Medical object surface 3D modelling based on interpolating iso – curves set

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Introduction. The 3D modelling of medical object and its visualization is an important and actual task in medical engineering. At the same time, the input data for this task often is described in the form of 2D layers (for example, medical images acquired with Magnetic Resonance Imaging, Computer Tomography, etc). In this case, the most important part of the complex visualization task is the 3D modelling of a medical object. There are multiple approaches for solving this task, for example, an approach, based on Bezier surfaces [1] or an approach, based on B-spline surfaces [2]. The input data for these approaches is a topological orthogonal set of points.

The approach, based on surface approximation using non-orthogonal set of points is described in [3]. But this approach gives imprecise surface (the surface doesn't pass through control point). It is not good for geometrical analysis. In this work, an approach of 3D modelling based on topological non-orthogonal set of point is described. This approach is based on object surface contraction based on interpolation iso-curves set.

Proposed approach for 3D modelling of medical object. The input data for developing the mathematical model of a medical object is a set of points, obtained from segmented regions [4]. At the same time the set of control points complies with the following conditions:

1. In 3D space the control points are described by layers;
2. Distance between layers is homogeneous;
3. Order of control points in every layer is pre-determined and creates closed contour;
4. Number of control points in every layer is not equivalent;

In this case, the surface should comply with the following criteria: the surface should be closer to control points and it should insure the reconciliation of object's form. If we take into account the conditions mentioned above, a problem of local surface interpolation will arise. In this case it is necessary to develop a sculpture surface, where every element interpolates object fragments between two proximal layers. The proposed method for parametrical surface development consists of two steps: curves set development in one parametrical direction and surface development based on the obtained curves set.

First step, curves set development consists of curve development task at every layer. The idea of the method is the interpolation of curve stage. Input data is P_i set with corresponding parameter u_i value in every consistent point. At every layer parameter u changes in diapason [0; 1]. Stage interpolation was commissioned with four row points and parametrical curve interpolates the stage between two central points of four. This method is described as parabolic blending [5]. Fig. 1a) illustrates this situation.

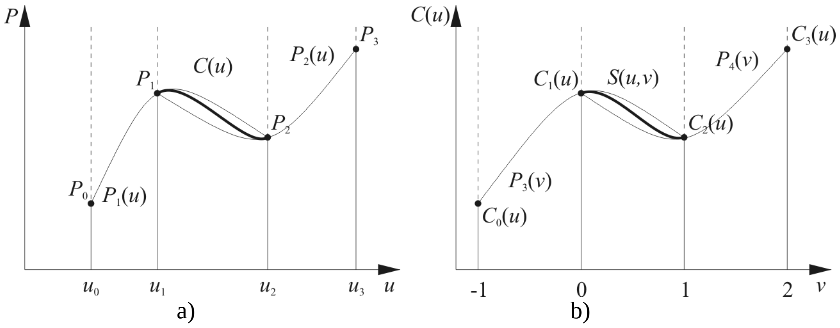

Fig. 1. Curved parabolic blending

The curved parabolic interpolation is described in the following way:

$$C(u) = \frac{u - u_2}{u_1 - u_2} \cdot P_1(u) + \frac{u - u_1}{u_2 - u_1} \cdot P_2(u) \tag{1}$$

where: $C(u)$ – curve stage at interval [u_1; u_2]; u_1, u_2 –values of parameters in control points; u – curve parameter.

Parabolic function can be calculated in the following way:

$$P_1(u) = a_1 \cdot u^2 + b_{.1} \cdot u + c_1 \text{ and } P_2(u) = a_2 \cdot u^2 + b_{.2} \cdot u + c_2 \tag{2}$$

The parabolic function coefficients can be calculated from linear equation system:

$$\begin{bmatrix} a_1 \\ b_{.1} \\ c_1 \end{bmatrix} = \begin{bmatrix} u_0^2 & u_0 & 1 \\ u_1^2 & u_1 & 1 \\ u_2^2 & u_2 & 1 \end{bmatrix}^{-1} \cdot \begin{bmatrix} P_0 \\ P_1 \\ P_2 \end{bmatrix} \text{ and } \begin{bmatrix} a_2 \\ b_{.2} \\ c_2 \end{bmatrix} = \begin{bmatrix} u_1^2 & u_1 & 1 \\ u_2^2 & u_2 & 1 \\ u_3^2 & u_3 & 1 \end{bmatrix}^{-1} \cdot \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} \tag{3}$$

Second step is surface development using curve development in second parametrical direction; curves set obtained in the first step is used as input data. This method is analogical to the first step. Taking into account that the distance between layers is similar it is possible to calculate *v* parameter values generally, and then the diapason between two central points will be the same [0; 1]. Fig. 1b) illustrates this situation in case of *u=const*. Taking into account Fig. 1b) descriptions, parabolic interpolation is described in the following way:

$$S(u,v) = (1 - v) \cdot P_3(v) + v \cdot P_4(v) \tag{4}$$

where: $S(u,v)$ – resulting surface; v – second surface parameter.

Parabolic function can be calculated by analogy with (2) as follows:

$$P_3(u) = a_3 \cdot u^2 + b_{.3} \cdot u + c_3 \text{ and } P_4(u) = a_4 \cdot u^2 + b_{.4} \cdot u + c_4 \tag{5}$$

Taking into account the even division of the parameter *v* it can be calculated in the following way:

$$\begin{bmatrix} a_3 \\ b_3 \\ c_3 \end{bmatrix} = -\frac{1}{2} \cdot \begin{bmatrix} -1 & 2 & -1 \\ 1 & 0 & -1 \\ 0 & -2 & 0 \end{bmatrix} \cdot \begin{bmatrix} C_0(u) \\ C_1(u) \\ C_2(u) \end{bmatrix} \quad (6)$$

and

$$\begin{bmatrix} a_4 \\ b_4 \\ c_4 \end{bmatrix} = -\frac{1}{2} \cdot \begin{bmatrix} -1 & 2 & -1 \\ 3 & -4 & 1 \\ -2 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} C_1(u) \\ C_2(u) \\ C_3(u) \end{bmatrix} \quad (7)$$

Experimental result. In this work the described method, as well as the methods described in [3] were implemented. Control points set obtained from [3] and [4] was used as initial data.

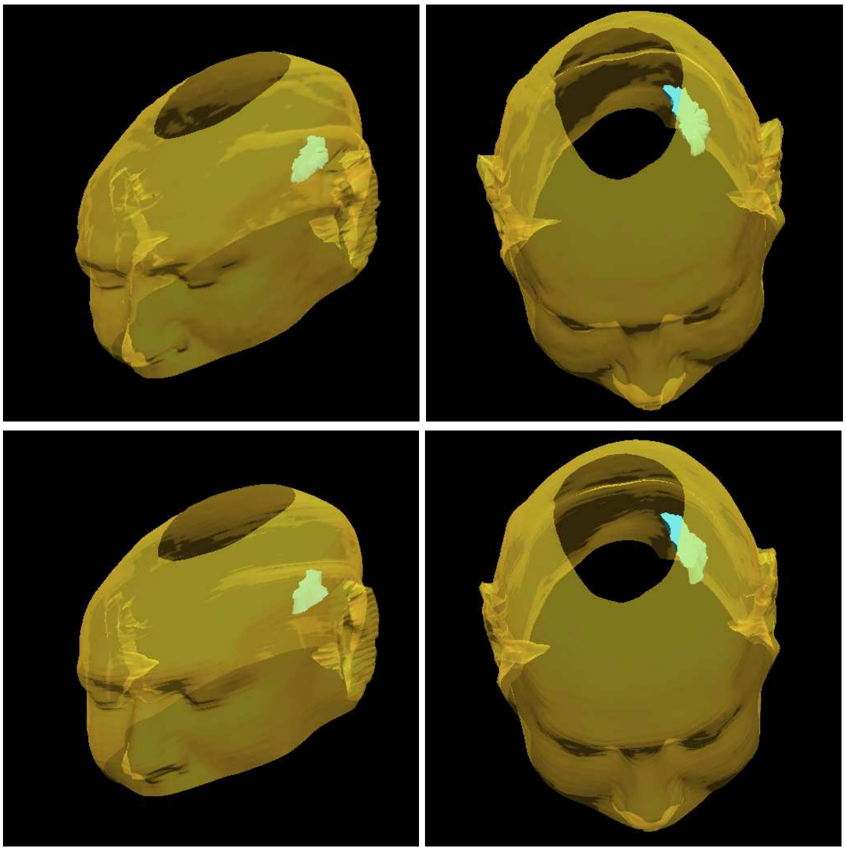

Fig. 2. Top row: Models obtained using proposed approach
Bottom row: Models obtained by method [3]

The size of the images in experiment is 512x512 pixels. The experiments were carried out on the computer with CPU Intel Xeon 3.2 GHz, RAM 2 GB. As a result an interpolating bi-cubic piecewise parametric surface is formed. The proposed method of 3D model creation was implemented in developed software. The model was visualized using OpenGL graphic library [6]. Fig. 2 top row shows the results of the visualization of human head and pathological zone. The comparison with Fig.2 bottom row shows, that the proposed method gives one solid surface of object, but method [3] gives a set of surfaces (in Fig. 2 bottom row it is seen as surfaces lines).

Conclusions. The described method is a flexible and powerful approach for medical object's 3D modelling and visualization. At the same, time this method is very elastic and sensitive to small impression of input data. So proposed methods needs to do smoothing modification for better practical use. The using area of proposed method is geometrical analysis of medical object (volume estimation etc.).

References

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One of the most important and actual tasks in medical engineering are 3D visualization of medical object. At the same time, the input data for this task often is described in 2D layer form In this case, the most important part of complex visualization task is the task of medical object 3D modelling. In this work, the approach of 3D modelling based on topological non orthogonal set of point is described. This approach is based on object surface contraction based on interpolation iso-curves set. This approach is a flexible and powerful tool for medical object 3D modelling, depending on the current medical task.