Research on the Reconstruction and Parameterization of Virtual Costume Draping Mannequin in OpenGL Environment

Xiaobo Wang¹, Xiaoming Qian¹* and Lijing Wang²

¹School of Textile Science and Engineering, Tiangong University, Tianjin, China
²School of Fashion and Textiles, RMIT University, Melbourne, Australia
Email: wangxiaobo@tiangong.edu.cn; qxm@tiangong.edu.cn

Abstract. In the 3D virtual design of clothing, the accuracy of virtual mannequin will significantly affect the fitness of the final garment. At the same time, parameterized mannequin can also improve the efficiency and effect of virtual clothing design. The traditional mannequin modeling method has been improved and the reconstruction and parameterized deformation of virtual costume draping mannequin has been realized in OpenGL environment. The parameterized reconstruction process of mannequin is mainly divided into four parts, namely the establishment of the basic mannequin, the reading of the model data, the parameterized deformation of the grid model and the rendering and drawing of the modal data. Finally, the new parameterized virtual human platform is built and the interactive interface is developed. And the virtual human mannequin can be edited and previewed in real time. The modeling result shows that the parametric reconstruction of the virtual draping mannequin is effective and can be applied to virtual costume designing and virtual fitting system.

Keywords. Three-dimensional virtual costume designing; costume CAD; mannequin reconstruction; OpenGL.

1. Introduction

With the development of computer graphics and modeling technology, mannequin modeling methods are becoming more and more diversified. Generally speaking, mannequin modeling methods can be divided into four categories, namely direct modeling, template modeling, image recognition modeling.

Direct modeling includes three-dimensional body scanning and bone modeling. Three-dimensional body scanning is the most accurate modeling method among various mannequin modeling methods. However, due to the high cost of 3D body scanning equipment and the inconvenience of parameterized deformation of obtained model, the application of 3D body scanning modeling method in the field of virtual costume draping mannequin modeling is limited [1]. In addition to the surface modeling of human body, bone modeling also requires the modeling of some internal tissues of human body, such as muscle, bone, subcutaneous tissues and so on. Although bone modeling is very realistic, it is rarely used in the field of costume CAD since its high cost. Template modeling is based on the basic model existing in the system, which is transformed by deformation function to obtain other required models. This method is widely used because of its simplicity, especially in some online fitting systems [2]. But it can’t guarantee its accuracy and most of these modeling methods can’t establish transformation relation among different parts of the human body. As for the image recognition modeling method, a series of photos about the modeling object are firstly taken, then the contour and feature data of the photographed human body are obtained through the image processing technology. This method reduces...
the cost and labor intensity to some extent, but it also has considerable limitations, for instance, the requirement on the shooting background of photos is strict, the models it builds are quite noisy [3].

In this paper, traditional template modeling method has been improved to realize the parameterized reconstruction of the virtual costume draping mannequin, also, the transition among each characteristic part is natural, in line with the change law of the human body shape.

2. Modeling

2.1. Obtaining Basic Model
Take Makehuman software as an example, a new female mannequin is built by creating a new command in this software, the parameters and posture of the model are adjusted appropriately and exported to FBX format. Then, we use 3DMAX to trim the model appropriately to match the shape of our daily used mannequin, and the resulting mannequin is exported as ASE format. The final model of the basic mannequin is shown in figure 1.

2.2. Preprocessing of Model Data
During the process of the mesh reconstruction of the model, the surface information of the model, namely the model information in the ASE file should be read. Some format characters in the ASE file will increase the number of loop judgement of the reading program, which is not conducive to the efficient execution of the program, so it can be preprocessed appropriately, that is to replace the TAB character and the consecutive space character with a single space character.

3. Mesh Reconstruction of the Model in OpenGl Environment

3.1. Structure of ASE File
The ASE file contains all the information needed for model reconstruction, its data structure is shown in figure 2.

![Figure 1. Basic mannequin model.](image1)

![Figure 2. ASE file data structure diagram.](image2)

The reading of the mannequin data information is indispensable to rebuild mannequin, the key of the data reading is the recognition of the model grid data information in the ASE file. The contents of the ASE file begin with basic information of 3DMAX file and some scene setting information. After the "*GEOMOBJECT" character is the model information in the scene, while starting with the "*MESH" character is the most important model grid and vertex information. The characters involved and their corresponding meaning are shown in table 1.

| Normal vector coordinates of the point | Texture coordinates of the point | Index of the point on the plane | Index of the texture on the plane | Normal vector coordinates on the plane |
|--------------------------------------|---------------------------------|--------------------------------|----------------------------------|---------------------------------------|

3.2. Reading of Model Data
The data reading module of the model splits the character string content in the ASE file into a single character to read-in and stores it into an array s[i]. When the reader reads a space character, it adds a
“/0” flag to the array s[i], processing the previously read character into a character string. The logical algorithm of the reading operation is shown in figure 3.

Table 1. Character string meaning in ASE file.

| Character string                  | Meaning                                                                 |
|-----------------------------------|-------------------------------------------------------------------------|
| * NODE NAME                       | The name of the model                                                   |
| * MESH NUMVERTEX                  | The number of points in the scenario that make up the model             |
| * MESH NUMFACES                   | The number of all faces that the model contains in a scenario           |
| * MESH VERTEX LIST                | List of points                                                          |
| * MESH VERTEX 0                   | Coordinate information of the 0th point in the scenario                 |
| * MESH FACE LIST                  | Face information list                                                   |
| * MESH FACE 0                     | The triangular mesh points that make up the 0th surface in the scene    |
| * MESH NORMALS                    | List of normal vectors                                                  |
| * MESH FACENORMAL 0               | The normal value of the 0th face in the scenario                        |
| * MESH VERTEXNORMAL 1             | The normal coordinates of the first point in the 0th face of the scenario|

After reading, it is necessary to recognize the read data, the recognition process is finished through the comparison function. That is to compare which key character information the character read in is same with, then decide where to store the data information read later. The recognition algorithm defines a string variate for each keyword and sets its initial value to corresponding characteristic character string. By determining whether the character string being read is the same as the characteristic string, the current character string being read is identified, and the numerical value of the flag bit is changed. The corresponding relationship between flag bit and character string information is shown in table 2 and the logical algorithm of recognition operation in figure 4.

When recognition operation is completed, the identified information needs to be classified and stored. Building the structure Object, whose members and stored information are shown in table 3.

After the recognition, reading and store of the model data, the triangle drawing function can be used to draw the triangular grid model of the virtual draping mannequin in OpenGL environment. The drawing effect is shown in figure 5.

![Figure 3. Reading operation algorithm.](image-url)

![Figure 4. Algorithm figure of recognition operation.](image-url)
### Table 2. Flag value corresponding to the character string.

| The value of flag | Corresponding character string information               |
|------------------|---------------------------------------------------------|
| 0                | initial value                                           |
| 1                | *3DSMAX_ASCIIEXPORT                                    |
| 2                | *GEOMOBJECT                                             |
| 3                | *MESH_NUMVERTEX                                         |
| 4                | *MESH_NUMFACES                                          |
| 5                | *MESH_VERTEX                                           |
| 6                | *MESH_FACE                                              |
| 7                | *MESH_VERTEXNORMAL                                      |
| 8                | *NODE_NAME                                              |

### Figure 5. Triangular grid figure of mannequin.

### Table 3. Storage array of grid model data.

| Array | Form | Storage Information                                      |
|-------|------|---------------------------------------------------------|
| x     | double | coordinate value $x$ of the storage grid point          |
| y     | double | coordinate value $y$ of the storage grid point          |
| z     | double | coordinate value $z$ of the storage grid point          |
| facex | int   | serial number of the first point in the storage triangular grid |
| facey | int   | serial number of the second point in the storage triangular grid |
| facez | int   | serial number of the third point in the storage triangular grid |
| nx    | double | $x$ coordinate value of the storage grid point normal vector |
| ny    | double | $y$ coordinate value of the storage grid point normal vector |
| nz    | double | $z$ coordinate value of the storage grid point normal vector |

### 4. Parameterized Deformation of Grid Model

The parameterized deformation of mannequin model should conform to the variation law of human body size [4-5]. Taking the waist of human body as an example, the waist of a standard mannequin should be inward concave, so if waistline increased, the most obvious change will be the gradually reduce of the extent of inward concave, as the continued increase of the size, concave will disappear and finally replaced by a bulge of the original inward concave. During this process, the degree of horizontal and vertical growth will be different. To achieve this, a different transformation coefficient must be assigned to each coordinate point, and the change in this coefficient should gradually decrease as it moves away from the center line until it reaches to zero. Therefore, according to characteristic of human body change, the corresponding transformation functions of different human body features are constructed through the Third-order Bezier curve. This is Third-order Bezier curve:

$$ r = (1 - t)^3 \cdot P_0 + 3t \cdot (1 - t)^2 \cdot P_1 + 3t^2 \cdot (1 - t) \cdot P_2 + t^3 \cdot P_3 $$  (1)
P1, P2, P3, P4 are four control point of the shape function of body size transformation that can be adjusted to set transformation coefficients conforming to the body size transformation law for different characteristic parts of human body (See figure 6).

![Figure 6. The Third-order Bezier curve control diagram.](image)

In order to carry out parameterized transformation of the mannequin grid model, it is also necessary to divide the characteristic part of mannequin [6-7]. The grid points of mannequin are divided into several regions according to the characteristic parts, then each region is transformed according to its corresponding transformation function to obtain the new grid data of mannequin model. Division of characteristic regions of the mannequin triangular grid model is shown in figure 7.

After the regional division of mannequin triangular grid, the parametric deformation of its model can be carried out with the transformation functions of different characteristic parts of human body. Figure 8 shows the triangular grid model of mannequin with increasing height, chest circumference, waistline and hipline according to the size of mannequin being transformed by transformation function.

![Figure 7. Regional division of mannequin triangular grid model.](image)

**Figure 7. Regional division of mannequin triangular grid model.**

**Figure 8. The parametric deformation of mannequin triangular grid model.**

5. The Rendering and Drawing of the Modal Data

The parameterized triangular grid model is to draw the basis of 3D mannequin in a virtual environment, then the illumination rendering of virtual mannequin model can be completed by giving normal vector value to each triangular grid in the grid model [8].

The basic method to get the normal vector of a point is to traverse all the planes passing through the point, find the normal vector value of the point in each plane and finally take its average value as the value of the normal vector of this point [9]. However, this algorithm has considerable limitations, when many small planes share a large plane or approach a large plane, local illumination is breezing, which is very unfavorable to the final effect of virtual mannequin. Based on the weight relation of the influence of normal vector of each plane to point, this paper calculates the final normal vector value of this point. As shown in figure 9, since the angle of the $\theta_2$ is larger, the normal vector of this plane has greater weight on the normal vector of point A. Based on it, the normal vector algorithm of point A is:

$$\text{nor}_A = \sum_{i=0}^{k_i} \text{nor}_i$$  (2)
\[ k_i = \frac{b_i}{2\pi} \]  

\textit{nori} is the normal vector of point A, \textit{nori} is the normal vector of the \textit{i} plane that passing through point A, \textit{ki} is weight coefficient. If three points on the \textit{i} plane, \((x_1, y_1), (x_2, y_2), (x_3, y_3)\) are known, then the normal vector coordinates of this plane are:

\[ x = \frac{(y_2 - y_1)(x_3 - x_1) - (y_3 - y_1)(x_2 - x_1)}{\sqrt{a^2 + b^2 + c^2}} \]  

\[ y = \frac{(x_2 - x_1)(x_3 - x_1) - (x_3 - x_1)(x_2 - x_1)}{\sqrt{a^2 + b^2 + c^2}} \]  

\[ z = \frac{(x_2 - x_1)(y_3 - y_1) - (y_3 - y_1)(x_2 - x_1)}{\sqrt{a^2 + b^2 + c^2}} \]  

By giving normal vector to each point in the grid model, illumination effect can be added to three-digit virtual mannequin so as to realize the parametric reconstruction of draping mannequin in OpenGL environment. Figure 10 shows the effect of illumination rendering on triangular grid model of mannequin in figure 8. it can be seen from the final rendering effect that the size of the characteristic parts of the virtual draping mannequin increases gradually with the increase of the characteristic parameters of height, chest circumference, waistline and hipline. The transition among the characteristic reign of mannequin model is natural and the overall effect is realistic.

\begin{figure}
\centering
\includegraphics[width=0.7\textwidth]{normal_vector_algorithm.png}
\caption{Normal vector algorithm of the point.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=0.7\textwidth]{parameterized_modeling_effect.png}
\caption{Parameterized modeling effect of draping mannequin.}
\end{figure}

6. Conclusion
As the basis of virtual costume design, the parametric modeling effect of virtual costume draping mannequin directly affects the quality of garments. In this paper, the basic model is established first, then the parameterized reconstruction is carried out in OpenGL environment to realize the rapid reconstruction of virtual draping mannequin, and the parameterized effect is good. Users can adjust and control the model from various aspects, which can be better applied to virtual fitting and virtual design, providing an efficient and accurate method for the establishment of basic draping mannequin in future virtual costume design.

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