Automatic recognition of lung lobes and fissures from multi-slice CT images

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ABSTRACT

Computer-aided diagnosis (CAD) has been expected to help radiologists to improve the accuracy of abnormality detection and reduce the burden during CT image interpretations. In order to realize such functions, automated segmentations of the target organ regions are always required by CAD systems. This paper describes a fully automatic processing procedure, which is designed to identify inter-lobe fissures and divide lung into five lobe regions. The lung fissures are disappeared very fuzzy and indefinite in CT images, so that it is very difficult to extract fissures directly based on its CT values. We propose a method to solve this problem using the anatomy knowledge of human lung. We extract lung region firstly and then recognize the structures of lung vessels and bronchus. Based on anatomy knowledge, we classify the vessels and bronchus on a lobe-by-lobe basis and estimate the boundary of each lobe region as the initial fissure locations. Within those locations, we extract lung fissures precisely based on an edge detection method and divide lung regions into five lung lobes lastly. The performance of the proposed method was evaluated using 9 patient cases of high-resolution multi-slice chest CT images; the improvement has been confirmed with the reliable recognition results.

Keywords: Multi-slice CT images, 3-D image processing, lung lobe, inter-lobe fissure

1. INTRODUCTION

The progress of multi-slice CT technology gave radiologists a possibility to scan a large volume of human body with a higher isotropic spatial resolution in one-time CT photography. The newest CT scanners [1,2] can easily provide a high quality (spatial resolution about 0.63mm) CT image covering the whole human chest within one breath hold time. However, interpretation of such a CT image by viewing a huge number of individual CT images slice by slice in front of a monitor (or a film screen) for each patient case needs much time and energy for radiologists. Therefore, computer-aided diagnosis (CAD) is strongly desired to assist radiologists in CT image interpretations.

A CAD system is always expected to find suspicious regions (SR) and show it to the radiologist for decision. That means the following functions: (1) detecting SR in different organs and giving a discrimination of benign or malignant lesions for each SR, (2) visualizing interesting regions of CT images in 2-D or 3-D should be included in a CAD system. In order to realize such functions, recognizing the different organ and tissue regions and understanding the normal structure of human body from a CT image are necessary. The lung is one of the most important regions for chest CT image interpretations, how to extract lung region and recognize lung structure correctly is an important process that should be resolved firstly by a CAD system. Although, many research works [3-9] have been reported for segmenting an individual region such as lung, airway, vessel and so on, few of them try to focus on recognizing the structure of whole lung regions.

We have been developing a system for extracting and recognizing thoracic organ and tissue regions automatically from 3-D multi-slice CT images [10], and presented a processing procedure used in this system for recognizing 9 kinds of internal organ and tissue regions and showed preliminary experimental results [11,12]. In this paper, we present a recent research work centers on automated recognition of lung lobes and inter-lobe fissures that is the most important parts for lung structure recognition. In section 2, we describe the processing method of lung lobe and fissure extractions

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in details, and then, we apply this method to 9 patient cases of real chest CT images and show recognition results of lung lobes and fissures in section 3. Finally, a brief discussion is given in section 4.

2. METHOD

Lung is the place for gas exchange and filled with air that has a low density (about –1000 HU) in CT images. In normal cases, the border of lung regions can be estimated by the air regions inside chest region. Lung regions are constructed by left and right lung. Left lung is further separated into 2 lung lobes (upper lobe and lower lobe) by oblique fissure. Right lung is also separated into 3 lung lobes (upper lobe, middle lobe and lower lobe) by oblique fissure and horizontal fissure. It can be considered that the first step for lung structure recognition is to extract inter-lobe fissures and use it to divide lung regions into 5 lung lobe regions. However, the inter-lobe fissures are disappeared as a very thin surface pattern with a light density in CT image and difficult to be extracted directly by traditional image processing techniques such as gray-level thresolding, region growing, edge detection and so on. Further more, inter-lobe fissures are incomplete in about 70% patient cases and impossible to be observed completely from original CT images even by a human expert [13,14]. Due to the above reason, we purpose a method to identify inter-lobe fissures and extract lung lobe regions using the anatomy knowledge of lung structure. Our method recognizes the bronchial tree structure firstly and then uses it to classification lung vessels and bronchus into 5 lobar groups. Based on the lobar vessels and bronchus, we divide the lung regions into 5 lobar regions and estimate the approximate locations of inter-lobe fissures. Finally, we use an edge enhance and selection analysis to extract the existed inter-lobe fissures from CT images preciously.

The processing flow includes 6 parts as shown in Fig.1. We describe the details in following section.

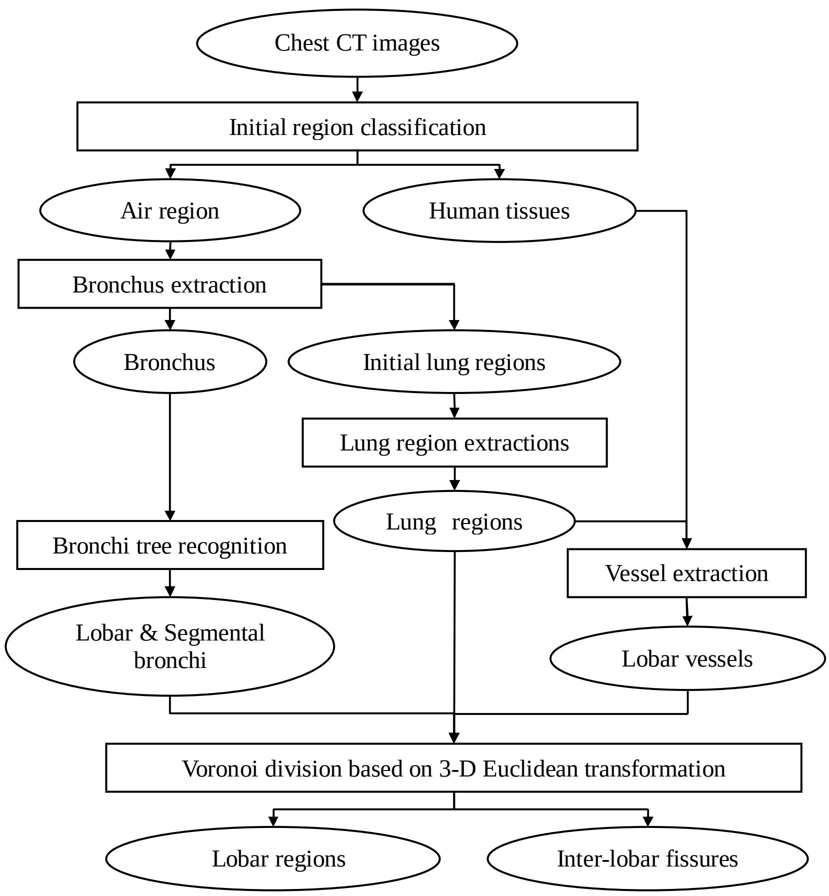

Fig. 1. Processing flow of lung lobe and fissure extractions.

2.1 Initial region classification

The goal of this step is to separate human body region from background and make an initial classification to divide human body region into 3 parts: fat, the other tissues (include bone, organ, vessels and et al.) and air regions. We use a gay-level thresholding method to identify each region based on their density distribution. Instead of using fixed threshold values to segment target regions, our process provides a histogram analysis method that can decide the optimal threshold value just for the current CT image automatically [15].

2.2 Bronchus extraction and bronchial tree recognitions

A 3-D region growing method is used to trace airway of bronchus [5]. We select the air region within human chest in the first slice nearest the human head by a connected component processing and regard it as the seed points of airway of bronchus. Using those seed points, a 3-D region growing method is applied to get the whole airway region from CT images. We separate the airway region into a binary tree structure using branch-by-branch analysis and recognize the sub tree of lobar bronchus by matching the branch points of airway region with the amatory structure of lung bronchial tree.

2.3 Lung region extractions

After deleting the airway region and the air regions with a small volume, we get the rest of air region inside human chest and regard it as initial lung regions. Then, we separate the initial lung region into left and right lungs by a connected component processing and close the lung region in lung hilum by smoothing the initial lung surface using a morphological filter. At last, we fill the hole inside the smoothed initial lung regions and output it as finial lungs.

2.4 Lung vessel extraction and lobar vessel classifications

We regard the other tissue regions except of air within lung regions as initial vessel regions. We use a 3-D region growing method to refine the initial vessel regions firstly, and then, identify the final lung vessels by deleting the bronchial walls from initial vessel regions based on the 3-D distances from the surface of airway that has been extracted in (2.2). The whole lung vessels are further divided into five lobar groups based on the distance to each lobar bronchial tree. In fact, we measure the 3-D distance between vessels and each lobar bronchus and classify the lung vessels into 5 special lobar groups by searching which group is the nearest to it.

2.5 Lung lobe region identifications

We have classified the bronchus and vessels into five lobar groups on above steps. Based on that information, we divide the whole lung into 5 lobar regions using a Voronori division algorithm. For details, we firstly set each lobar vessel and bronchi region as the “skeleton” of corresponding lung lobar region, and then, we measure the 3-D distances from the “skeleton” of the each lobar region to each voxel of lung region using 3-D Euclidean distance transformation method [16]. Finally, we classify each voxel of lung region into a special lung lobe whose “skeleton” is nearest to it.

2.6 Lung fissure extractions

Using the extraction results of five lobar regions, we define the boundary between the different lobar regions as the initial locations of inter-lobe fissures. Due to the accuracy of lung vessel and bronchi extractions, the positions of initial fissures always have a small shift comparing to the real fissures in many cases. Here, we limit the scope around the initial fissures and do a further extraction of fissures by detecting edges based on density distribution in original CT images and selecting the surface pattern around initial fissures as final inter-lobe fissures.

3. EXPERIMENTS AND RESULTS

We applied the proposed methods to 9 patient cases of multi-slice chest CT images. Each image covers the entire human chest region with an isotropic spatial resolution (about 0.63 mm) and 12-bit density resolution. No contrast media had been used during the CT scans. 2 experimental results (1 successful case and 1 failure case) are shown in Fig. 2. Each lung lobe region and fissure were shown in 3-D by different gray levels for distinguish and 2 slices of original CT images (2 sagittal planes of left lung and right lung) that were overlapped by the extracted inter-lobe fissures for evaluation were illustrated in this figure.

4. DISCUSSIONS

Anatomy structure based method has been proved very effectively for lung lobe and fissure extractions from our experimental results. We confirmed that our method could extract the lung lobe and inter-lobe fissures correctly and stably from 7 patient cases in which the lung fissures can be observed clearly from original CT images. Using human sketches of inter-lobe fissures as golden standards, we evaluated the accuracy of fissure extractions by our method for 7 patient cases. We measured the 3-D Euclidean distance from each voxel of extracted fissures to the golden standards and get the minimum distance as the extraction error in this voxel. We found that our method can extract inter-lobe fissures preciously with about 0.5 mm mean error from the manual sketches for 7 patient cases [Fig.2(a)]. For the other 2 cases that the fissure could not be observed completely from CT images, our method only provided extraction results of lung lobes and gave up the extraction of incomplete parts of inter-lobe fissures [Fig.2(b)].

5. CONCLUSIONS

We developed a fully automatic processing procedure to recognize lung lobes and inter-lobe fissures from high-resolution chest CT images. Our method use the information of anatomy structure of bronchial tree to divide lung regions into 5 lung lobes and extract real inter-lobe fissures by edge detection. We applied our method to 9 patient cases of high-resolution CT images and confirmed that our method can provide a stratified extraction results of lung lobes and inter-lobe fissures for 7 patient cases correctly and stably.

Lung lobes | Inter-lobe fissures | 1 slice of left lung | 1 slice of right lung

Fig. 2 Results of lung lobe and fissures extractions [(a): successful case and (b): failure case].

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