MEDICAL OBJECT 3D VISUALIZATION METHOD BASED ON THE BÉZIER TRIANGLES

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ABSTRACT

This paper describes an approach that is aimed to solve several medical image processing tasks – the object's surface 3D reconstruction and the following 3D visualization. The proposed 3D visualization method uses a Bézier triangle surface based model creation rather than polygon-based systems to significantly improve computational accuracy and the quality of generated 3D models. The proposed approach was tested on the medical images of a brain acquired by computer tomography and proven to be applicable to different types of region of interest. The results can be used to provide practical improvements to the reliability of medical diagnostics.

KEYWORDS

Bézier triangle, smooth, surface reconstruction.

1. INTRODUCTION

The 3D visualization of a medical object is an important aspect of image analysis and research. Analysis and visualization of different medical images, obtained by computer tomography (CT) or magnetic resonance imaging (MRI), is important to medical research and clinical practice. In this case, some of the most important initial phases of medical image processing are tasks of extraction and analysis of different image regions (a medical object or a pathology zone) [9].

In relation to this, a necessity to solve the task of 3D visualization of the region of interest emerges in computer diagnostics. The ability to visualize the orientation, position and size of structures in medical images can be vital to researchers and physicians. In order to obtain a 3D model of the region, the medical image must first be segmented, followed by region extraction from the medical image. Afterwards, the extracted region's contour control points, which are later used for 3D visualization of the object must be selected. Although there are methods that allow segmentation and visualization of the medical image [10], the existing approaches of 3D visualization are not always able to provide a high-quality smooth surface of the 3D model. The resulting 3D models have a distinct aliasing (staircase) effect [2]. The well-known marching cubes algorithm also has flaws, like the aliasing effect and other negative aspects described in [8].

This paper proposes an approach to smooth 3D geometrical modeling of a medical object. The proposed method of 3D visualization uses a Bézier triangle based surface model creation rather than polygon-based systems to significantly improve computational accuracy and the quality of generated 3D models. The proposed method results in a better quality surface of the 3D model.

2. PROPOSED APPROACH

The obtained 3D model of a medical object in [2] is created using polygons. The interpolation approach is based on Bézier triangle surface. The Bézier triangle surface interpolates each polygon and the set of Bézier triangles create the sculpture surface of the object. This approach can be described by the following three steps.

Step 1: Each polygon is described by three points and three normal vectors (Fig.1.a.).

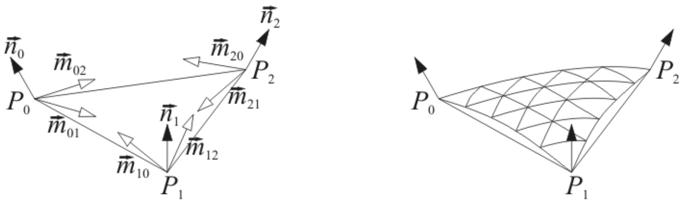

Figure 1. Polygon with normal vectors and tangent vectors

The normal vector of a polygon is a twist vector for surface interpolation and it fulfills the condition:

$$\left|\vec{n}_i\right| = 1, \quad i = 0;1;2. \tag{1}$$

Step 2: The tangent vector m_{ij} from point P_i to point P_j must fulfill the following condition:

- tangent vector m_{ij} must be perpendicular to the normal vector n_i and
- tangent vector m_{ij} must belong to the plane, created by n_i and the vector between point P_i and P_j.

From these conditions the tangent vector can be calculated by a cross product of two vectors as follows:

$$\vec{m}_{ij} = h \cdot \left(\vec{n}_i \times \left(P_j - P_i\right)\right) \times \vec{n}_i \,. \tag{2}$$

where: h – is the length coefficient.

Step 3: The Bézier triangle surface can be described as follows:

$$S(u,v,w) = \sum_{\substack{i,j,k=0 \\ i+j+k=n}}^{n} \frac{n!}{i! \cdot j! \cdot k!} \cdot u^i \cdot v^j \cdot w^k \cdot p_{i,j,k}, \quad u+v+w=1. \tag{3}$$

where: u,v,w – surface parameters.

The interpolated surface can be described as a cubic Bézier triangle (n=3). In this case the control points at the triangle corners can be describes as follows:

$$p_{003} = P_0; \quad p_{030} = P_1; \quad p_{300} = P_2 \,, \tag{4}$$

where: p_{ijk} – are control points of a Bézier triangle; P_i – are points of a polygon.

The control points on the triangle edges can be described as follows [4]:

$$\begin{array}{lll} p_{012} = P_0 + \frac{1}{3} m_{01}; & p_{021} = P_1 + \frac{1}{3} m_{10}; & p_{201} = P_2 + \frac{1}{3} m_{20} \\ p_{102} = P_0 + \frac{1}{3} m_{02}; & p_{120} = P_1 + \frac{1}{3} m_{12}; & p_{210} = P_2 + \frac{1}{3} m_{21} \end{array} \tag{5}$$

where: p_{ijk} – are control points of a Bézier triangle; P_i – are points of a polygon; m_{ij} – are tangent vectors.

The control point in the triangle center can be described as follows [4]:

$$p_{111} = \frac{1}{4} \cdot \left(p_{012} + p_{102} + p_{021} + p_{120} + p_{201} + p_{210}\right) - \frac{1}{6} \cdot \left(p_{003} + p_{030} + p_{300}\right). \tag{6}$$

The resulting Bézier triangle surface interpolation of the initial polygon is shown in Fig.1.b.

3. EXPERIMENTS

The proposed approach was tested on a real object. The object in the experiment was the medical images of a human head fragment, acquired with computer tomography. The result of the proposed method was compared with the approaches [2] and a 3D imaging software 3D-Doctor [1]. Fig. 2 illustrates the comparison of various methods.

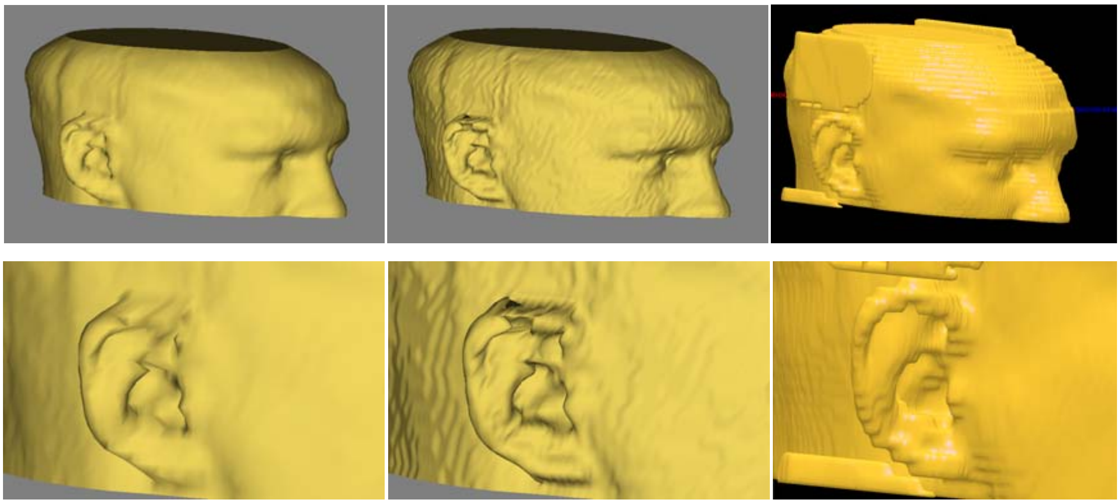

Figure 2. Comparison of different methods. Left - Visualization by a polygon - based method, middle – proposed approach, right - 3D Doctor.

The experimental results also show that the proposed approach has an effect on 3D model quality on an example of a real object.

4. CONCLUSION

This paper proposes an approach to a smooth 3D reconstruction of the medical object's surface and it's visualization. The proposed method have been tested on the medical images of a brain acquired by computer tomography.

The proposed method have been compared with existing solutions and the experiments show that the proposed approach gives a better visual result than existing approaches [2] and the method of 3D-Doctor [1]. The surface of the model is smoother, without the aliasing effect. Overall, Bézier triangle -based approach show stable results in visualization and may be implemented in medical software to provide better 3D visual quality of the reconstructed medical object.

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