Segmentation of Abdominal Aortic Aneurysms with a Non-parametric Appearance Model

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Abstract. This paper presents a new method to segment abdominal aortic aneurysms from CT angiography scans. The outer contour of lumen and thrombus are delineated with independent 3D deformable models. First the lumen is segmented based on two user indicated positions, and then the resulting surface is used to initialize the automated thrombus segmentation method. For the lumen, the image-derived deformation term is based on a simple grey level appearance model, while, for the thrombus, appearance is modelled with a non-parametric pattern classification technique (k-nearest neighbours). The intensity profile along the surface normal is used as classification feature. Manual segmentations are used for training the classifier: samples are collected inside, outside and at the given boundary. During deformation, the method determines the most likely class corresponding to the intensity profile at each vertex. A vertex is pushed outwards when the class is inside; inwards when the class is outside; and no deformation occurs when the class is boundary. Results of a preliminary evaluation study on 9 scans show the method's behaviour with respect to the number of neighbours used for classification and to the distance for collecting inside and outside samples.

1 Introduction

Contrast CT angiography images (CTA) of abdominal aortic aneurysms (AAA) provide information about the aortic anatomy, making it possible to visualize lumen, calcifications, and thrombus (Fig. 1). A patient-specific model of the abdominal aorta based on these data can be used, for example, for simulation or for pre-operative planning and post-operative follow-up of AAA repair surgery (e.g. [1]). While several methods for lumen segmentation and tracking are reported in the literature (e.g. [2, 3]), only a few researchers have addressed the more complex issue of thrombus segmentation in CTA data. Due to the low contrast between thrombus and surrounding tissue in CTA images, segmentation methods have difficulty to delineate the correct boundary. Approaches based on image gradient often fail because strong responses from neighbouring objects,

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such as the spine and lumen, distract the method from finding the correct boundary. Threshold-based approaches are also prone to fail, since the same intensity value is found inside the thrombus and in the neighbouring structures.

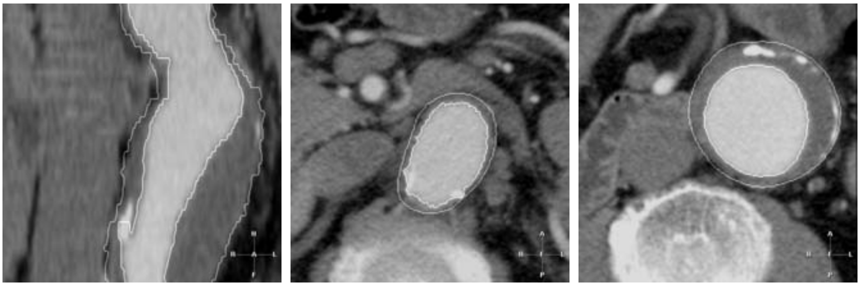

Fig. 1. Slices of abdominal CTA scans showing lumen (inner) and thrombus (outer) contours delineated by experts: coronal and axial slices.

A few attempts to segment the thrombus have been reported in the literature ([4, 5, 6]). The method proposed by De Bruijne et al. in [4] is based on a slice-by-slice approach. The user has to draw a contour in one slice, and this contour is propagated to the adjacent slice based on the similarity between the grey values in both slices. At any time, the user can correct a contour generated automatically and resume propagation. The method proposed by Subasic et al. in [5] is based on the level-set technique. A sphere positioned by the user inside the lumen initializes a deformable model that segments the lumen using image gradient as image feature. This result is used to initialize the thrombus segmentation method, which uses specific image features derived from a pre-processing step (threshold, morphological operations, and image gradient). Another method proposed by De Bruijne et al. in [6] consists of a 3D active shape model in which the appearance of grey values is modelled with a non-parametric pattern classification technique. As initialization, the user has to draw the top and bottom contours, as well as to indicate an extra position corresponding to the approximate aneurysm centre.

The above mentioned methods suffer from two shortcomings. In [4] and [6], the reported results are accurate (in average, 95% of volume overlap with a gold standard), but the amount of user intervention is significant. Typically, a large number of contours must be manually drawn in [4], and two contours in [6]. Moreover, in both cases the lumen and thrombus are handled separately, requiring extra interaction for the reconstruction of a complete AAA model. In [5], user intervention is limited to indicating the centre and radius of the initial sphere, but the reported results do not seem sufficiently accurate (no comparison with a gold standard was presented in that paper).

In this work we perform the segmentation of lumen and thrombus in a combined manner, as in [5]. First the lumen is segmented based on minimal in-