Contour processing and 3D visualization in medical images

K. Bolochko*, A. Glazs

Processing and Computer Graphics Department,
Riga Technical University, Latvia
**E-mail: katrina.bolocko@rtu.lv*

Introduction. One of the most important tasks in medical image processing is pathology zone extraction and its analysis. In those cases, when a surgical intervention is required, 3D visualization of the medical image aids physicians in planning the operation.

In order to obtain a 3D model of the medical object and its surroundings, the desired medical object must be first extracted from the medical image slices. Then medical objects contour control points, which are further used for 3D visualization of the object, must be selected.

In this paper, a method of visualizing a selected medical object is proposed. The method uses a polygonal-based 3D model. The necessary control points for the 3D model are acquired from the extracted contour and a 3D mesh is constructed and then visualized in the developed software.

Proposed method. The proposed approach combines two methods – contour processing for obtaining control points and visualization – the construction of a 3D surface from the acquired points.

Firstly, a medical object in the image is selected and its contour processed to obtain control points that are necessary to reconstruct the 3D model. The proposed method for contour processing is based on the modification of a method described in [1]. This modification includes combining the method with the clockwise point selection [2] and implementing an adaptive threshold T_{ij} for each part between the adjacent points $p_{i,j}$ and $p_{i,j+1}$ of the adaptive contour on slice i, in a way that a lesser distance would require a stricter threshold:

$$T_{i,j} = \frac{T_0}{d_0} \cdot d \quad , \tag{1}$$

where T_0 – initial threshold for a fixed distance d_0;

d – actual distance between points $p_{i,j}$ and $p_{i,j+1}$.

The proposed method consists of two stages, illustrated by Fig. 1: the selection of initial control points for the adaptive contour using the clockwise algorithm and adjustment of the adaptive contour to match the objects contour.

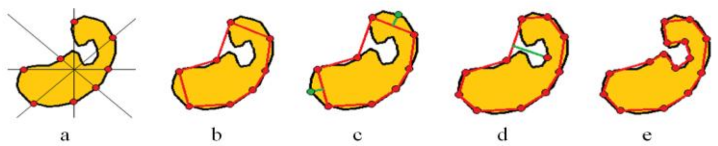

Fig. 1. a) selection of initial control points, b), c), d), e) adaptation

Each j^{th} point $p_{i,j}$ of the contour on slice i is assigned a special parameter $t_{i,j}$ that is further used to create a 3D mesh from the control points. The parameter $t_{i,j}$ is calculated according to the following equation:

$$t_{i,j} = \frac{l_{i,j}}{P_i}, \qquad (2)$$

where P_i – is the perimeter of the contour on slice i;
$l_{i,j}$ – is the contour length from the point $p_{i,0}$ to point $p_{i,j}$.

The result of the proposed algorithm is a 2D representation of the acquired control points, where each point its own parameter $t_{i,i}$ value (see Fig. 2).

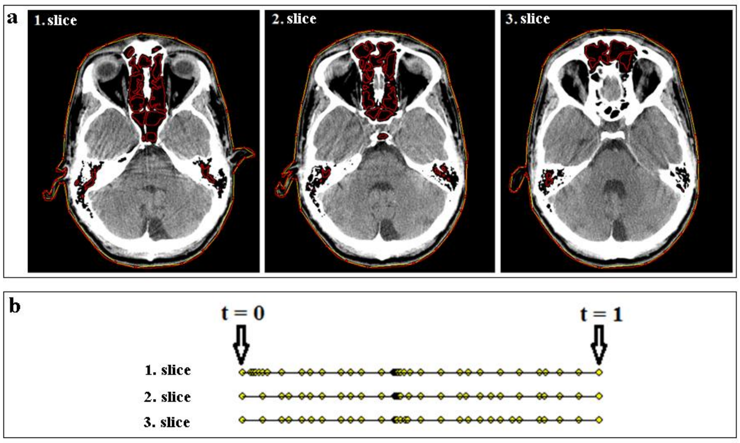

Fig. 2. a) acquired control points, b) control points 2D representation

Secondly, when the control points had been acquired from the medical objects contour, the proposed triangulation algorithm creates a mesh surface for visualization. The algorithm uses the 2D representation of the control points. In this case, each slice s_i has N points $p_{i,j}$. Each point has its own parameter $t_{i,j}$. The triangulation algorithm processes the data consecutively, analyzing two adjacent slices. The adjacent slices are processed in two stages:

1. The slice s_i is considered as the base for triangulation, meaning that 2 points on slice s_i are taken as base vertexes for the triangle and the third vertex is taken on the slice s_{i+1}.

1.1 The base vertices of the triangle are formed by neighboring contour points on slice s_i: $(p_{i,0}, p_{i,1})$, ..., $(p_{i,j}, p_{i,j+1})$,..., $(p_{i,N-1}, p_{i,N})$.

1.2. For each pair a third vertex $p_{i+1,k}$ is found on slice s_{i+1} (see Fig. 3). The point $p_{i+1,k}$ is added as the third vertex if the difference between its parameter and the base vertices parameter is minimal:

$$\left| \frac{t_{i,j} + t_{i,j+1}}{2} - t_{i+1,k} \right| \to \min \qquad (3)$$

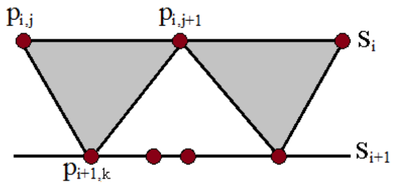

Fig. 3. Finding the third vertex

2. During the second stage, the remaining connections between the two slices are found.
2.1. The base vertices of the triangle are formed by neighboring contour points on slice s_{i+1}: $(p_{i+1,0}, p_{i+1,1})$, ..., $(p_{i+1,j}, p_{i+1,j+1})$,..., $(p_{i+1,N-1}, p_{i+1,N})$.
2.2. For each pair a third vertex is found on slice s_i. For the current pair of points on slice s_i, two adjacent existing triangles *A* and *B* are found (see Fig. 4). The pair points may or may not be vertices of these triangles. Then, the vertex p_{AB} that is shared by both these triangles is added as the third vertex.

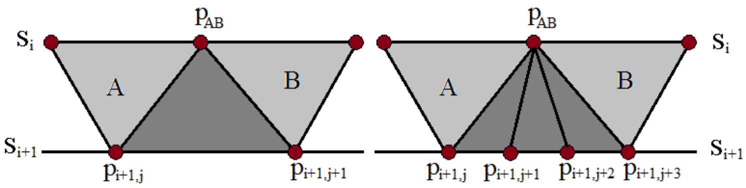

Fig. 4. Finding the third vertex

As a result, a 2D representation of the mesh is formed, which can then be visualized in 3D (see Fig. 5). The results of the proposed method were compared with a 3D imaging software 3D-Doctor. The results are presented on Fig. 6.

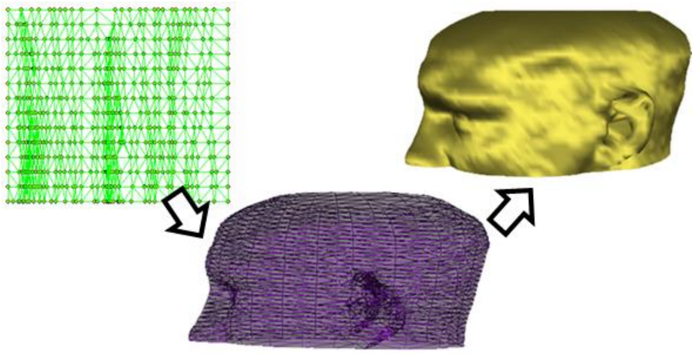

Fig. 5. 2D mesh representation in 3D form

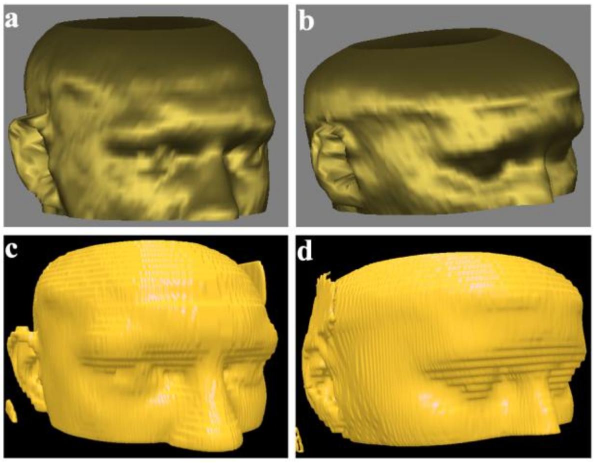

Fig. 6. a), b) Results of the visualization, c), d) 3D-Doctor visualization

Conclusions. The results show that the proposed method of acquiring control points is precise and ensures the precision of the 3D model. The proposed method of 3D visualization was experimentally compared with a 3D imaging software – 3D-Doctor. The results show that the surface generated by the proposed method is of higher quality, than the surface generated by 3D-Doctor. The surface generated by 3D-Doctor has an aliasing effect, while the surface generated by the proposed algorithm is smooth. The results show that the proposed methods can be sucessfully used to visualize the medical objects with high precision, therefore aiding the physicians in diagnostic tasks.

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Image Processing and Computer Graphics Department, Riga Technical University, Latvia

This work describes several methods that intend to solve such medical image processing task as 3D visualization of the medical object. The proposed method of 3D visualization was experimentally compared with a 3D imaging software – 3D Doctor. The results show that the surface generated by the proposed method is of higher quality and the proposed method can be successfully used to visualize the medical objects with high precision, therefore aiding the physicians in diagnostic tasks.