Virtual Display Method of Garment Design Details Based on Computer Vision

Shu Fang[1](✉) and Fanghui Zhu[2]

[1] College of Art and Design, Guangdong Industry Polytechnic, Guangzhou 510300, China
yly052232@163.com

[2] School of Education, Xi'an Siyuan University, Xi'an 710038, China

Abstract. In order to facilitate customers to see the details of clothing design more intuitively on the Internet, and select fitting clothes truly and effectively. A virtual display method of garment design details based on computer vision is studied. This paper introduces computer vision technology, designs the virtual expression scheme of garment design details, scans garment details with 3D laser scanning technology, obtains laser point cloud data and conducts three kinds of processing. Based on laser point cloud data, 3D reconstruction is carried out to obtain 3D clothing image. Design display page to realize virtual display of costume design details and virtual interaction. The experimental results show that the proposed method has good virtual display effect of clothing design details, and the information entropy of 3D image is greater than that of 2D image. This proves that the method studied in this paper can show more details of fashion design.

Keywords: Computer Vision · Clothing Design · 3D Laser Scanning Technology · Design Details · Virtual Display

1 Introduction

At present, most online clothing displays are based on text and two-dimensional pictures [1], which can only provide a flat effect, and there is a certain gap with the real object; The information that can be provided to customers is limited, and there is a lack of human-computer interaction and visibility, which is not conducive to the application and development of e-commerce; At the same time, the traditional demand analysis is generally submitted in written form or obtained through discussion between marketing personnel and customers. However, due to the gap in professional fields and the difference in demand expectations, the demand is often unclear and changeable, and the change in customer interest and value cannot be grasped, the value of existing customer relationships to the company cannot be effectively analyzed, and potential customers or markets cannot be found, As a result, it is unable to provide new products or services to valuable customers in a timely and correct manner. Therefore, it is very necessary to conduct online virtual dynamic clothing display with information technology [2].

Reference [3], based on the analysis of the feature elements of the special-shaped structure template model of the full-formed double-layer clothing, carries out parametric

B. Wang et al. (Eds.): ICMTEL 2023, LNICST 533, pp. 73–87, 2024.
https://doi.org/10.1007/978-3-031-50574-4_6

design of the double-layer template model after the component classification, establishes the topological geometric mapping relationship between the two-dimensional template and the three-dimensional template model, and applies the spring-mass model to realize the three-dimensional component modeling of the inner and outer two-dimensional template. Through the use of digital yarn simulation and texture mapping technology, Calibrate and align the process structure feature points of the two-dimensional template after texture mapping, and finally realize the virtual modeling design and rapid virtual simulation display of the seamless parts of the fully formed double-layer knitted clothing. Reference [4] introduces in detail the integration of holographic projection technology and virtual clothing display in order to promote the in-depth application of holographic projection technology in the clothing industry. Reference [5] has developed a personalized virtual clothing display system based on adaptive deformation of clothing. First, a three-dimensional human body reconstruction framework based on body shape parameters is established; Then, the hybrid skin algorithm is used to establish the relationship between the vertices of the human body model and the vertices of 3D clothing; Finally, the dual quaternion is interpolated to realize the human body deformation driving clothing deformation and complete the adaptive adjustment of clothing. A virtual clothing display system for advanced customization is developed based on Unity platform.

However, the above methods are limited by the mapping relationship between two-dimensional clothing pieces and corresponding three-dimensional clothing in the process of clothing virtual display. Facing this situation, this paper studies a virtual display method of clothing design details based on computer vision. Use 3D laser scanning technology to obtain laser point cloud data and conduct three kinds of processing. Based on this, 3D reconstruction is carried out to obtain 3D image of clothing, and the display effect is optimized.

2 Computer Vision Technology

The core problems in computer vision technology include: segmentation; 3D reconstruction; Motion analysis. Stereoscopic vision refers to obtaining the three-dimensional geometric information of the target object from the process of reference and comparison of multiple images. In biology, almost all biological vision systems are composed of two eyes. When two eyes observe objects from different angles at the same time, they will have a sense of distance and depth. At present, the very popular 3D stereoscopic movies imitate the principle of stereoscopic vision in biology, so that the two-dimensional pictures have a realistic sense of depth. The essence of 3D stereoscopic film is: in the process of shooting, two cameras are used to take pictures together at the same time from different angles; During playback, the images played by two cameras at different positions are simultaneously superimposed and projected onto the large screen. The polarization theory of light in physics is borrowed, so that the audience's eyes can see the pictures taken by the left and right cameras at the same time, just like the picture information seen by people's eyes in the real scene, as if they were in the scene. Therefore, in the computer vision system, if you want to simulate a three-dimensional picture, you only need to use two cameras to capture two images of the same object from different angles at the same time [6]. Then, according to the 3D reconstruction principle, the 3D image in the real scene is reconstructed by the computer program from the 2D information, so as to recover the real spatial position information of the object.

For customers, what they see in the interface layer are specific clothing display effect pictures, fabric drawings and specific attribute information and parameters expressed in the form of text. For the clothing display effect picture, because the image information is relatively rich in the virtual clothing display process, and the customer hopes to be able to watch the realistic details display results in real time, if the image information is directly stored in the database, it will increase the storage pressure of the database server, and the interaction time will increase, which will become the bottleneck of the real-time clothing display. In order to effectively ensure the reliability and efficiency of data transmission. In this paper, the images related to clothing silhouettes and styles are directly stored in the WEB server in the form of files, while the fabric drawings, due to size constraints, occupy relatively small space, so they are stored in the database server together with attribute information and other parameter information. After the designer completes a series of operations such as style definition, outer contour definition, fabric selection and other parameters, and then through the selection of fabrics in different regions, the system will return the fabric texture mapping effect map of the selected clothing style, and then smooth the clothing mapping effect map to obtain a realistic rendering effect map of clothing [7]. In order to ensure the real-time and integrity of system data interaction, the system needs to conduct unified and effective management of clothing style image data and attribute data. Therefore, a virtual expression scheme of clothing design details is proposed, as shown in Fig. 1.

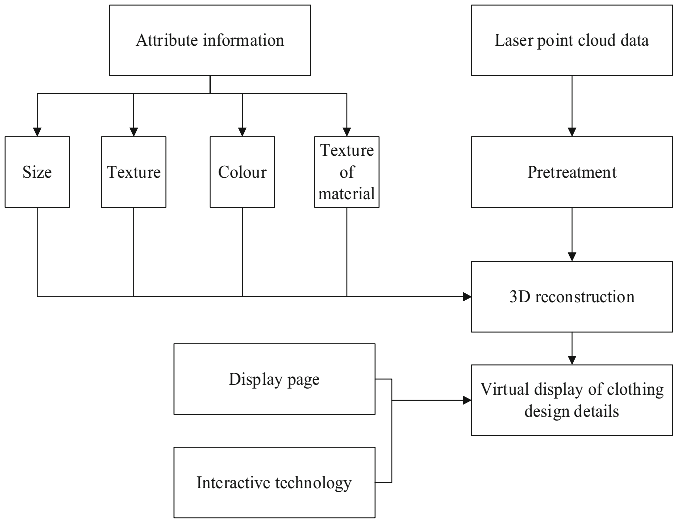


Fig. 1. Virtual Expression Scheme of Costume Design Details

The virtual display of clothing design details based on computer vision technology is mainly divided into three parts: clothing design details scanning; 3D reconstruction; Virtual display. The following is a detailed analysis.

3 Scanning of Garment Design Details

The purpose of clothing design detail scanning is to collect materials of clothing design details. The scanning method selected in this chapter is 3D laser scanning technology [8]. Different scanners have different working principles, but they all need to obtain the 3D point cloud data on the surface of the scanning object, and then process the point cloud data to obtain the 3D mesh model of the scanning object through denoising, simplification, triangle network model conversion, etc. The key of 3D scanning technology is how to quickly obtain the three-dimensional information of objects.

According to the size, surface fineness and scanning site environment of the scanned clothing, the hand-held Artec Eva 3D laser scanner is used, which is faster and more suitable for scanning clothing artifacts. In the early stage of scanning, you can choose to load the texture information of the clothing itself, which is convenient and fast, with the accuracy of 0.1 mm and the resolution of 0.2 mm to meet the scanning requirements. The 3D model and various data obtained from the scanning shall be one-to-one in accordance with the solid scale. The scanning process is fast and can capture accurate measurement data with high resolution, without providing additional equipment for almost any application. The scanning process of costume design details is as follows: Open the Artec Studio software and click the "Start" button to start scanning. Since the costume is a three-dimensional object with front and back, the method of moving scanning first and then multi side scanning is adopted. During the scanning process, you can intuitively view the scanning on the computer screen in real time. If the scanning is not complete, you can conduct additional scanning. When one side is scanned and the other side is scanned and both sides are scanned, you can choose to align all scans to form a whole, and finally save to complete the scanning [9].

After 3D scanning, the generated data information file cannot be used as a clothing model in virtual reality. After being processed by 3D auxiliary software, clothing can be used in other software. The models that need to be obtained by scanning objects with scanners are prone to the phenomenon of holes, noise and repeated points. Faced with this situation, we need to fill holes, denoise and reduce.

(1) Void filling

In the scanning work, due to the scanning speed and angle, the scanning data obtained after the scanning is not complete, such as the texture display on the clothing is incomplete and hollow. Therefore, it needs to be filled.

First, construct a kd tree of point cloud data, obtain its k-nearest neighbor for each data point of all data points, then solve the least squares fitting plane of the data point and its k-nearest neighbor, project the data point and its adjacent area to the least squares fitting plane, then detect the boundary points according to a certain algorithm, and then draw the boundary line in a clockwise (counterclockwise) direction, Finally, based on moving least squares, the method of repairing point cloud holes [10].

(2) De-noising

When the laser scanner is used to obtain the sampling point data of the object surface, there will inevitably be noise points due to the influence of measuring instruments and other environmental factors. The noise points are mainly caused by the following three factors: first, the errors caused by the surface factors of the scanned object, such as the errors caused by different roughness, surface materials, ripples, color contrast and other reflection characteristics. When the surface of the subject is dark or the reflected light signal of the incident laser is weak, it is also easy to generate noise under poor lighting conditions. The second is accidental noise, that is, point cloud data errors caused by some accidental factors during scanning should be deleted or filtered out. The third is the error caused by the measurement system itself. For some contact measuring equipment, the sensitivity of the measuring equipment and the experience judgment of the measuring personnel have a great impact. The system error and random error of the measurement are the main reasons for the noise points. For the current common non-contact three-dimensional laser scanning equipment, it is more affected by the nature of the object itself. Through the analysis of the original scanning data, it is found that if the point cloud is not denoised, the shape of the constructed entity is very different from the original research object [11]. The statistical results show that 0.1%–5% noise points need to be removed from the measured point cloud data. Data denoising is generally discussed according to ordered point cloud and scattered point cloud.

The point cloud data after noise removal by average filtering is relatively uniform, so the average filtering method is used for noise removal. The denoising formula is shown in formula (1):

$$s_i = \frac{\sum_{i=1}^{n} \hat{s}_i}{n} \tag{1}$$

where, s_i represents the point cloud data after noise removal; $\hat{s}_i$ represents the original noisy point cloud data; n stands for window size.

For the latter, the scattered point cloud data is first gridded, and the noise removal of point cloud data is realized on the basis of gridding. The process is as follows:

Step 1: Determine the minimum outer envelope box of the point cloud data, compare the maximum and minimum values of all points in the x, y, z directions, and determine the coordinates of the eight vertices of the point cloud data outer envelope box.

Step 2: Calculate the average density of the point cloud in the outsourcing box, as shown in Formula (2):

$$\rho = \frac{(\max x - \min x)(\max y - \min y)(\max z - \min z)}{m} \tag{2}$$

where, $\max x$, $\max y$ and $\max z$ represent the maximum values in x, y and z directions; $\min x$, $\min y$ and $\min z$ represent the minimum values in x, y and z directions; m represents the total number of point cloud data.

Step 3: Specify the number of point clouds in each small cube, and determine the side length H of the small cube, as shown in Formula (3):

$$H = \left(\frac{\rho}{M}\right)^{1/3} \tag{3}$$

where, M represents the number of point clouds in each small cube.

Step 4: Given the threshold, delete the noise points near the feature point surface.

Step 5: Calculate and determine the center position of the small cube, and then calculate the distance from all points in the small cube area to the center point, as shown in Formula (4):

$$d = \sqrt{(x_i - \hat{x})^2 + (y_i - \hat{y})^2 + (z_i - \hat{z})^2} \tag{4}$$

where d represents the distance.

Step 6: Determine the point with the shortest distance as the center of gravity.

Step 7: Calculate the distance from each small cube point cloud to the center of gravity, and record it as D_i.

Step 8: Calculate the average value $\overline{D}$ and standard deviation A of the distance, such as Formula (5) and Formula (6):

$$\overline{D} = \frac{\sum_{i=1}^{M} D_i}{M} \tag{5}$$

$$A = \sqrt{\frac{\sum_{i=1}^{M} (D_i - \overline{D})^2}{M}} \tag{6}$$

where, M represents the total number of points.

Step 9: Delete the points corresponding to the distance that does not meet the conditions according to different limit errors, and complete the noise removal of the small cube.

Step 10: Determine whether all small cubes have been processed? If yes, complete point cloud data denoising; If not, complete the noise removal of the next small cube.

(3) Reduction

For duplicate point cloud data, reduction is required. The process is as follows:

Step 1: Create a kd tree to build a spatial index of point cloud data, so as to obtain the neighborhood of each data point.

Step 2: According to the K-nearest neighbor obtained in Step 1 and the principal component analysis method, the fitting plane of the local data point can be obtained, so that the normal vector of each data point can be calculated.

Step 3: Calculate the dot product of the normal vector of the data point and the normal vectors of all points in its adjacent area (to avoid the problem of inconsistent normal orientation, the absolute value is taken here), and the result is the dot product of K pairs of vectors.

Step 4: Average the K values in step 3, and use the value as the characteristic value of the data point.

Step 5: The point cloud data is divided into a fixed number of blocks according to the characteristic value in step 4 and its value from small to large, and the corresponding number of blocks is N.

Step 6: According to a series of preset reduction ratios, use the random reduction method to reduce the point cloud data of each block accordingly, and finally consolidate the reduced point cloud data of all levels, and the reduction is completed.

In the process of point cloud data collection for clothing, due to human factors, sunshine and other experimental errors. Even if preprocessing methods such as 3D point cloud simplification and denoising are used, the reconstructed 3D point cloud will inevitably have missing points, especially in the collar, cuffs and other details. In order to ensure that the missing points do not affect the calculation of subsequent parameters, this study makes detailed compensation for the model based on Geomagic Wrap 2014 [12].

4 3D Reconstruction of Garment Design Details

In this paper, 3D StudioMax software is selected for 3D modeling. 3D StudioMax is the most widely used modeling software today, with high-quality graphic output, very fast operation speed, and a large number of special effects. And because 3D StudioMax runs on an open platform, it can integrate nearly 1000 kinds of plug-ins developed by third parties, greatly enriching the creative means. 3D StudioMax provides a variety of modeling methods. Flexible choices of modeling methods such as basic stacking, mesh editing modeling, surface modeling, and graphite modeling provide users with more convenient means and possibilities to create. After continuous version upgrading, more and more functions are added, and the software becomes more and more perfect. In particular, the graphite modeling method in 3D StudioMax2010 and later versions further simplifies and improves the modeling method. The animation function has also been further enhanced, which is unparalleled in 3D modeling software. 3D reconstruction of garment design details based on 3D StudioMax is as follows:

Step 1: Extract garment phenotype parameters;

Step 2: import the phenotype parameters to SubstancePainter for material painting;

Step 3: triangulate the point cloud. Triangulation of the model is to divide the surface of the model into triangles on the premise of maintaining the characteristics of the original model. Triangulation of discrete points is to connect all points into triangular patches according to certain rules. In two-dimensional space, the triangulation of discrete point clouds is shown in Fig. 2.

Considering that the greedy projective triangulation algorithm based on PCL is fast in mesh reconstruction, and the reconstruction effect is good, this method is used in this paper to grid point cloud data. The greedy projection triangulation algorithm based on PCL projects the point cloud data to a two-dimensional plane through the normal, and then uses the space region growth algorithm based on De launay to select triangles to connect the points in the neighborhood that meet the expansion criteria, so that the boundary will continue to expand to form a mesh surface, and then restore to the three-dimensional space according to the topological relationship of the point cloud to form a three-dimensional mesh surface. During mesh reconstruction, the parameters to be set are: the product coefficient mu of the distance from the sample point to the nearest neighborhood, the maximum number of neighborhood searches nnn, the maximum side length radius of the triangle, and the maximum triangle after triangulation_Angle and minimum angle min_Angle, neighborhood search method, etc.

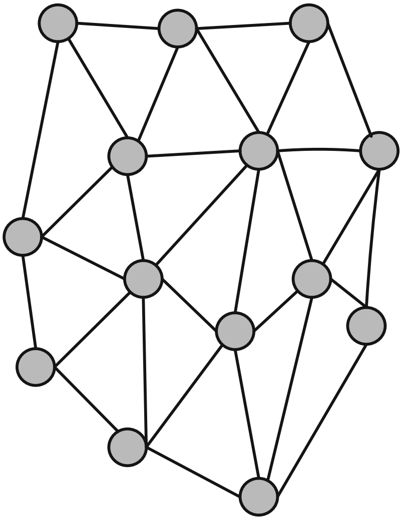


Fig. 2. Schematic Diagram of Triangulation of Discrete Point Cloud

Step 4: Texture mapping. The so-called free texture mapping is that the texture camera can move and place freely under the condition of keeping the focus unchanged, and the texture mapping process can be completed by taking the texture image. To complete the free texture mapping, it is necessary to find the exterior orientation parameters of the texture camera and the binocular system when the position of the texture camera changes. For the proposed method, the internal parameters of the texture camera need to be calibrated in advance. When the texture camera moves freely to take pictures, the texture of the object being measured and the information of the marked points can be obtained at the same time. The marked points can reflect the current position and attitude of the texture camera in time. By using the coordinate position transformation relations of the marked points in the world coordinate system, the texture camera image pixel coordinate system and the binocular left camera image pixel coordinate system, the coordinate position transformation of the freely moving texture camera and the binocular system can be completed. Then, according to the imaging model, the corresponding relationship between the three-dimensional point cloud and the texture pixel can be obtained, and finally the mapping of the free texture can be completed [13].

Step 5: Render the rendering. After polygon modeling, material assignment, UV mapping, texture mapping and other links, the designer optimizes the details of the virtual clothing model, including light settings, details baking and so on.

(1) Lighting layout: light is the basis of interface visual information and visual modeling, and can reflect the shape, texture and color of the target. The lights in Unity can simulate different light source types in real life, and enhance the realism of the scene by arranging lights for the scene. In the lighting layout of the entire Han costumes hall, a directional light is used to simulate the sunlight, a point light source is used to simulate the bulb on the ceiling, and a spotlight is used to simulate the flashlight

to separately light the exhibits, and the light position, quantity and parameters are properly adjusted to achieve the desired effect.

(2) Baking lights: The main purpose of baking is to optimize the scene and improve the running speed of the system. Baking technology can be used to pre render lighting effects into mapping effects, simulating lighting and shadow effects. In the baked scene, even if the lights are deleted, the scene will also have strong lighting and shadow effects, reducing the pressure of real-time lighting and shadows on computer operation. After the baking step is set to static for all objects except lights, set Lightmapping to Bake Scene. Create a Light Probe Group in the Hierarchy panel, then select Baked in Ambient GI in the Lighting panel, check Baked GI, and click Build to bake. After that, you can achieve the real-time lighting effect.

Step 6: Color the material. Use the Miss – st skin maya shader in the mental ray renderer to simulate the color of cloth, and then render and output the virtual clothing model.

5 Virtual Display of Costume Design Details

5.1 Display Interface Design Content

When browsing clothing, users can click the clothing introduction button to listen to the relevant text content of the clothing while watching. They can also click the auto display button to automatically rotate the model. At the same time, the zoom function is also provided. Users can slide the mouse wheel forward and backward to zoom the model. If the wheel slides forward, the model will be enlarged. If the wheel slides backward, the model will be reduced. Click the clothing introduction button, a text box will pop up, which is a text introduction of the clothing, and there will be an automatic voice introduction. Click the detail introduction to display the texture pattern and detailed photos of the dress, or click the line drawing to mark the 3D model.

5.2 Real Time Clothing Animation

The current simulation models have been able to reproduce the dynamic effects of clothing realistically, but for the real-time requirements, the calculation of these models is still too much. This complexity comes not only from the complexity of formulas in the model, but also from collision detection. At present, only the real-time dynamic simulation of small fabrics can be realized. To realize the real-time dynamic simulation of clothing, interpolation, geometric modeling and other technologies can be used to simplify the simulation process context. Weil was the first person to carry out real-time research. He used a model based on geometry. Hindst and Grimsdale and others later made further research in this area. Although the geometric model can meet the real-time requirements in terms of speed, the effect is not very ideal because the physical characteristics of clothing are not taken into account. Another disadvantage of geometric models is that they require human interaction.

In the physics based model, in order to improve the operation speed and meet the real-time requirements, the simplest and fastest method is to treat the surface of the clothes as a mesh composed of vertices, and each vertex is connected with the neighboring vertices through a damping spring to form a "mass spring" model. This model has been widely used to simulate clothes simply and quickly before 1997. Here, a hybrid technology of explicit/implicit Euler integral proposed by Meyer and Desbrun is used to realize real-time clothing animation, and a collision detection algorithm based on Voxel is adopted. Explicit Euler integral is shown in Formula (7):

$$\begin{cases} v_i^{t+1} = \int_{t=1}^{T} \frac{C_i^t}{\lambda} + v_i^t \mathrm{d}t \\ g_i^{t+1} = \int_{t=1}^{T} v_i^{t+1} + g_i^t \mathrm{d}t \end{cases} \tag{7}$$

where, v_i^{t+1} and g_i^{t+1} represent the speed and position at time $t+1$ respectively; v_i^t, g_i^t represents the speed and position at time t respectively; t represents time; λ represents the integration step; C represents an explicit operator.

The basic idea of implicit Euler integration method is to replace the force at time W with the force at time $t + \mathrm{d}t$.

5.3 Virtual Interaction

You can roam around the scene at will to view the internal layout of the scene in an all-round way. Click on a dress with the mouse to view it freely, or manually rotate to view the details, which can be zoomed in and out. Click a button to display the text introduction of the dress, and use C# language programming to achieve the interactive function initially set. It is found in the research that it is more reasonable and resource efficient to dynamically display the model. When the camera is close to the object, it displays the model with high accuracy, while when the camera is far away, it displays the model with low accuracy. When running in the scene, click any dress on the wall to switch to the perspective of camera 2, and instantiate a high-precision dress model. Automatically rotate in the scene, and the rest of the background is in a fuzzy state. Click the auto display button on the right side to stop the auto display and switch to manual display. A text introduction box will automatically enter on the right side, which will introduce the style and history of the dress. At the same time, there will be voice broadcast. Click the detail button to introduce, you can view each high-definition texture picture on the dress, and you can click the line marking button to mark and paint the picture at will. Click the Close button to exit the view angle of camera 2 and switch back to the view angle of the main camera.

6 Method Application Test

3DStudio MAX and SoftImage are used to reconstruct the scene of the virtual display of clothing design details. Combined with Laser projection information fusion technology, image information is sampled. The number of samples collected from the laser scanning image of the clothing design details display is 140, and the pixel of the laser scanning image is set to 500×600, the similarity coefficient is 0.55, and the test is conducted according to the above parameter settings.

6.1 Two Dimensional Clothing Calculation Example

Based on several garments, the hand-held Artec Eva 3D laser scanner is used to scan and generate basic data information files. Some clothing examples are shown in Fig. 3.

Fig. 3. Example of clothing

6.2 3D Virtual Image of Clothing

Based on the 3D reconstruction technology and the scanned point cloud data, a 3D mesh model is established, as shown in Fig. 4.

Then, texture mapping, rendering of renderings and material coloring are performed on the 3D mesh model to obtain the 3D clothing image, as shown in Fig. 5.

6.3 Virtual Display Effect

Information entropy represents the richness of information. The information entropy formula is as follows (8):

$$\psi = -\sum_{i=0}^{R-1} \phi_i \lg(\phi_i) \tag{8}$$

where, ψ represents information entropy; R represents the maximum gray level; ϕ_i is the probability that the pixel gray value is i. The greater the information entropy, the more detailed and comprehensive the detailed information displayed in the image.

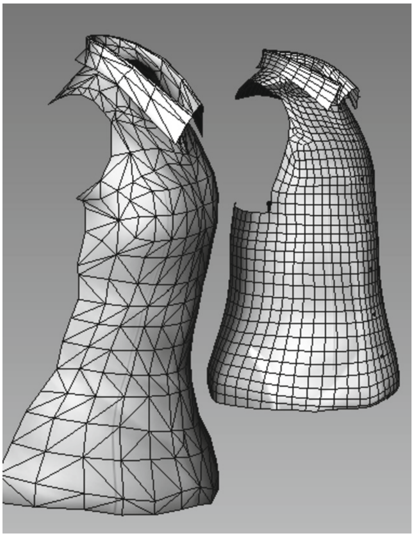


Fig. 4. Three dimensional grid model

(1) Peak Signal to Noise Ratio *PSNR*

$$PSNR = 10 \times \lg\left(\frac{255^2}{MSE}\right) \tag{9}$$

where, *MSE* is the mean square error between images. The larger the *PSNR*, the higher the resolution, and the better the image quality.

(2) MTF

MTF is calculated by finding the contrast between the maximum brightness point $\Im_{\max}$ and the minimum brightness point $\Im_{\min}$ in the line pair, as shown in Formula (10):

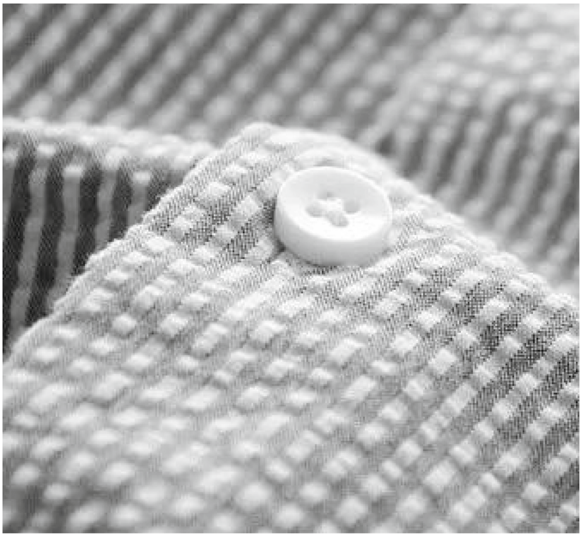
$$MTF = \frac{\Im_{\max} - \Im_{\min}}{\Im_{\max} + \Im_{\min}} \tag{10}$$

MTF calculation will not be greater than 1. And the closer to 1, the better.

The information entropy, peak signal-to-noise ratio and MTF of 2D and 3D images of 200 pieces of clothing in 10 categories were counted, and the results are shown in Table 1.

It can be seen from Table 1 that the information entropy of 3D images is higher than 8.422 in 10 groups of different types of clothing, which is higher than the maximum value of 8.213 in 2D images. Therefore, the detailed information displayed in 3D images is more detailed and comprehensive. The peak signal-to-noise ratio of 3D image is higher than 17.213, which is higher than the maximum value of 14.872 of 2D image, that is, 3D image resolution is higher and image quality is better. The MTF of 3D image is higher than 0.924, which is higher than the maximum value of 0.887 of 2D image, that is, the MTF of 3D image is closer to 1, which has better display effect. To sum up, the

(a) Overall



(b) Details

Fig. 5. Three dimensional image of clothing

information entropy, peak signal-to-noise ratio and MTF of 3D images are greater than those of 2D images, which proves that the information displayed by the method studied is more comprehensive, rich and clear.

Table 1. Comparison of Information Entropy, Peak Signal to Noise Ratio and MTF

Project	ψ		*PSNR*		MTF	
	3D image	2D image	3D image	2D image	3D image	2D image
Clothing1	9.236	7.235	18.254	10.154	0.954	0.841
Clothing2	8.422	7.142	17.262	12.546	0.935	0.836
Clothing3	9.214	6.325	17.625	10.154	0.924	0.864
Clothing4	8.874	8.213	18.876	14.872	0.947	0.821
Clothing5	8.695	7.123	17.542	12.213	0.933	0.871
Clothing6	8.472	6.233	16.987	10.545	0.925	0.847
Clothing7	8.469	7.014	17.213	9.875	0.947	0.887
Clothing8	9.012	7.320	17.245	11.201	0.966	0.836
Clothing9	9.045	6.685	18.687	10.335	0.970	0.814
Clothing10	8.712	6.755	19.546	10.872	0.957	0.798

7 Conclusion

From the perspective of application innovation, this research has strengthened the exploration of the cross field of clothing design and computer vision technology, and applied computer vision technology to clothing design. The whole implementation process is completed, and the practicability of the design method is evaluated. Some technical achievements of this paper are as follows:

(1) Through in-depth analysis of computer vision technology, we successfully introduced computer vision technology into the display and design of clothing details, integrated the existing clothing in a file, re developed the design, and completed the entire virtual clothing design process. And this display is not to let users passively accept information, but to actively search and consult. Interactive display is realized.
(2) The complex process from 2D garment design to 3D virtual stitching to generate virtual garment model is effectively overcome by selecting 3D scanning garment model.

Although this research has done a lot of work, 3D clothing display still faces many problems to be solved. The next research will focus on the physical properties of fabrics, not only on the appearance of clothing, but also on the accurate representation of local structure, showing the drape and texture of clothing.

References

1. Wang, Y.-X., Liu, Z.-D.: Virtual clothing display platform based on CLO3D and evaluation of fit. J. Fiber Bioeng. Inform. **13**(1), 37–49 (2020)
2. Memarian, B., Koulas, C., Fisher, B.: Novel display design for spatial assessment in virtual environments. Proc. Hum. Factors Ergon. Soc. Annu. Meet. **65**(1), 1437–1442 (2021)

3. Zhan, B., Li, Y., Dong, Z., et al.: Research on virtual display of fully-formed double-layer knitted clothing parts. J. Text. Res. **43**(8), 147–152 (2022)
4. Yong, J., Lin, F., Fan, J.: The integration and application of holographic projection technology and virtual clothing display. Video Eng. **46**(4), 211–213, 220 (2022)
5. Lin, J., Chen, M., Shi, Y., et al.: Personalized virtual fashion show for haute couture. J. Zhejiang Univ. (Sci. Edn.) **48**(4), 418–426, 434 (2021)
6. Sharma, S., Koehl, L., Bruniaux, P., et al.: Development of an intelligent data-driven system to recommend personalized fashion design solutions. Sensors **21**(12), 4239 (2021)
7. Qiao, W., Ma, B., Liu, Q., et al.: Computer vision-based bridge damage detection using deep convolutional networks with expectation maximum attention module. Sensors **21**(3), 824 (2021)
8. Wu, Z., Chen, Y., Zhao, B., et al.: Review of weed detection methods based on computer vision. Sensors **21**(11), 3647 (2021)
9. Zhu, H., Pang, J., Wen, Z.: Study on outliers suppression denoising method based on Kalman filter and least square fitting. Comput. Simul. **39**(7), 366–370 (2022)
10. Amabilino, S., Bratholm, L.A., Bennie, S.J., et al.: Training atomic neural networks using fragment-based data generated in virtual reality. J. Chem. Phys. **153**(15), 154105 (2020)
11. Kim, S., Lee, S., Jeong, W.: EMG measurement with textile-based electrodes in different electrode sizes and clothing pressures for smart clothing design optimization. Polymers **12**(10), 2406 (2020)
12. Mosleh, S., Mosleh, S., Abtew, M.A., et al.: Modeling and simulation of human body heat transfer system based on air space values in 3D clothing model. Materials **14**(21), 6675 (2021)