5 shows Virtual model wearing the Mazu Clothing design in a store or showroom setting, with different angles and lighting conditions.

Figure 3 A virtual model wearing a Mazu Clothing design walking down a runway.

Figure 4 Mazu Clothing design in different lighting conditions, such as natural light, artificial light, and low light. This can help demonstrate how the color and texture of the fabric change in different contexts.

Figure 5 Virtual model wearing the Mazu Clothing design in a store or showroom setting, with different angles and lighting conditions.

Comparison between virtual design and traditional design

Clothing design takes clothing as the object and is a unity of design elements and functions. It is conceived according to the requirements of the design object, and the entire process of creative behavior is completed by using appropriate design methods and expressions. Fashion design is a comprehensive technology of multiple disciplines, which not only integrates artistic visual thinking, but also has engineering logic thinking. The frame and style of fabrics, including the design of the outer contour, the organization of the inner line and the design of the patch, have distinct historical or national cultural characteristics. The fabric determines the appearance of the garment, and the accessories determine the quality and elegance of the fabric. Different colors can take different forms to feel. Table 3 shows the comparison of virtual simulation design and traditional design methods for Mazu Clothing, and highlights the advantages and disadvantages of each method in terms of time, cost, accuracy, and ease of use.

Table 3 Comparison table

Factor	Virtual simulation design	Traditional design
Time	Virtual simulation design can be completed faster than traditional design methods due to the use of software and automation.	Traditional design methods may take longer due to the need for manual labor and multiple iterations.
Cost	Virtual simulation design can be more cost-effective than traditional design methods because it requires less physical materials and can be done remotely. However, the cost of software and equipment may be a barrier.	Traditional design methods may be more expensive due to the cost of materials, production, and labor.
Accuracy	Virtual simulation design can be more accurate than traditional design methods because it allows for precise measurements and simulations of garment movement.	Traditional design methods may be less accurate due to the limitations of manual measurements and the difficulty of predicting how a garment will look and move in real life.
Ease of Use	Virtual simulation design can be easier to learn and use because it relies on software and automation. However, there may be a learning curve for the software and equipment.	Traditional design methods may require more training and experience to master, but can also be done with basic tools and materials.

Conclusion

Through literature retrieval and sorting, the basic style and structure characteristics of Mazu culture and Mazu clothing are analyzed. Taking the improved Mazu clothing as an example, CorelDraw X4 is used to draw the style structure of Mazu clothing. Based on the 160/84A standard female body size data, the size specification of Mazu clothing is set; rich peace clothing CAD software is used for pattern drawing; according to the structural composition of Mazu clothing, the pieces are decomposed to complete the pattern design. The CLO 3D software is used to carry out the 3D virtual stitching and simulation design of Mazu clothing. The software is based on the concept of stitching and fitting, simulating the production process of clothing stitching, and the operation is simple; and it comes with a large number of material resources, and the simulation effect is good. At the same time, the dynamic and static virtual display of Mazu clothes can be quickly realized. This paper took the 3D virtual simulation design of Mazu clothing as an example, and comprehensively applied the 2D and 3D clothing digital design technology. The basic method of virtual simulation design of traditional clothing was discussed. It laid a foundation for the digital design and application of Mazu clothing, and also provided research ideas for the research on digital simulation and virtual display of traditional clothing.

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Compliance with Ethical Standards

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Authors declare that there is no conflict of interest exists.

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