

SASOMI

Semi-Automatic Segmentation of Medical Images

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Abstract. This paper presents an interactive graphical user interface that provides an intuitive solution for refining an automatic pre-segmentations of abdominal aortic aneurysms. With current applications the segmentation of aneurysm thrombus has to be done completely manual without the possibility to refine automatic pre-segmentations. The SASOMI software therefore provides interpolation methods based on NURBS surfaces combined with edge fitting to accelerate the process of segmentation. The implementation was done using C++, Qt and OpenGL. Robustness and user friendliness have been tested in a set of different experiments.

1 Introduction

Many clinical applications involve exact segmentation of anatomical structures in all kind of 3D images. When automatic methods fail to meet the required robustness, user interfaces that allow for refining automatic segmentation results are of great help for the medical staff.

In the current paper, we focus on abdominal aortic aneurysm (AAA). It is a permanent, irreversible, localized dilatation in the abdominal section of the aorta. In most cases, an aneurysm thrombus is present caused by a rupture of the most inner layer of the aortic wall through. This allows blood to enter in between the two layers and coagulate.

For diagnosis and detection of AAA, computed tomography angiography (CTA) is the standardized imaging modality. The aortic lumen is highlighted by injected contrast agent and has strong gradient values to surrounding structures. The aortic wall and aneurysm thrombus, however, are visually very hard to detect without any anatomical expertise. Additional difficulties for segmentation algorithms are introduced by severe calcification occurrence inside the thrombus.

For allowing an optimal treatment planning of AAAs, the focus of medical as well as engineering research goes towards integrating biomechanical models in the medical workflow. In order to give realistic simulation results, the geometry of the aneurysm and its thrombus need to be extracted as accurate as possible. In the last decade, several approaches have been published allowing fully- or semi-automatic AAA segmentation [1, 2]. Despite of their promising results,

it has been shown that in clinical practice, these methods fail to provide the required robustness.

Graphical user interfaces for segmentation of anatomical structures have become extremely popular in clinical practice. Here, a variety of commercial and non-commercial software is available for general usage [3, 4] as well as for specific medical applications [5]. In the case of abdominal aortic aneurysms a CTA scan can consist of up to 1000 slices. Therefore a segmentation tool needs to support some kind of interpolation in-between the slices as well as post-refinement possibilities, to improve usability. Furthermore intensity region growing is not applicable as a semi-automatic approach, since the ROIs are not always surrounded by clear and closed contours. To the best of our knowledge, there is no such refinement software available for the segmentation of AAAs.

In this paper, we present an interactive graphical user interface that provides for the medical staff an intuitive solution for refining an automatic AAA pre-segmentation. The software transforms the pre-segmented volume in a NURBS surface providing an intuitive way of interacting with already present segmentation.

2 Materials and Methods

As displayed in Fig. 1, the software consists of four different views: axial, sagittal, coronal and volume 3D. While each of the first three gives a slice based view of the loaded image according to its direction, the Volume view shows a 3D visualization of the segmentation that can be zoomed and rotated. The segmentation tree underneath the main view offers possibilities to change color and opacity of all

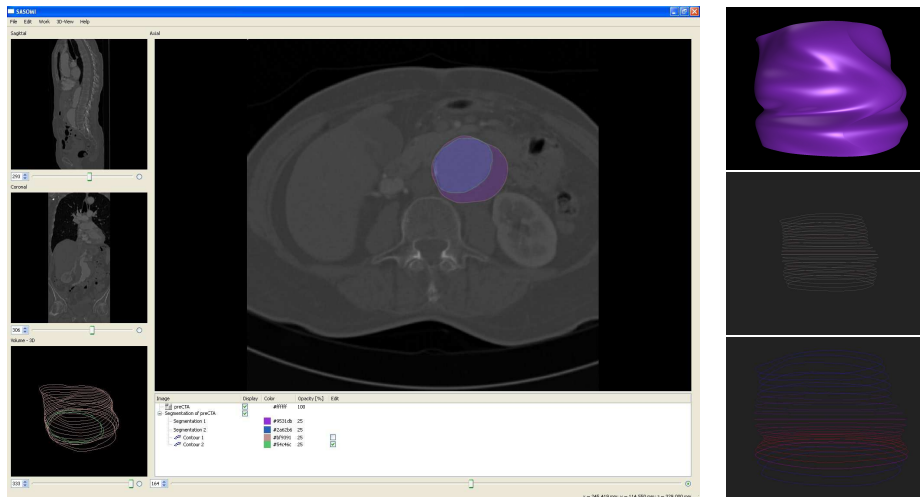


Fig. 1. SASOMI software. Left: overall layout; right: three volume views.

segmentations. In the following, we describe some of SASOMI's main features that also represent the main contribution of this paper

- *Tracing*: In addition to free-hand-drawing of a contour in a 2D slice, SASOMI supports edge tracing that simplifies following the outline of an edge using edge detection. While in tracing mode, edge points that are detected in the nearby area of the mouse pointer are displayed as yellow dots (Fig. 2). To refine an already present contour it is possible to start tracing at one point of the contour and finish at second point. The part in between will then be substituted by the new one. Erasing the last drawn points can be done by drawing backwards. Thanks to edge detection it is not necessary to hit these points exactly.
- *Slice interpolation*: Since it is quite time-consuming to do segmentations on every slice, SASOMI computes a NURBS surface [6] from already segmented slices which is then used to generate the missing slices in-between. It also closes gaps in segments that lie within the same slice. Already segmented slices are transformed into a NURBS curve for a more accurate and smoother visualization.
- *Edge fitting*: To refine the interpolation result this function fits the segmented points to the closest edge found in the image. The calculation of the edge points itself uses a quadratic 2D facet model on the gradient image. Compared to region growing one could consider the contour resulting from the interpolation as a seed which is in most cases already quite close to the actual gradient in the image. Accordingly a lot less comparisons are needed and the given shape also helps the algorithm to stay in a certain boundary.
- *Directional edge fitting*: A more enhanced version of the popular edge fitting method. Edge points are captured only in the approximate direction of the curve's normal (Fig. 2, left). In addition, a search along the new edge is performed and while points that are not likely to be part of this edge are removed, missing edge points are included. The result will then be transformed into a NURBS curve (Fig. 2, right). Compared to the standard Edge Fitting method it can return more accurate results especially in corners.

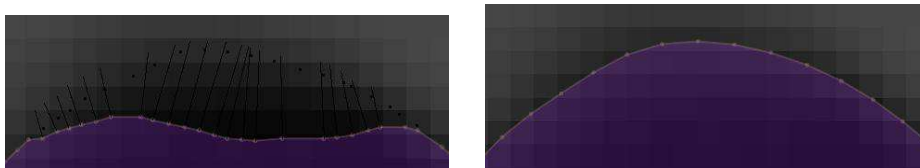


Fig. 2. Edge fitting.

Table 1. Evaluation (R=Robustness, U=Usage, IT=Interaction tools, TE=Time effort, V=Visualisation).

	Task1					Task2				
	R	U	IT	TE	V	R	U	IT	TE	V
E1	10	10	9	6	5	10	10	9	6	5
E2	10	9	8	5	5	10	10	10	5	5
E3	10	9	8	6	7	10	7	9	6	7
M1	10	7	9	10	5	10	7	10	10	5
M2	10	9	10	10	6	10	9	10	10	6
M3	10	9	9	9	6	10	9	8	9	6

3 Results

The SASOMI software was implemented in C++ using a Qt-based User Interface and OpenGL as graphics engine. We tested its robustness and user friendliness in a set of different experiments. We asked three engineers and three medical doctors to evaluate the software in two steps. The first task consisted of loading an abdominal CTA scan of a patient suffering from AAA and segmenting the AAA thrombus manually with the help of the given interaction tools. Secondly, these presegmentations were mixed and each user was given one segmented volume created by a different user. They were then asked to use our software to refine this segmentations.

The evaluation results are presented in Tab. 1. The users had to rank the software in each category in numbers 1 (bad) to 10 (excellent).

While the other categories were found to be good to excellent, all users complained about the insufficient volume views. All medical doctors stated that such a volume view of the segmentation does only make sense within a volume rendering environment of the surrounding anatomical structure. The engineers criticized the missing mesh visualization that would make more sense for accessing the geometry in detail.

To test the improvement of interaction time, gained by using the implemented functions, we selected several persons with different level of experience considering the use of graphics software or SASOMI itself. While beginners are users with little or no experience, three users in our test are working as graphic- or web designers. Both got a short introduction in the program's user interface. The persons called experts are using SASOMI already for several weeks.

The task was to segment an object over 20 slices using the different functions the program provides. It is quite obvious that edge detection already accelerates the segmentation process. In addition the variance of the results between the different users is reduced. With interpolation it was enough to process only every fifth slice. The interpolation time of 0.7 seconds for this scenario is already included in the results. It should also to be mentioned that even with nurbs

Table 2. Interaction time.

User Level	Beginner			Experienced			Expert		
User	1	2	3	4	5	6	7	8	9
Free Hand	6:22	4:52	5:12	3:56	4:13	4:28	4:09	3:58	3:26
Edge Detection	2:48	3:02	3:48	2:26	1:59	2:08	2:09	1:57	1:49
Edge Detection +Interpolation	0:50	0:57	1:02	0:52	0:46	0:42	0:46	0:35	0:34

surfaces interpolation does not produce perfect results for every object. Edge fitting can then be used to reduce the effort of refinement.

4 Discussion

The advantages of SASOMI clearly lie in facilitating the process of segmentation and providing an intuitive way of interacting with already present segmentation. Additionally the 3D-model enables a more realistic impression of the segmented areas. Although SASOMI has been developed in the context of abdominal aortic aneurysms it is applicable for a variety of fields. For example it is currently used for segmentation of midbrain area in ultrasound volumes.

As future work, we plan to integrate the user feedback and adapt the volume visualization to be more usable. Also, a further adaptation of the software and an optimization of the internal algorithms for ultrasound images is already planned. Another idea is integrating new and alternative interaction methods like haptic devices or 3D displays. Providing an intuitive set of adjustable parameters could make the edge fitting function adaptable for a larger variety of situations. So far the application has only been tested with Windows XP, but portability is given through the use of C++, Qt and OpenGL for implementation.

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