Pulmonary Artery and Vein Classification using Spatial Arrangement Features from X-ray CT Images

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Abstract *In this paper, we propose a method to classify pulmonary artery and vein in chest X-ray CT images automatically. When a doctor discriminates between benign or malignant of lung tumors, kind of pulmonary blood vessels which are involved in tumors is very important. However there is no difference on CT values. So it is difficult to classify vessels based on CT values. Our method uses anatomical positional relations between bronchus and each vessel, and analyzes tree structure of vessels to generate appropriate vessels groups. We applied this method to three X-ray CT images. The experimental result showed that about 87% of pulmonary artery and vein were classified correctly.*

Keywords: pulmonary artery, pulmonary vein, chest X-ray CT image.

1. Purpose

Recent progress in such CT imaging devices as multidetector-row CT scanners enables us to take more precise slice images of a patient. But this huge number of slice images also increases the burden on doctors to diagnose. The development of a computer-aided diagnosis (CAD) system has reduced such burdens on doctors and the quantification of diagnosing. CAD systems for the lungs must include the following functions: (a) detection of such suspicious regions as tumors, and (b) the discrimination of benignancy or malignancy of those suspicious regions. When discriminating between benign or malignant lung tumors, the kind of pulmonary blood vessels involved in tumors is very important. For adenocarcinoma, since tumors tend to be located around the interlobar and pulmonary veins positioned roughly in the center of tumors, the kind of vessel is useful supplemental information to discriminate lung tumors with computers(Figure 1).

This paper describes a method for the automatic recognition of pulmonary arteries and veins by using anatomical positional relationships between each bronchus and vessel. There are some papers trying to discriminate pulmonary vessels[1,2]. However, they only focused on the relation between bronchus and vessels. The lung region is composed of several segments whose approximated shape is extended in a pyramid from the bronchial bifurcation. The

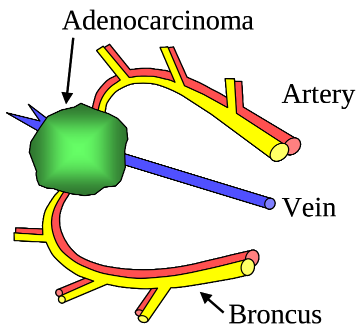

Figure 1. Why should we discriminate vein and artery

pulmonary artery and the bronchi run along the center of the each lung segment. On the other hand, the pulmonary vein runs between bronchi near the

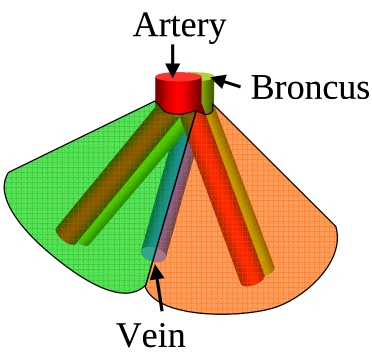

Figure 2. Spatial arrangement of bronchus and pulmonary vessels.

interlobar of each segment(Figure 2). We classify vessels based on the following two anatomical features. First, we measure the distance from the bronchus region to the vessel segment (Db). Second, we calculate the distance between the nearest interlobar to the vessel (Dv). The interlobar is approximately defined by a 3D extended Voronoi diagram [2] for the bronchial branches, because it is impossible to detect directly from CT images. It is expected that the Db for the branch of the pulmonary artery will be smaller than the pulmonary vein because the pulmonary artery runs parallel to the bronchi. And the Dv for the branch of the pulmonary vein becomes relatively small because it runs near to the interlobar of the lung segment.

2. Methods

Input images were three-dimension chest X-ray CT and label images composed of the bronchus and lung regions. We modified the peripheral part of the bronchus regions, which was an insufficiency extracted by Kitasaka's method [4]. After applying a thinning method, we divided the bronchus branch by removing all of the bifurcation points. The interlobar is approximately defined by a 3D extended Voronoi

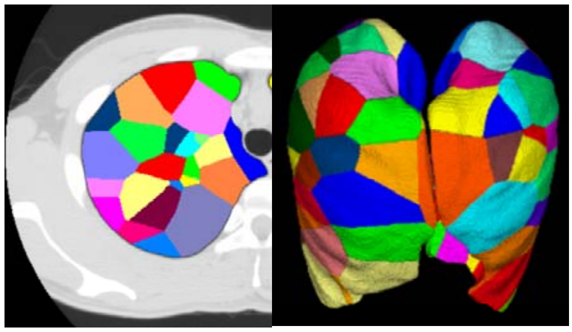

Figure 3. Example of 3D Voronoi diagram. Left: a section of lung, Right: surface of lung

diagram by Hirano et al.'s method [2] for the bronchial branches. Figure 3 shows a 3D extended Voronoi diagram for a CT data. In measuring the distance feature Dv, border of each Voronoi region which is generated between parent bronchus edge and its child edge is removed in order to agree with anatomical knowledge about pulmonary vessels(Figure 4).

We also extracted vessel regions by a region growing method using spherical structured elements. The starting points of the growing were set for all the voxels that simultaneously satisfied the following three conditions: (i) located inside the lung region; (ii) CT value higher than -400H.U.; (iii) minimum distance of 4 mm from the voxel with a CT value lower than -400 H.U. We extracted vessels near the hilum part by a region growing method using spherical structured elements with a radius of 4 mm. Then we removed these from the vessel region to be classified because the anatomical features mentioned above do not apply to the vessels around the hilum. Extracted vessel regions were also thinned and divided in the same manner as the bronchus region.

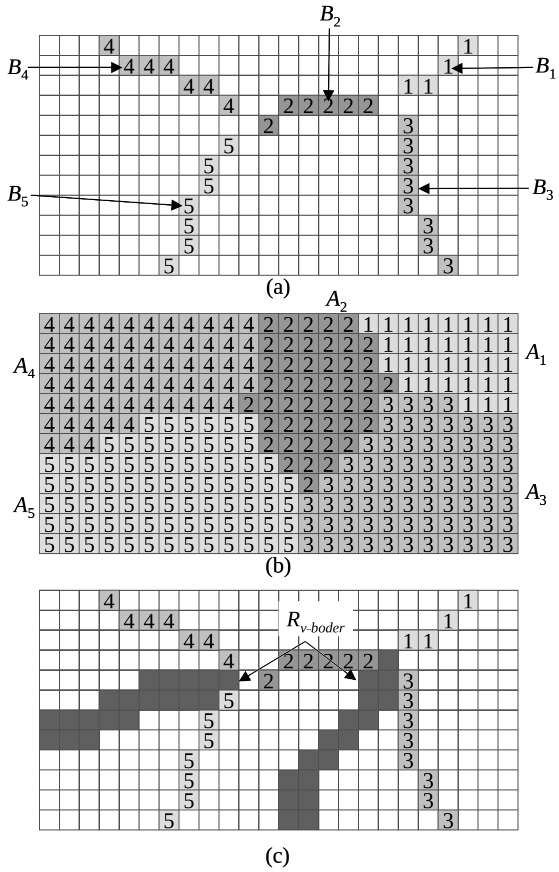

Figure 4. Illustration of Voronoi Tessellation and generation of its border region. (a) Medial axis of each bronchus branch. (b) Result of extended Voronoi tessellation. (c) Voronoi border regions for measurement the distance.

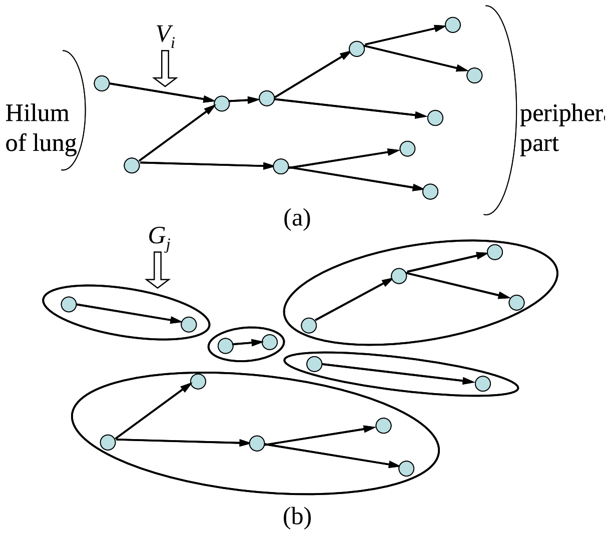

Figure 5. Partitioning of pulmonary vessels edge. (a) Directed graph generated from pulmonary vessels. (b) Partitioning of the graph.

For all vessel branches, we measured distance features Db and Dv. To stabilize these features, the blood vessel branches were merged to groups considering the connection relationship and the existence of the contact part of the pulmonary artery and vein(Figure 5). Each group was classified based on the average of the Db and the Dv in each group(Figure 5).

3. Results and Discussion

We applied the proposed method to 3 cases of chest X-ray CT images that included both sides of the lungs. CT image acquisition parameters were: 512 x 512 pixels per slice, 156~330 slices, pixel sizes of 0.61 x 0.61 or 0.625 x 0.625 mm, 1.0 mm reconstruction, and an X-ray beam width of 1 or 2 mm. The experimental results were precisely confirmed by a lung specialist. Frontal view and side views of automated classification result is shown in figure 7. Table 1 shows the classification results for each image. In the best cases, about 95% of the vessels were classified correctly by the proposed method. Even in the worst cases, more than 80% of the blood vessels were classified correctly. Most errors occurred when the number of blood vessel branches belonging to the group was too small because of the contacting part of both vessels and the spurious branches generated by a thinning method. These errors were located at the contacting part of the arteries and veins or at the hilum of the lung.

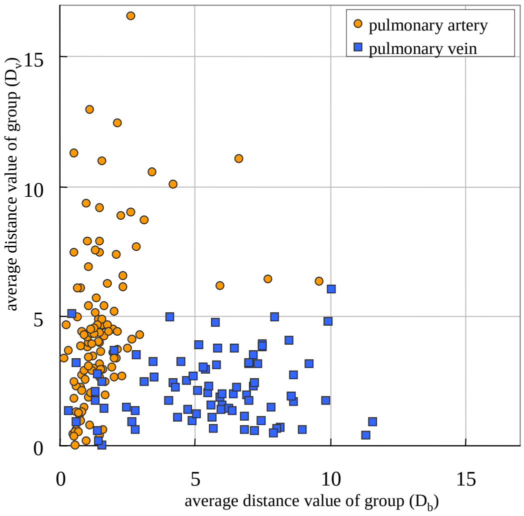

Figure 6. Scatter diagrams of distance features for pulmonary artery and vein.

Table 1. Classification results using two distance features for edge group.

(a) Data1			
Doctor ＼ Computer	artery	vein	rate
artery	293	17	94.5%
vein	22	223	91.0%
(b) Data2			
Doctor ＼ Computer	artery	vein	rate
artery	327	53	86.1%
vein	49	322	87.0%
(c) Data3			
Doctor ＼ Computer	artery	vein	rate
artery	339	78	81.3%
vein	98	412	80.8%

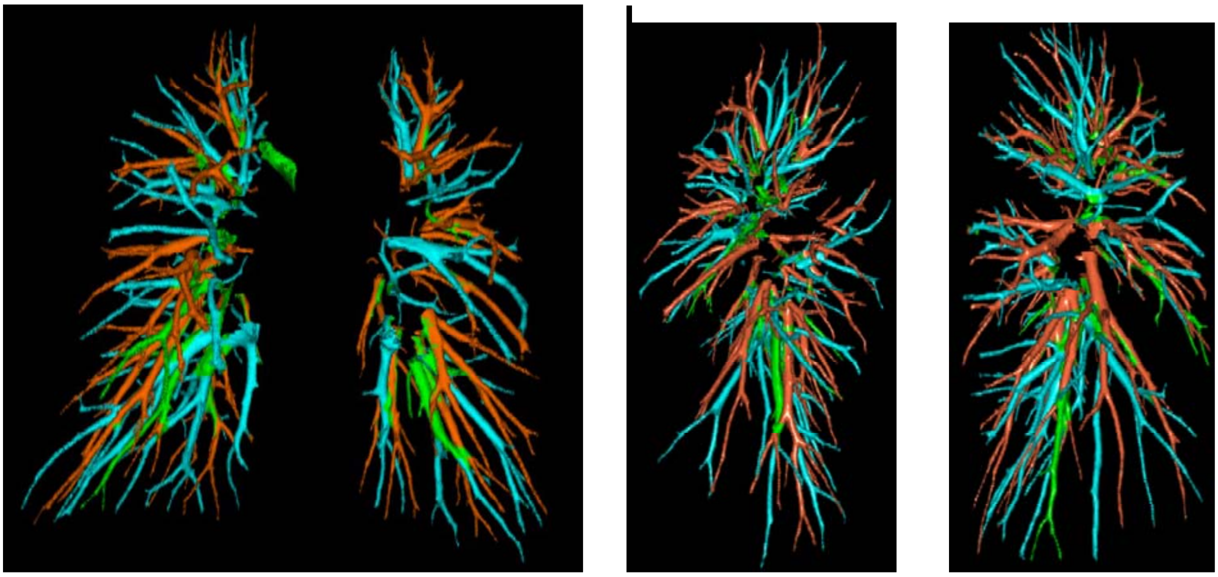

Figure 7 Frontal and side views of automated classification results(red: pulmonary artery, blue: pulmonary vein, green: miss classified regions)

4. Conclusion

This paper proposed a method that automatically recognizes pulmonary arteries and veins from chest X-ray CT images by using an anatomical distribution feature between the bronchus and lung vessels. The results show that the proposed method correctly classified 80~95% of vessel branches. Future work includes: (a) improvement of the usage of features, (b) extraction of accurate vessel regions, and (c) an improvement method for the grouping of vessel branches.

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