Centerline Extraction in Virtual Endoscopy Based on Severe Domain Mesh Decimation

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Abstract. Navigation path in virtual endoscopy is extracted prior of exploration of the targeted organ as a guiding support for the virtual camera that inspects the inner details of the organ. In this paper we introduce a method for centreline extraction based on severe mesh decimation of triangulated model of the segmented domain. The target organ geometry is first extracted using segmentation; then a triangulated model is created on the to drastically reduce its size while preserving its topology. Finally, from the decimated mesh we retain only a minimal set of points to define the centreline.

1. Introduction

Virtual endoscopy relies on the combination of multiple image processing techniques, including 2D data packing in volumes, data processing using smoothing and noise reduction filters, data resample, followed by data segmentation for tubular organ separation and model triangulation. Fast rendering techniques are also important to ensure the real-time user experience. Last but not least is the necessity to ensure a stable and predictable user inner navigation.

The exploration trajectory must comply with easily defined criteria: uniformly staying away from the boundary, continuity, single-voxel (or zero) thickness, no looping and branching, smoothness. In case of non-ideal geometries - as is the case with most of the anatomical cavities - finding a smooth "central" path becomes a problem with multiple solutions.

Most of the existing centerline extraction methods can be classified into three categories: manual extraction, topological thinning, and processing based on distance maps. Manual extraction requires the user to identify and pick the succession of points that define the path. Even though it is considered uncomfortable and lengthy (especially for long or sinuous organs), it is still a preferred method in clinical practice as it ensures robustness and allows complete control. Topological thinning generates the exploration trajectory by eliminating layers of voxels (peeling) until the last one-voxel-thin core [1]. This last layer is designated to be the object skeleton, and represents one of the possible solutions of centerline extraction problem. One key and resource-demanding element of the iterative process is continuously finding the set of voxels (simple points) whose deletion does not modify the object topology. One version of thinning strategy is to use successive steps of mesh contraction technique to extract domain skeleton [2].

The underlying idea of distance-map based methods is to make direct use of what can be called the "lateral information", that is, the distance of each composing voxel to its closest boundary [3]. The path is ideally placed along the map singularities. Difficult problems arise in case of complex geometries, when significant local maxima appear. Various variants have been proposed to cope with these cases [4], for example refining initially multi-branched graphs whose nodes are placed in the local maxima [5]. A forward-looking strategy combined with distance map technique was proposed elsewhere [7].

The algorithm proposed in this paper is based on extreme mesh decimation applied to original model obtained from triangulation of the targeted organ boundary. The decimated model will be further processed to retain only a minimal set of points defining the centerline for guided navigation inside the targeted cavity organ.

2. Algorithm description

From the initial set of 2D raw scan data, we apply *connected threshold* segmentation algorithm [8] to the targeted organ for virtual endoscopy. From the segmented domain we extract first the triangulated model with Marching Cubes algorithm and simple decimation with vtkDecimate algorithm [8]; this model is used for rendering; to obtain the skeleton of the target organ, we apply first to the same segmented domain 99.5% decimation using vtkQuadricDecimation algorithm [8]. Subsequently, to this mesh is applied a further mesh reduction technique, eliminating the surfaces elements and keeping only inflexion points.

3. Results

From the segmented domain of aorta and iliac arteries, obtained from a set of 512 × 512 pixels, 72 slices of CT raw data of abdominal procedure with contrast substance, we obtain both targeted organ rendered model (in Fig. 1 with gray color) and decimated model for centerline extraction (in Fig. 1 with black color).

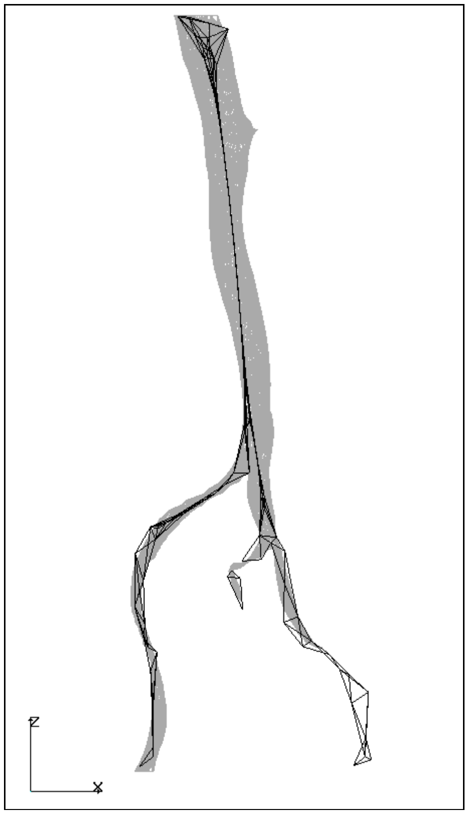

Fig. 1 Full model, used for rendering (grey) and extremely decimated model, used for centreline extraction (black).

4. Conclusions

A simple and extremely fast method for centerline extraction was proposed. The method is based on applying quadric decimation to the original, triangulated model of the targeted organ, while preserving the topology of the domain. From the extremely decimated model, a minimal set of points is extracted to define the navigation path.

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