Intrapulmonary vessels segmentation from CT based on topographical connectivity and anatomical knowledge

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The developed vessel segmentation approach exploits the grayscale connectivity between the high-intensity structures in the parenchyma but also the anatomical adjacency existing between blood vessels and pulmonary airways. The proposed algorithm is fully automatic and performs on the windowed grayscale data [-1000, 200 HU] $\rightarrow$ [0, 255], according to the following steps:

1. Identification from the DICOM data of the top/bottom lung boundaries and trachea position for airway segmentation, according to the approach presented in the EXACT09 challenge [1] (Fig. 1). In the VESSEL12 challenge, the DICOM data not being provided, the selection of the processed volume (start/end image) was specified by the user without impacting the process automation.
2. The 3D lung mask is computed (with trachea removed) and the pulmonary parenchyma selected (Fig. 2).
3. The local caliber computation of the segmented airways [2] allows building up a level set function for the local estimation of the airway wall thickness. The airway wall intensity is then attenuated for the important bronchi, thus removing the connectivity with the vessels (Fig. 3). For small bronchi, the airway wall is naturally attenuated due to the partial volume effect.
4. The intrapulmonary vessels are obtained by grayscale reconstruction hysteresis thresholding within the lung parenchyma texture, followed by a specific skeleton-based filtering [3]. The low threshold for candidate selection (Fig. 4) is setup according to the CT protocol parameters and varies from 60 (for larger collimation and/or low frequency reconstruction kernels which induce important smoothing and partial volume effect) to 80 (for thin collimation, medium-high frequency reconstruction kernels); its value can be learnt for several manufacturers and protocols (cf. [1]). The high threshold is set to 200. At this stage, intrapulmonary nodules may be connected with the vascular system (Fig. 5).
5. Detection of nodules connected with the vessels using the shape variation (dilatations) detection approach developed for airways [2], Fig.6. Note that, due to the vessels cropping by the lung mask, the start point of some large vessels may be misled for a dilatation.
6. The binary vessel segmentation is transformed into a probability map based on Euclidian distance computation, with adapted attenuation in the regions of detected nodules (Fig.7).

Discussion

The developed approach performs well irrespective to the use of contrast agent for majority of cases. However, the performances degrade when inflammatory/fibrosis (dense) regions are present (e.g. at the lung fissure) in contact with the vessels.

The average computation time for each major step is as follows:

- Airway segmentation and caliber computation: 6 min
- Vessels segmentation: 8 min
- Nodule detection and probability map built-up: 2.5 min

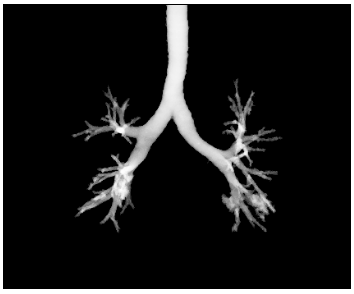

Fig.1: segmented airways

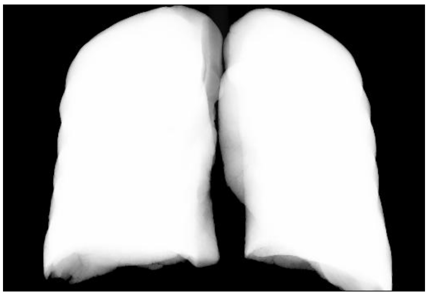

Fig.2: Segmented lung mask

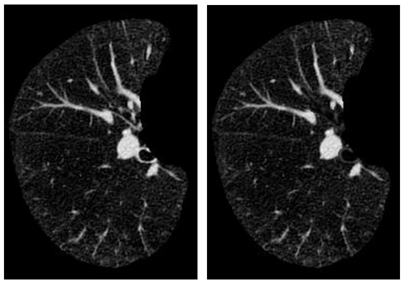

Fig.3: Airway wall attenuation

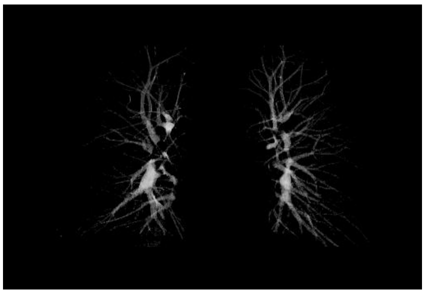

Fig.4: Vessel candidates

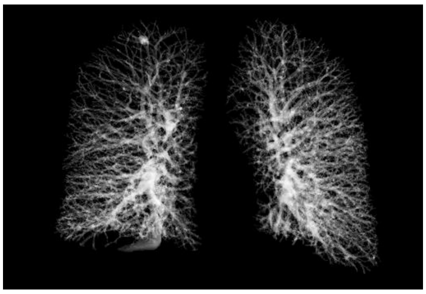

Fig.5: Vessel reconstruction binary)

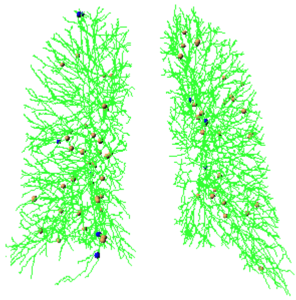

Fig.6: Shape dilation detection (blue spheres)

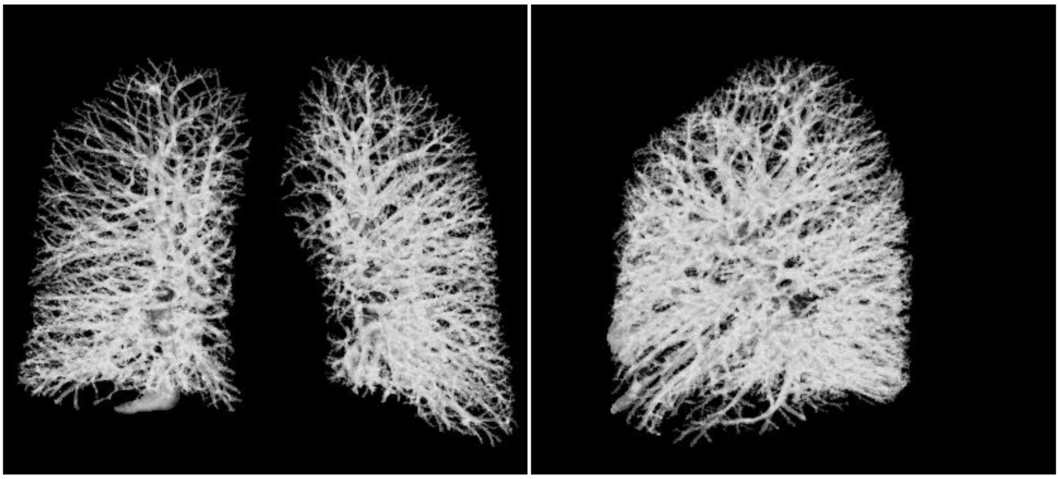

Fig.7: Vessel segmentation – probability map (coronal and sagittal view)

References:

[1] Fetita C., Ortner M., Brillet P.-Y., Prêteux F., Grenier P., "A morphological-aggregative approach for 3D segmentation of pulmonary airways from generic MSCT acquisitions"**, Proc. of Second International Workshop on Pulmonary Image Analysis** - *Second International Workshop on Pulmonary Image Analysis in conjunction with MICCAI'09*, (2009)

[2] Fetita C., Ortner M., Prêteux F., Brillet P.-Y., Ould Hmeidi Y., "Airway shape assessment with visual feed-back in asthma and obstructive diseases"**, Proc. SPIE on Medical Imaging '10** - *Visualization, Image-Guided Procedures, and Modeling*, (2010)

[3] Fetita, C., Brillet, P., Prêteux, F. J., "Morpho-geometrical approach for 3D segmentation of pulmonary vascular tree in multi-slice CT," Proceedings of SPIE Vol. 7259, 72594F (2009).