Evaluation of Probability Functions used for Fuzzy Pulmonary Vessel Segmentation in CTA Data

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EVALUATION OF PROBABILITY FUNCTIONS USED FOR FUZZY PULMONARY VESSEL SEGMENTATION IN CTA DATA

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1. Introduction

Pulmonary vessel segmentation in CTA data is a required step in applications, such as the detection of pulmonary emboli (PE), which appear as dark centers surrounded by contrast agent. Especially for smaller vessels such emboli can be easily missed due to the complexity of the vascular tree. Hence we seek to reliably segment pulmonary vessels as a basis for further automatic detection steps.

2. Problem Description

PE applications require that all relevant arteries are captured with high sensitivity, since each missed artery is lost for subsequent detection steps. Using a region growing based segmentation method, one needs to define an inclusion criteria that is able to deal with inhomogeneities caused by image noise, an unequal distribution of the contrast agent, or PEs. Vessel boundaries need to be detected as stopping criteria in the presence of partial volume effects and airway walls, which can be confused with vessels.

3. Solution Method

To automatically detect and segment pulmonary vessels, we use a fuzzy approach [2]. Initially, we segment the vessel tree threshold-based with a high specificity to detect multiple seed-points. Next, fuzzy connectedness region growing [4] is applied to get a second, accurate, fuzzy segmentation of the vessels.

Fuzzy connectedness is based on a probability measure that describes how likely neighboring voxels belong to the same class. Hence the probability that a voxel belongs to the vasculature is iteratively determined in a region-growing fashion.

As a probability function we evaluate and compare linear combinations of intensity- and gradient-based functions. Additionally we have used functions that consider both features simultaneously, similar to the opacity feature [3]. That is, such function allows inhomogeneities in areas with intensity values similar to the expected one while resulting in a low probability value even for small gradients if the considered intensity value is unlikely to belong to the vessel tree. Furthermore, we have incorporated higher-level knowledge in the probability function. Therefore voxels in close spatial proximity to the airway lumen are considered as the airway wall and hence receive a low probability.

4. Experimental Results

The proposed system has been evaluated on 10 different CT scans from clinical PE cases. As reference, 58 randomly selected regions of interest of size 50^3 voxels have been semi-automatically segmented using the random walker algorithm [1]. We could show that gradient-based functions behave very unstable because such methods grow very fast along the mostly uniform background once leaked into non-vessel structures because of, e.g., partial volume effects. Functions using opacity-like features result in a more accurate segmentation but could not outperform the intensity-based function. Considering additionally the distance to the airway wall increases the segmentation accuracy in areas close to major airways. The segmentation sensitivity equals 89% at a specificity of 98% when converting the fuzzy into a binary segmentation using a threshold that segments the vessels relevant for PE applications equally well.

5. Innovative Contributions

We have presented a system for automatic lung vessel segmentation in CTA data and have experimentally compared different probability functions that influence the growing behavior of the proposed method. We have focused especially on PE applications, which are probably the most prominent clinical applications for such an objective.

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