3D garment model reconstruction based on scattered point cloud

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Abstract. We describe a method to quickly reconstruct 3D garment model. We first use a depth camera scanning device to quickly obtain 3D point cloud data on the surface of the clothing, pre-process the point cloud data. Then combining the region growth algorithm and Delaunay triangulation algorithm, we propose a surface reconstruction algorithm that takes undirected point clouds as input and generates interpolated surfaces in the form of triangulation to reconstruct the clothing model. We build this systematic 3D garment modeling program. Through our method we obtain a uniformly distributed grid, smooth patches, and also retain the original shape of the clothing point cloud. Our method increases the convenience of garment modeling, reduces the manpower and time for garment modeling, helps expand the garment database of the virtual fitting system, and provides ideas for garment electronic sales.

1. Introduction

3D virtual fitting is an emerging technology in the apparel industry and one of the key technologies for the digital innovation and development of textile and apparel. It mainly uses computer recognition and graphics related technologies to enable customers to perceive the actual effect of clothing on the body in advance. This technology can improve consumers’ shopping efficiency and help consumers buy clothing that suits their body shape, and improve consumer satisfaction [1]. With the popularity of the Internet and the development of virtual reality technology, virtual fitting is widely used in the field of clothing, such as 3D clothing CAD and clothing display. This technology has a great impact on the clothing industry, bringing more innovative thinking to garment design and enriching the manifestation of clothing marketing [2]. In the clothing online sales system, clothing displays are mostly in the form of two-dimensional pictures. However, 2D pictures cannot comprehensively and directly display information from all angles of clothing. Therefore, a technology that can quickly build clothing models is needed to solve this series of problems.

We propose a method for rapid reconstruction of garment models based on the point cloud data obtained by 3D scanning of physical clothing. It can optimize the user experience, emphasize easy operation, and can complete clothing modeling without too much professional knowledge and operation process. The model established by our method can better meet the technical requirements of 3D clothing modeling, help to expand the clothing database, and increase the utilization rate of the virtual fitting system.

2. Related work
At present, the main research methods of 3D garment modeling can be divided into the following three forms:

Garment physical modeling is to transform clothing into a corresponding particle model in a discrete form, using the interaction between particles to simulate the physical characteristics of clothing [3]. The basic method of this type of modeling is to construct and sew the garment pattern to form a 3D garment model [4]. Its technical points mainly include the garment pattern modeling, virtual stitching technology and collision detection technology [5]. The clothing model constructed by this method is usually simple in style, and the visual effect is not real enough. In response to these problems, Fang Guisheng [6] realizes a method of garment pattern construction based on grass drawing. This method mainly deals with the contour line of garment pattern, realizes the interactive design of garment pattern, and enriches the style of garment model. Umetani et al. [7] presents a tool for interactive modeling and editing of garment. This tool can obtain a virtual stitched 3D garment model by editing the 2D garment patterns, making the 3D effect of garment more intuitive.

The method of garment geometric modeling is to generate a clothing model through the changes of various geometric topologies on the surface of the three-dimensional model. Turquin et al. [8] use the human body model as a reference, draws the contour of the clothing on the projected contour of the human body model, and then reconstructs the 3D clothing mesh model based on the calculation of the distance field. This method can generate a variety of styles of clothing models, but the calculation of complex styles is very large. Wang et al. [9] use sketches to control clothing surface deformations for clothing design, but this method can only achieve functions such as surface stretching deformation and cutting and unfolding surfaces. Brouet et al. [10] propose to use the same clothing model to generate new clothing models of different sizes for different personalized human bodies. This method is based on scaling code rules in the pattern making of the garment structure, adjusting the vertices of the garment model pieces to realize the deformation of each part of the overall garment model. However, due to the need to store and calculate a large amount of vertex information, this modeling method is very inefficient. The modeling method based on 3D scanning has more research on human body modeling, but relatively less on garment modeling.

Because of the large amount of calculation of fabric simulation in physical modeling, and geometric modeling cannot meet the dynamic simulation effect of clothing, some scholars try to combine the two modeling methods. In the sewing process of 2D garment pattern, Wang considers the tension of the garment, calculates the distribution of the garment tension on the human body, and controls the deformation effect of the garment model under tension during stitching, thereby improving the simulation effect of the garment model [11]. Oshita et al. [12] propose to use geometric modeling to generate wrinkle details on sparse particles. This method uses the PN triangulation proposed in [13] to generate a smooth fabric-like surface, and then uses texture mapping technology to make the model have a fabric appearance effect. The wrinkles generated by this method will be affected by the given picture when the initial texture is mapped, so there is much room for improvement in the simulation effect of the fabric.

3. Method

3.1. Acquisition and pre-processing of clothing point cloud data
In the field of clothing modeling, point cloud data is mainly collected through depth camera scanning. The point cloud data we use is obtained by a smart 3D body measuring instrument (Figure 1). The basic principle of the device is to project light with certain structural characteristics onto the measured object, and then collect it through a special infrared camera.

3.1.1. Extraction of point cloud in clothing area and establishment of topological relationship of scattered point cloud
Before garment modeling, the point cloud data of clothing needs to be segmented and extracted. Before segmenting scattered point clouds, it is necessary to establish a topological
relationship between data in order to quickly obtain domain information. We use the KD tree method to build a topology for point cloud data.

![Figure 1. 3D measuring instrument of garment intelligent customization.](image1)

![Figure 2. Effect comparison before and after point cloud segmentation in clothing area.](image2)

We use a colour-based region growth algorithm for segmentation. The experimental result of point cloud segmentation in clothing area is shown in Figure 2. The upper picture is the original point cloud collected, and the lower picture is the clothing area point cloud obtained from the original point cloud through the colour-based region growth algorithm.

3.1.2. processing of clothing point cloud data We use three common types of point cloud denoising algorithms to perform denoising experiments on clothing point cloud data, which are Statistical outlier removal, Radius outlier removal, and Pass-through filtering. The denoising effects of the three methods are shown in Figure 3, Figure 4 and Figure 5, respectively. The upper part is the original point cloud of clothing, and the lower part is the denoised point cloud.

![Figure 3. Effect comparison before and after Statistical outlier removal.](image3)

![Figure 4. Effect comparison before and after Radius outlier removal.](image4)

![Figure 5. Effect comparison before and after Pass-through filtering.](image5)

Statistical outlier removal has a good denoising effect on discrete points, and the calculation speed is relatively fast; Radius outlier removal runs fast and has a relatively good denoising effect. However, the radius of the circle and the number of points in the circle need to be manually specified, which is not convenient enough; Pass-through filtering basically has no denoising effect on the main discrete points,
and the division of the filtering range is strictly required. Therefore, we choose Statistical outlier removal as the denoising algorithm for discrete points.

The point cloud reduction algorithm needs to remove a large amount of redundant data while retaining data points that can reflect the characteristics of the model. The Random downsampling method, Average grid sampling method, and Nonuniform grid sampling method are simple to calculate and can make the point cloud density more uniform. Therefore, we compare the point cloud reduction effect of these three algorithms and select the appropriate point cloud reduction algorithm. The effect of point cloud streamlining is shown in Figure 6. When the parameters of the three algorithms take different values, the number of point clouds after reduction is shown in Table 1.

![Figure 6. Result of point cloud downsample.](image)

![Figure 7. Point cloud smoothing.](image)

### Table 1. Comparison of cloud point number.

| Algorithm                        | Parameter value | Number of points |
|----------------------------------|-----------------|-----------------|
| Random downsampling              | percentage = 0.1| 9049            |
|                                  | percentage = 0.3| 27146           |
|                                  | percentage = 0.5| 41755           |
|                                  | gridStep = 0.1  | 18798           |
| Average grid sampling            | gridStep = 0.15 | 8059            |
|                                  | gridStep = 0.2  | 4403            |
|                                  | maxNumPoints = 6| 16384           |
| Nonuniform grid sampling         | maxNumPoints = 10| 9781           |
|                                  | maxNumPoints = 12| 8192           |

It can be seen from Figure 6 that after the point cloud filtering, there are still a few discrete points on the edge, but after the point cloud reduction, these discrete points are removed. The more streamlined the point cloud, the less detailed features are left. Comparing the results when the three algorithms take different parameters, we choose the reduced result when the Average grid parameter is 0.1 for subsequent processing.

In order to build a smooth and complete model, the surface of the object must be smoothed and holes repaired. The point cloud resampling algorithm can reconstruct the missing parts of the surface by performing high-order polynomial interpolation on the surrounding data points. We use moving least squares to achieve point cloud smoothing. The clothing surface after point cloud reduction and point...
cloud smoothing is shown in Figure 7. Point cloud smoothing mainly has a smoothing effect on the undulating points of the clothing contour surface.

3.2. 3D garment model reconstruction

Combining the region growth algorithm and Delaunay triangulation algorithm, we propose an algorithm that takes undirected point clouds as input and generates interpolated surfaces in the form of triangulation to reconstruct the clothing model. Starting from the seed triangle with the Delaunay tetrahedron result as the input point, the Delaunay triangles connected to the initial front edge are added one by one to gradually form a curved surface. In the process of surface growth, by changing the selection criteria of triangles and adjusting the order of adding triangles, the topology errors and the number of holes caused by adding inappropriate triangles can be reduced. Specific steps are as follows:

3.2.1. Selection of seed triangle

The selection of seed triangles is an important step in all regional growth methods. Correct selection of seed triangles is a prerequisite for high-quality surface reconstruction. The key to finding the correct seed triangle is to ensure that the selected triangle is a curved triangle. When a point is in a well-sampled area, the triangle with the smallest circumscribed circle connected to the point is usually on the surface. In addition, a well-sampled surface can be considered locally flat. Based on these theories, we propose a seed triangle selection strategy with high accuracy and low complexity.

3.2.2. Selection of candidate triangle

In the triangle adding process of the region growing algorithm, each edge connected to only one curved triangle is called the leading edge. The result of surface reconstruction is greatly influenced by the selected triangle. We propose a fast, efficient, and feasible candidate triangle selection strategy. This method can improve the quality of surface reconstruction in downsampling and thin layer regions.

3.2.3. Mesh generation

The process of mesh growth is the process of adding candidate triangles to the mesh one by one. In a well-sampled area, the angle between the candidate triangle and the adjacent curved triangle is usually smaller than the angle in the under-sampled area. Based on the theory that candidate triangles in a well-sampled area are more reliable than candidate triangles in an under-sampled area, the candidate triangles can be added to the surface in this priority order by calculating the average value of the cosine of the three angles of the candidate triangle.

4. Result

By controlling the number of grid growth, the grid process of clothing point cloud can be seen. As shown in Figure 8, the triangle with a green border is a seed triangle. Starting from the three leading edges of the seed triangle, the candidate triangles are spread out and added, and then the candidate triangle is continued to be added from the leading edge of the candidate triangle.

![Figure 8. Clothing point cloud gridding process.](image-url)

The final result of the reconstruction of the entire clothing point cloud surface is shown in Figure 9 (right), which generated a total of 34960 triangle meshes. In order to show the superiority of our algorithm, we use Greedy projection triangulation method and Poisson method to reconstruct the same clothing point cloud data for comparison. The effect is displayed in three views, as shown in Figure 9.
It can be seen from Figure 9 that our reconstruction method has both the advantages of Greedy projection triangulation method and Poisson method. The result is that the grid is evenly distributed, the patches are smooth, and the original shape of the clothing point cloud is also retained. And the original opening of the clothing point cloud can be well preserved. In order to verify the universality of the algorithm, the point clouds of the other two sets of different styles of garment were reconstructed for comparison. As shown in Figure 10, our method also obtains a better reconstruction effect.

5. Conclusions
We introduce the reconstruction of the 3D garment model. First, collect 3D point cloud data on the surface of the physical clothing. Then the point cloud data is de-noised, streamlined and smoothed. Finally, combining the area growth algorithm and Delaunay triangulation algorithm, we propose a surface reconstruction algorithm that takes undirected point clouds as input and generates interpolated surfaces in the form of triangulation to reconstruct the garment model.

Our method increases the convenience of garment modeling. It can be combined with the human body model to realize the display of virtual fitting, and help to expand the clothing database of the virtual fitting system. The clothing model we reconstructed is a geometric modeling form for static clothing simulation. In order to show the effect of dynamic clothing during the simulation of fitting, in the next step we can add relevant research on clothing dynamic simulation.

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References
[1] Wang M Y, Yu C M, Fang F 2017 *Wool Textile Journal* **45** 78-83
[2] Wu Z M, Mao L J, Zhao Y Y 2010 *Journal of Beijing Institute of Clothing Technology (Natural Science Edition)* **30** 13-18
[3] Liang X X, Han H J, Zhang C M 2014 *Journal of Computer Research and Development* **51** 31-40
[4] Aileni R M, Farima D and Ciocoiu M 2010 *Proc. Int. Conf. Tex Sci* vol 10 (Czech Republic: Liberec) pp 1-8
[5] Jiang J F. Generating 3D virtual garment based on 2D sketches[D]. Shanghai: Donghua University, 2012:1-3
[6] Fang G S 2013 *Journal of Textile Research* **34** 133-139
[7] Umetani N, Kaufman D M, Igarashi T and Grinspun E 2011 *J. ACM Transactions on Graphics* **30** 1-12
[8] Turquin E, Wither J, Boissieux L, Cani M P and Hughes J F 2007 *J. IEEE Computer Graphics and Applications* **27** 72-81
[9] Wang J, Li W L, Chen L, Lu G D and Sakaguti Y 2009 J. Computer-Aided Design 41 614-625
[10] Brouet R, Sheffer A, Boissieux L and Cani M P 2012 J. ACM Trans. on Graphics 31 1-11
[11] Wang C C L and Tang K 2010 J. Computer-Aided Design 42 18-86
[12] Oshita M and Makinouchi A 2001 Proc. Computer Animation (Korea: Seoul) pp 220-227
[13] Vlachos A, Peters J, Boyd C and Mitchell J 2001 J. Symposium on Interactive 3D Graphics 159-166