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Extraction and recognition of the thoracic organs based on 3D CT images and its application

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Abstract

A method for extracting and recognizing thoracic organ regions from three-dimensional (3D) CT chest images has been proposed in this paper. This method can be simply described as a pixel-labelling process, that is, each pixel in a chest CT image is attached with a predefined label that indicates a special organ or tissue of human body. The density distribution and strength of connectivity of different organ regions have been investigated and used for the recognition process. We developed a system to visualize the 3D CT images based on volume rendering technique and intergraded this method into it. We found that with the recognition results we can view the shape of a special organ without any overlap and can understand the relationship of human organs more clearly and easily.

Keywords: Three-dimensional CT images, image segmentation, thoracic organ recognition.

1. Introduction

With the development of high-speed and high-quality radiological imaging devices such as multi-slice CT scanner, three-dimensional (3D) digital images have been becoming more and more popular in medical diagnosis since they can provide three dimensional information of the human body for physicians as well as patients directly and precisely in few seconds. However, in order to find out the suspicious regions and understand the 3D structure of the human body, medical doctors always have to spend much time and energy to view a lot of individual slices of 3D images on screen. Therefore, computer-aided diagnosis (CAD) and visualization of 3D images are strongly desired to reduce this burden.

The CAD systems are always required to provide an automatic detection of suspicious regions and a 3D view of the interesting regions based on CT images. As the first step of such a process, a reliable extraction of the human organs and recognition of the normal structure of the human body from CT images are necessary. Although a number of techniques have been proposed for extracting a special organ and detecting its abnormality, few of them put emphasis on identifying all the organs and recognizing the normal structure of the human body.

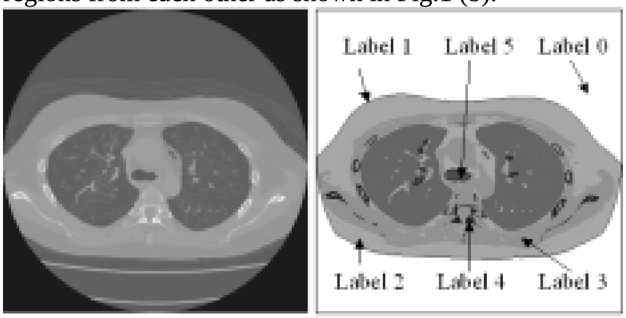
We have developed an image processing system that can recognize the different organs from chest CT images. The identifying process of this system can be simply described as a pixel-labelling process, that is, each pixel of the CT image is attached with a label that represents a special region or organ of the human body. In this paper, a framework of image processing procedures for organ identification used in this system is described firstly, then, this method is applied to identify the thoracic organs from real chest CT images, and the result images are shown finally.

2. Methods

The input of the system is a 3D chest CT image as shown in Fig.1 (a). The output is a labelled image in which each target region has been identified with a predefined label that appears as a density value as shown in Fig.1 (b). A framework of image processing procedures is used to split the whole region of the original CT image into several target regions which are predefined as shown in Fig.1 (c).

2.1 Target organs and tissues

Each target region which should be recognized from an original CT image is defined in Fig.1 (c). Each label has been attached with a special intensity value used to distinguish regions from each other as shown in Fig.1 (b).



Label 0	The region out of the human body
Label 1	Skin
Label 2	Soft tissue
Label 3	Muscle
Label 4	Skeleton
Label 5	Airway of the bronchus
Label 6	Trachea
Label 7	Mediastinum
Label 8	Parenchyma
Label 9	Lung vessel
Label 10	Liver, Spleen

(a) 1 slice of a CT image (b) Recognition result (c) Labels definition

Fig. 1: Target regions which should be recognized from the CT images.

2.2 Extraction and recognition

The flow of the recognition process is shown in Fig.2. The air around the human body has a unique gray-level in CT image, so that the air region is extracted at first using a gray-level thresholding based on a histogram analysis. The extracted air regions are divided into 2 parts by the human body. The air region inside the human body is used to get the initial lung region and extract airway of the bronchus[1]. The air region outside of the human body is used to extract the contour of the body surface. As the next step, a combination of border following and filling process is used to extract the skin and segment the human body form the CT image. Based on the histogram of the region of human body, the soft tissue and initial skeleton regions are separated from the other organs sequentially using a gray-level thresholding process.

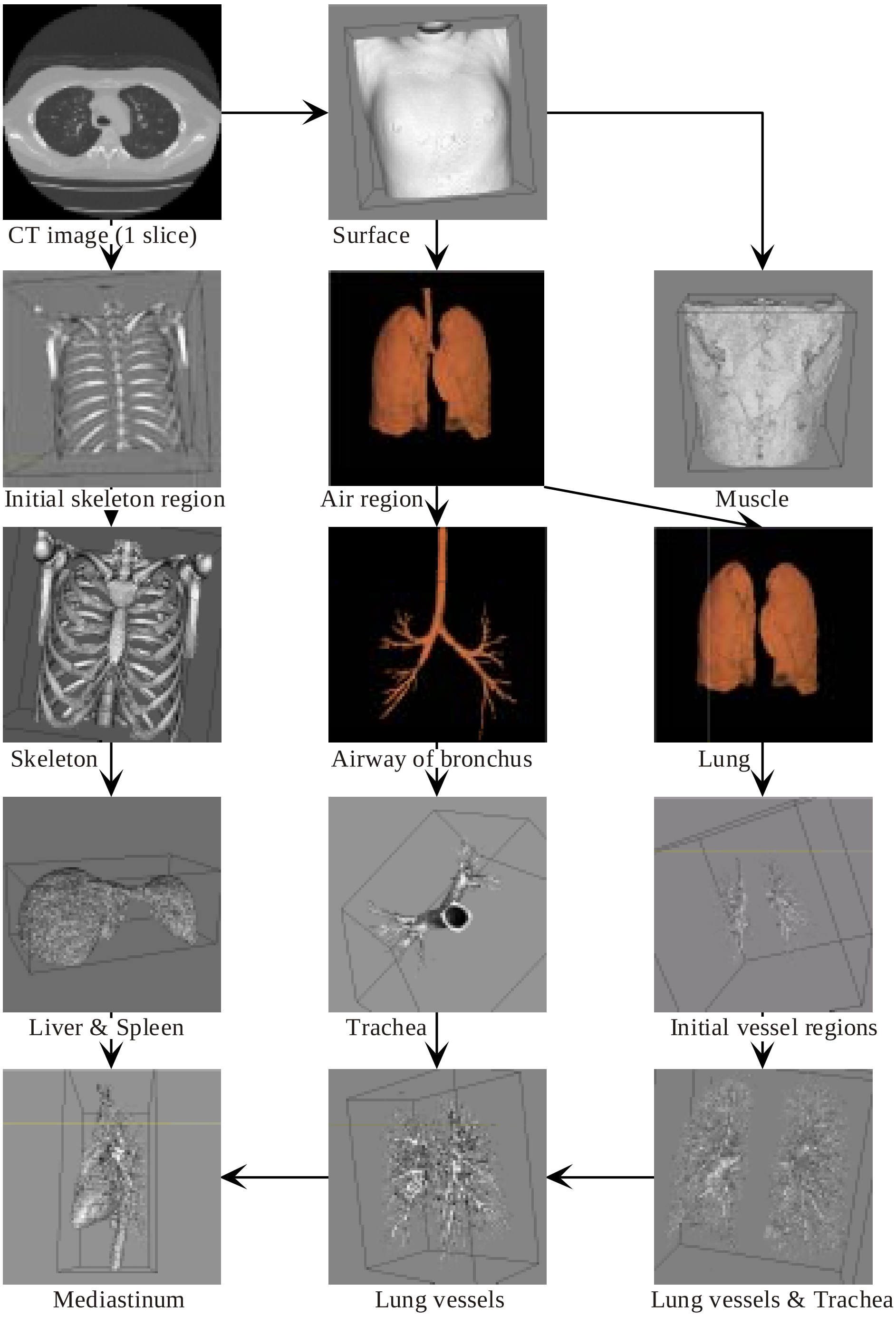


Fig. 2: The flow of the recognition process.

The density distributions of the other organs (such as liver, mediastinum, vessels, etc) are overlapped together, so that we cannot separate those organs by only using gray-level thresholding. We noticed that each organ seemed to be constructed by a set of pixels which have similar density values and hang together closely with each other. Due to this property, strength of connectivity of each pixel has been defined and used to identify skeleton, liver, and mediastinum regions. In fact, a 3D region growing process has been applied to extract bone, liver and mediastinum regions sequentially using the initial skeleton regions as the seed points.
The trachea region is extracted using the information of the density value and Euclidean distance[2] from the surface of the airway of bronchus. In pulmonary hilum region, a 2D snakes method has been used to separate the connection between mediastinum and lung vessels. A combination of gray-level thresholding and 3D region growing process has been applied to separate lung vessels from parenchyma region.
The threshold values and parameters of region growing used above are optimized automatically during the recognition process.

2.3 Visualization of CT images
A friendly user interface has been developed for visualization of 3D CT images (Fig.3). A 3D CT image can be viewed slice-by-slice from 3-directions at the same time under an intensity mode or a maximum-intensity projection (MIP) mode. A 3D view is also provided based on volume rendering and surface rendering techniques. With the recognition results stated above, we can select and view a special organ region or a set of them freely and easily.

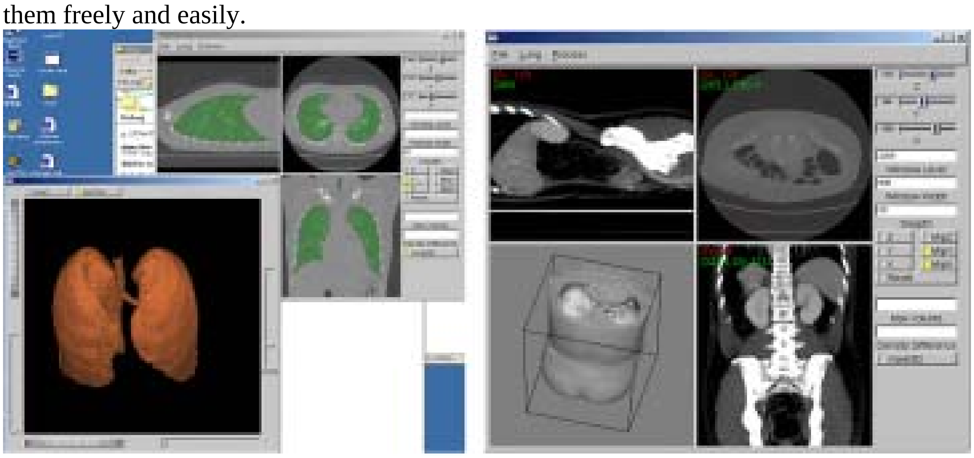


Fig. 3: A user interface for 3D CT image visualization.

3. Experimental results

We applied this framework to identify the thoracic organs from real 3D chest CT images. Two patient cases of multi-slice CT images were used in the experiment and each of them covers the entire human chest region. Every image is 512x512x500-600(pixel) digital image with 12 bits gray-level and high-resolution of 0.625x0.625x0.5(mm^3), and is obtained by a half-second Realtime Helical CT scanner “Aquilion” of Toshiba Medical

Systems Corporation. With the recognition results, shown in Fig.1 (b), a series of 3D views has been obtained, as shown in Fig.4, to present the human body details from the outside to the inside.

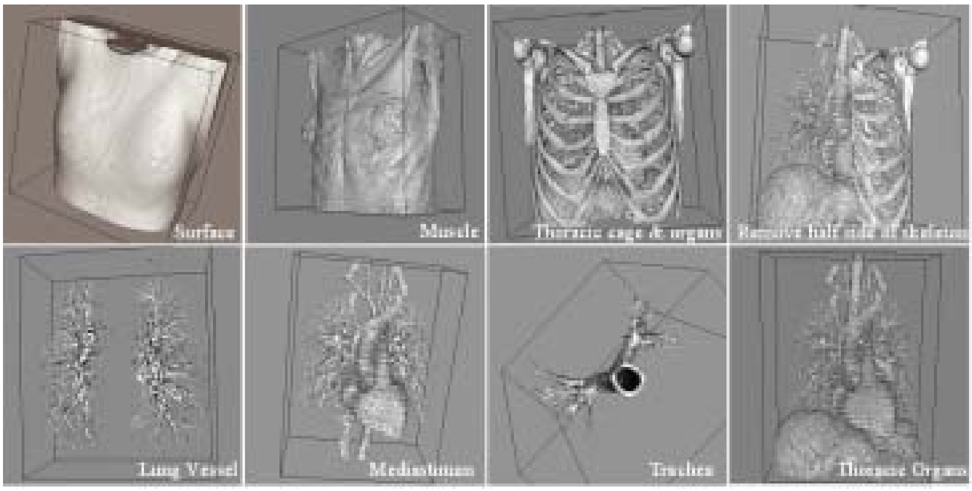


Fig. 4: 3D views of the human body from outside to inside based on recognition results.

Using the recognition results, we integrated CT values of pixels along rays casting through an entire volume to produce a 2D image resembling conventional chest radiography. By adjusting the projection coefficient of each organ before the 2D projection process, we can easily estimate or emphasize the influence of a special organ through reducing the obscurity caused by the overlap of organs and tissues in a volume (shown in Fig.5). It is helpful for trainee doctors to understand the human structure from 2D chest radiography images in image-diagnosis (interpretation) training. As another application, the storage space of CT images can be reduced based on recognition results. A multi-slice CT image covering the entire human chest region will need 200-300MB. In our experiment, we can simply delete the external region of the human body in a CT image and can save about 30% storage space without any information loss.

4. Conclusion

Several conclusions can be summarized as follows from the experimental results.
(a) The framework presented in section 2 can extract the thoracic organ regions successfully from multi-slice chest CT images. From the preliminary results, we confirmed that each target region defined in Fig.1(c) has been recognized and attached with a correct label.
(b) Because the human organs and tissues hang together and construct the human body, the policy of separating the human body into several detailed organ regions sequentially seemed more effective and easier to do than segmenting each special organ individually.
(c) The recognition results would be beneficial to the design of abnormal region detection by CAD system. Based on the recognition results, the detecting algorithm can be designed more specially and accurately. For example, instead of using one image-processing

algorithm to scan the whole lung region and detect the lung cancer regions, using three algorithms for scanning blood vessel, trachea, and parenchyma regions seems to be more effective.

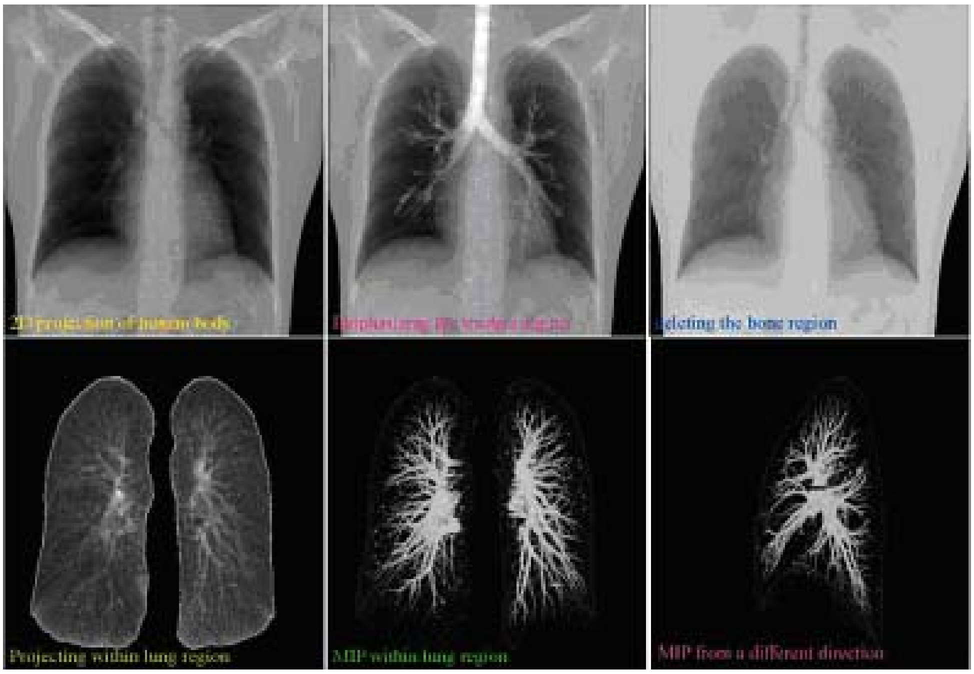


Fig. 5: Projection images based on 3D CT image.

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