

Construction of human bone surface model

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Abstract. For the local area shape after feature segmentation, the feature contour line is used to reconstruct the feature area surface, and the transition surface is combined to create a complete femoral surface model. This not only improves the reconstruction accuracy of the femoral surface model, but also simplifies the model data structure and improves the model weight. At the same time, it provides a basis for the semantic representation and editing of the femoral model in the subsequent processes.

Keywords: Surface shape, 3D construction, human bone, surface feature.

1. Introduction

As a research hotspot in the field of computer graphics for more than ten years, the construction of human bone surface models has been widely used in many medical research and clinical work [1-4]. Up to now, the existing skeletal surface modeling work can be roughly summarized into two categories. One is pure geometric reconstruction based on the idea of interpolation or fitting of mathematical geometric objects [1, 2]. This type of method is limited to reconstructing femoral surfaces at the geometric level, and lacks The focus on the typical anatomical shape of the femur and its specific medical functions has led to the inaccuracy of surface reconstruction in some key anatomical regions; the other is to reconstruct the three-dimensional surface by combining the bone shape and anatomical landmarks. This type of method makes up for it to a certain extent. The lack of bone anatomical information in the geometric reconstruction method [3,4]. Veselinovic et al. proposed a three-dimensional surface model reconstruction method of the human tibia, which uses feature points and reference axes to assist in describing the anatomical structure and feature shape of the bone. Sholukha et al. decomposed the shape of the femur into several anatomical functional areas, and used statistical methods to construct a quadric surface model of the femur. Although this method can realize the surface reconstruction of the anatomical feature area, the accuracy of the reconstructed femoral model is not high because the quadric surface is difficult to accurately represent the shape characteristics of the complex surface. After years of in-depth research by scholars, although the surface modeling technology has achieved fruitful research results in industrial design and other fields, due to the very complex anatomical structure and surface shape of the human bones, the existing surface reconstruction is oriented to the application of digital orthopedics. The method is still insufficient in accurately representing the overall structure and local details of the femur.

Therefore, for the local area shape after feature segmentation, the feature contour line is used to reconstruct the feature area surface, and the transition surface is combined to create a complete femoral surface model. This not only improves the reconstruction accuracy of the femoral surface model, but also simplifies the model data structure and improves the model weight. At the same time, it provides a basis for the semantic representation and editing of the femoral model in the subsequent processes.

2. Methods

2.1 Feature contour creation

The characteristic contour line is the basis for this chapter to accurately describe the characteristic shape of the femur. The number of contour lines and their generation methods are not only closely

related to the accuracy of femoral surface reconstruction, but also affect the number of underlying geometric objects in the surface model, which in turn determines the efficiency of the femoral surface model reconstruction algorithm. Directly using the protruding (large curvature) vertices in the spline can reconstruct the main feature shape of the contour, but because the curvature is very sensitive to model noise, if only the protruding vertices are relied on, the accurate reconstruction of the contour cannot be guaranteed. A reasonable way to solve the above-mentioned problem is to use the contour line containing the prominent AFP of the characteristic area to represent the local shape of the femur. Therefore, the key to accurately reconstruct the contour of the femur is how to create a limited number of characteristic contour lines. The basic idea of contour creation in this chapter is to extract femoral surface anatomical feature points AFP based on ARE, combined with AFP cutting feature area mesh model to generate cutting lines, and then extract cutting line control vertices on this basis, and then reconstruct femoral NURBS spline contour lines.

The anatomical feature points are distributed on the convex or concave surface of the femoral anatomical area, which is closely related to the medical anatomy and function of the femur. The key to the accurate creation of the femoral feature contour line is to effectively describe the feature points on the surface of the femur with typical medical anatomy significance. Combining femoral anatomical features and medical prior knowledge [5], this paper extracts a series of AFPs with significant medical semantics on the surface of the tuberosity and condyle area, as shown in Figure 1.

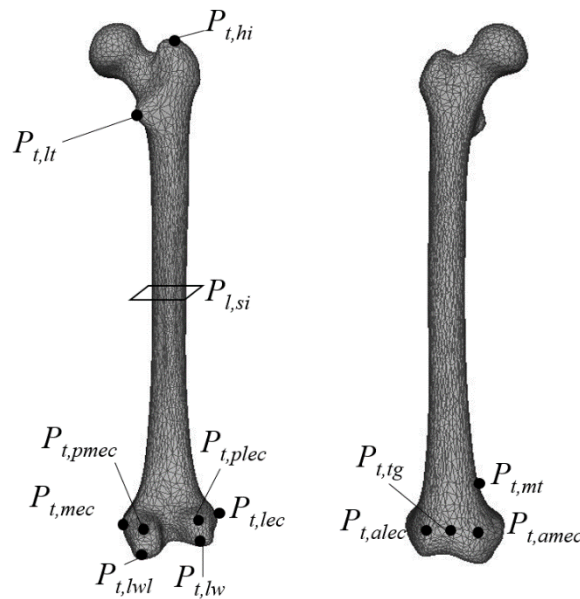


Fig. 1 Femoral surface anatomical feature points.

This paper uses mesh cutting to create contour lines, combined with specific surface generation algorithms, to achieve accurate reconstruction of the femoral surface model. Although a large number of cutting lines can improve the accuracy of model reconstruction, it also brings a series of problems such as complicated operation and low modeling efficiency; on the contrary, if there are too few cutting lines, the femoral shape feature information cannot be fully expressed. Therefore, the key to surface reconstruction is how to use a small number of cutting lines to best describe the feature information of the femur shape. Considering that AFP and ARE contain the local shape features and anatomical structure information of the femur, this paper combines the AFP and ARE objects to reasonably cut the mesh model. Under the premise of fully obtaining the feature shape information of the femur, the number of contour lines is reduced as much as possible to improve Three-dimensional surface model reconstruction efficiency, simplified model structure. A careful analysis of the shape of the femoral feature area is not difficult to find: the head features are very simple and the shape is similar to a hemispherical surface, while the other four areas have relatively complex shapes, as shown in Figure 2.

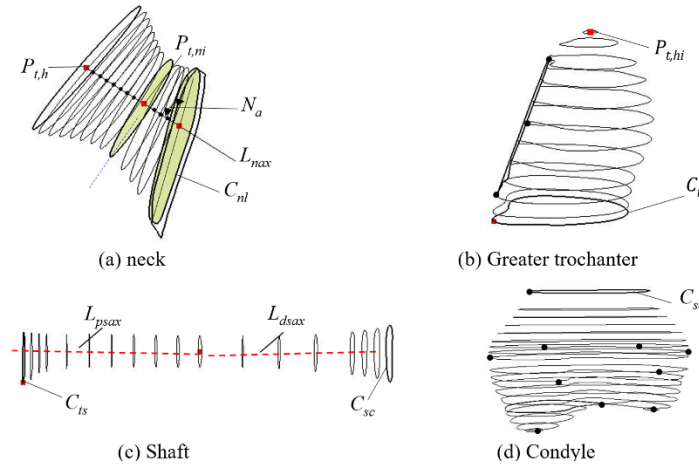


Fig. 2 Cutting lines of the characteristic area of the femur

The method of extracting salient feature points based on the above-mentioned feature area mesh cutting lines and creating a feature area contour spline curve is very simple, and this article will not introduce it in detail. The main steps are as follows:

- (1) Extract 8~10 control vertices (significant feature points) with large curvature including the corresponding AFP in the cutting line;
- (2) Create a NURBS spline curve based on the above feature points to reconstruct the contour line of the femoral feature area, as shown in Figure 3.

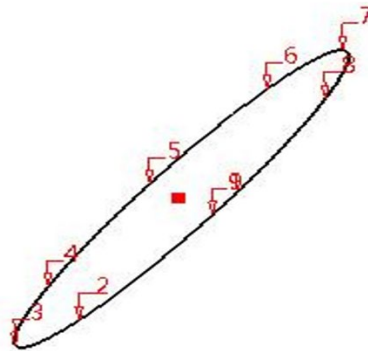


Fig.3 Contour lines and vertices.

2.2 Feature surface model generation

After femoral feature segmentation, the overall shape and complexity of the five regions are quite different. It is obviously difficult to reconstruct the surface using a unified method, and the accuracy of the feature surface reconstruction cannot be guaranteed. In order to accurately describe the local detailed shape of the femur, for the typical features of the local area, we use a combination of regular and free-form surfaces to generate a surface model of the characteristic area, as shown in Figure 4. The specific reconstruction method is as follows:

(1) Femoral head curved surface: Except for the concave femoral head, the femoral head approximates a hemisphere. Therefore, this paper uses the hemispherical regular method to generate the characteristic surface of the femoral head. First, the least squares method is used to solve the head point cloud, and the radius and the center of the sphere are obtained; then, referring to the axis of the neck, the center point is the center of the sphere to create a hemispherical surface.

(2) Other characteristic curved surfaces: the neck, tuberosity, diaphysis and condyle have complex shapes, high degrees of freedom, and lack of significant geometric characteristics. Reconstruct the self-surface model by contour skinning and filling algorithm. For both ends of the neck and backbone are open, the contour skinning algorithm is used to reconstruct the characteristic surface; the shape of the tuberosity and the condyle is open at one end and closed at the other end, which is created by

a combination of contour skin and closed end contour filling. The curved surface finally realizes the effective expression of the shape of the local anatomical features.

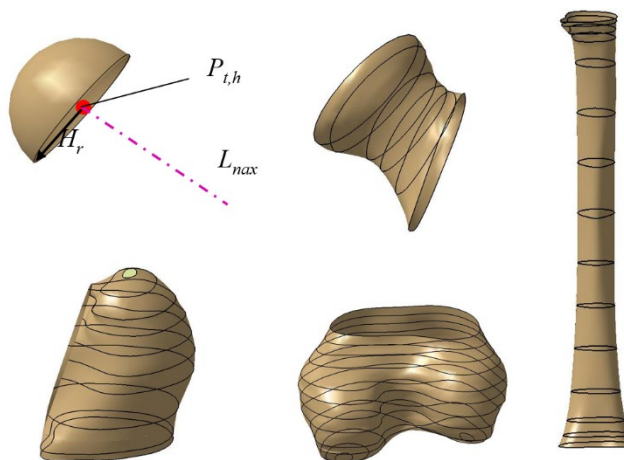


Fig. 4 Feature surface model generation.

2.3 Femur curved surface model construction

If the above-mentioned feature surfaces are directly combined, problems such as poor anastomosis between adjacent features and non-smooth surfaces will occur, resulting in low overall accuracy and effectiveness of the femoral surface model. For this reason, this paper draws on the idea of transition characteristics, and uses the method of skinning the boundary lines of adjacent characteristic surfaces to create transition surfaces and reconstruct the overall surface model of femur. As shown in Figure 5 orange, light blue, blue, gold, and red respectively represent the reconstructed surface of characteristic areas such as the femoral head, neck, trochanter, diaphysis and condyle; the yellow part represents the skinning method based on adjacent boundary contour lines. The resulting transition surface. In summary, the use of transition surfaces to smoothly connect adjacent characteristic surfaces can realize the reconstruction of a complete three-dimensional surface model of the femur.

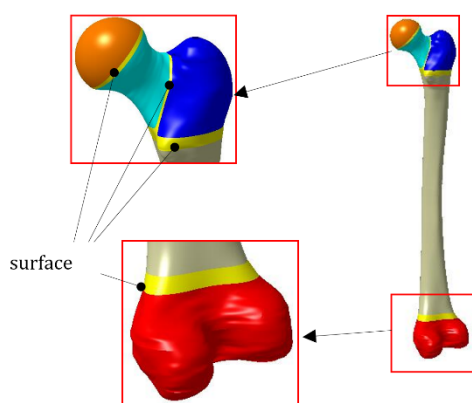


Fig. 5 Bone surface model reconstruction.

3. Experiment results

In order to verify the accuracy of the reconstruction model of this research method, a reconstruction experiment was carried out on 1 averaging model and 4 normal individual femur models, and the errors between the reconstructed model and the original model were compared and tested. The average length of the femur tested in the experiment was 435.83 ± 4.57 mm. The experimental results of the reconstruction of the curved surface model of the femur sample A are shown in Figure 6. The experimental results show that the reconstruction method in this paper can

describe the typical anatomical shape of the original model, and the errors in the representation of local details are slightly different.

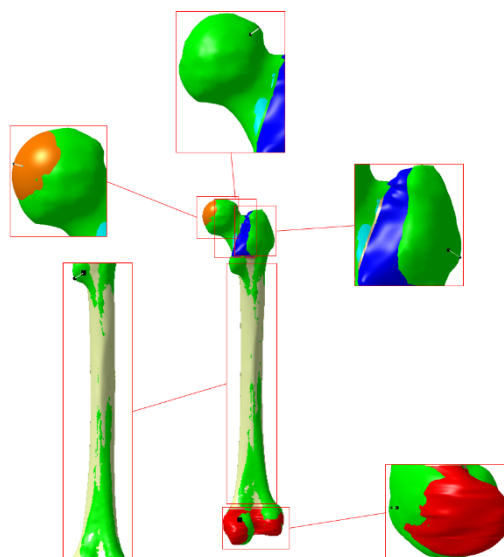


Fig. 6 Comparison of the feature shape of the reconstructed sample A model and the original model.

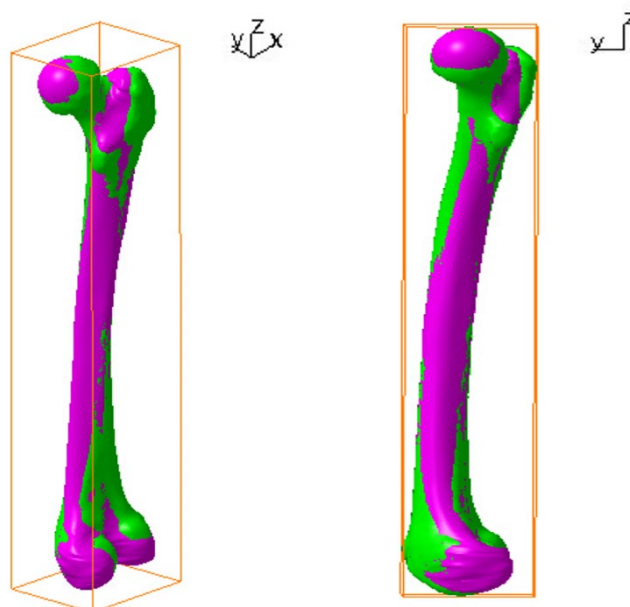


Fig. 7 Sample B reconstruction model compared with the original model.

In order to compare and analyze the similarity between the reconstructed model and the original model as shown in Figure 7, this paper uses Hausdorff distance as the evaluation index [6] to quantify the reconstruction error of the femoral surface model.

4. Discussions

Experimental results show that the reconstruction model has an error of less than 0.4mm in the characteristic areas of the neck, tuberosity, diaphysis and condyle, and the average error of the reconstruction model is lower than the quadric surface reconstruction error (0.5~1.2mm) in the literature [4], And the error of the rotating cutting skinning method mentioned in the literature [3] is relatively close. Compared with other sample femurs, the reconstructed model error of the averaged femur model is the smallest. The main reason is that the femur samples have different degrees of

shape differences, and the averaged bone model shields such individual differences. For all test models, the head error is slightly larger than other characteristic regions. The reason is that the characteristic shape of the head is expressed in a hemispherical way, ignoring the existence of the femoral head concave, because this local detailed shape lacks significant significance in the later implant design.

5. Conclusions

Aiming at the problem of femoral anatomical feature three-dimensional surface model reconstruction, this chapter proposes a femoral surface model reconstruction method based on feature segmentation. Experiments show that the proposed method has the advantages of strong medical semantics of segmentation results and accurate surface model reconstruction.

The method in this paper can not only segment the femur shape into a number of significant anatomical feature regions based on medical semantics, but also realize the accurate reconstruction of regional feature surfaces and femoral surface models. It also provides a basis for the femoral surface feature parameterization and feature deformation research.

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