A VIRTUAL TRAINING SYSTEM FOR CHEST RADIOGRAM INTERPRETATIONS USING ANATOMICAL HUMAN STRUCTURES IN HIGH-RESOLUTION CT IMAGES

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ABSTRACT

We have developed a virtual system for interpretation training of chest radiograms. Chest radiograms are widely used in clinic medicine, because it can be acquired and then display the internal region of human body quickly, conveniently and inexpensively. However, the overlap of the different human organ regions in chest radiograms prevents doctors (especially for trainee doctor) from understanding 3-D anatomical structures and find out abnormality of human body (patient). A system has been developed to help mainly trainee doctors to understand anatomical structures and view the different organ regions in chest radiograms more easily. The system recognized the different organ and tissue regions from the high-resolution CT images firstly, and then generates resembling conventional chest radiograms by projecting the 3-D CT images into a 2-D plane. By adjusting the projection coefficient of each organ region, we can easily reduce the obscurity problems of human organs in chest radiograms. In conclusion, the sophisticated prototype virtual training system for interpreting chest radiograms may be useful and we are now investigating the effect of actual thoracic abnormalities on the training with this system.

KEY WORDS

CT images, radiogram interpretation, training system

1. Introduction

The 2-D projection chest radiograms are widely used in clinical medicine even now, because it can provide information of human chest easily, inexpensively and quickly. However, in such a projection imaging, the anatomical structure is more complex, as the projection of the 3-D anatomy creates overlaps in the 2-D image plane. Especially, the interpretation of the chest radiograms is known to be a very difficult task because normal anatomical structures such as lung tissue, ribs, bronchi, blood vessels are overlapped together, which is often called a structured noise, so that the signal or pulmonary lesion cannot be seen ("camouflaging" effect) [1]. Kundel and Revesz introduced the concept of *conspicuity* to describe those properties of an abnormality and its surrounding which either contribute to or distract from its visibility [2]. Recent progress of new image acquisition modalities, such as computed tomography (CT) and image-processing techniques that can suppress anatomical textures [3,4] or alert the radiologist to possible locations of lung lesions [5] and thus improve diagnostic performance, is being developed.

How to help the trainee doctor to understand the anatomical structure and recognize the different organ regions from chest radiograms efficiently and quickly is the purpose of our research. On the other hand, CT images can provide the information of human body in 3 dimensions without any overlap problems. Recently, the remarkable progresses of multi-slice (multi-detector raw) CT technology enable radiologists to scan a larger volume of human body in a shorter scan time with a higher isotropic spatial resolution in one-time CT photography. Now, the newest CT scanner can easily provide 500-600 slices of high quality (spatial resolution about 0.63mm) CT image covering the whole human chest within one breath hold time. However, interpretation of 500-600 CT images slice-by-slice is a hard work for a radiologist. Using CT images to generate a series of simulated projection chest images ("simulated radiograms") for interpretation is our idea to solve this problem. This is due to the following 2 reasons: (1) CT images have the 3-D information of human body that can solve the overlap problem in 2-D chest radiograms. (2) Radiologists are familiar with interpretation of the chest radiograms. Although some research works can create traditional chest radiograms by simply projecting 3-D CT images into a 2-D plane [6], few of them can solve the organ region overlap problem that is the fault of the chest radiograms. Here, we develop a system, which uses 3-D information in high-resolution multi-slice CT images to generate a series of resembling conventional chest radiograms [7-9]. In order to solve the overlap problem of human organ

regions in chest radiogram, we develop a system to recognize 9 kinds of human organ and tissue regions and human structures automatically from chest CT images before generating 2-D chest radiogram. Based on the pre-recognition results of human structure from CT images, we generate 2-D simulated chest radiograms by projecting the 3-D CT images into a 2-D plane. By adjusting the density of each organ region, we can easily estimate or emphasize the density of a special organ region in simulated chest radiograms, which was impossible before. In the following sections, we introduce the methods for organ recognitions from CT images firstly, and then, we show the method of generating chest radiograms and experimental results.

2. Automated organ recognitions from CT images

We developed a processing flow (Fig.1) to recognize 9

kinds of human organ regions from CT images [Fig.1(a)] automatically [7,10,11].

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. The thresholding value is decided automatically 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 [Fig.1(b, d, e)]. The air region outside of the human body is used to extract the contour of the body surface [Fig.1(c)]. 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 images. Based on the histogram of the region of human body, soft tissue, muscle [Fig.1(g)] and initial skeleton regions are separated from the other organs sequentially using a gray-level thresholding process.

(a) CT images

(b) Air region

(c) Human body

(d) Airway of bronchus (e) Lung (f) Skeleton (g) Muscle

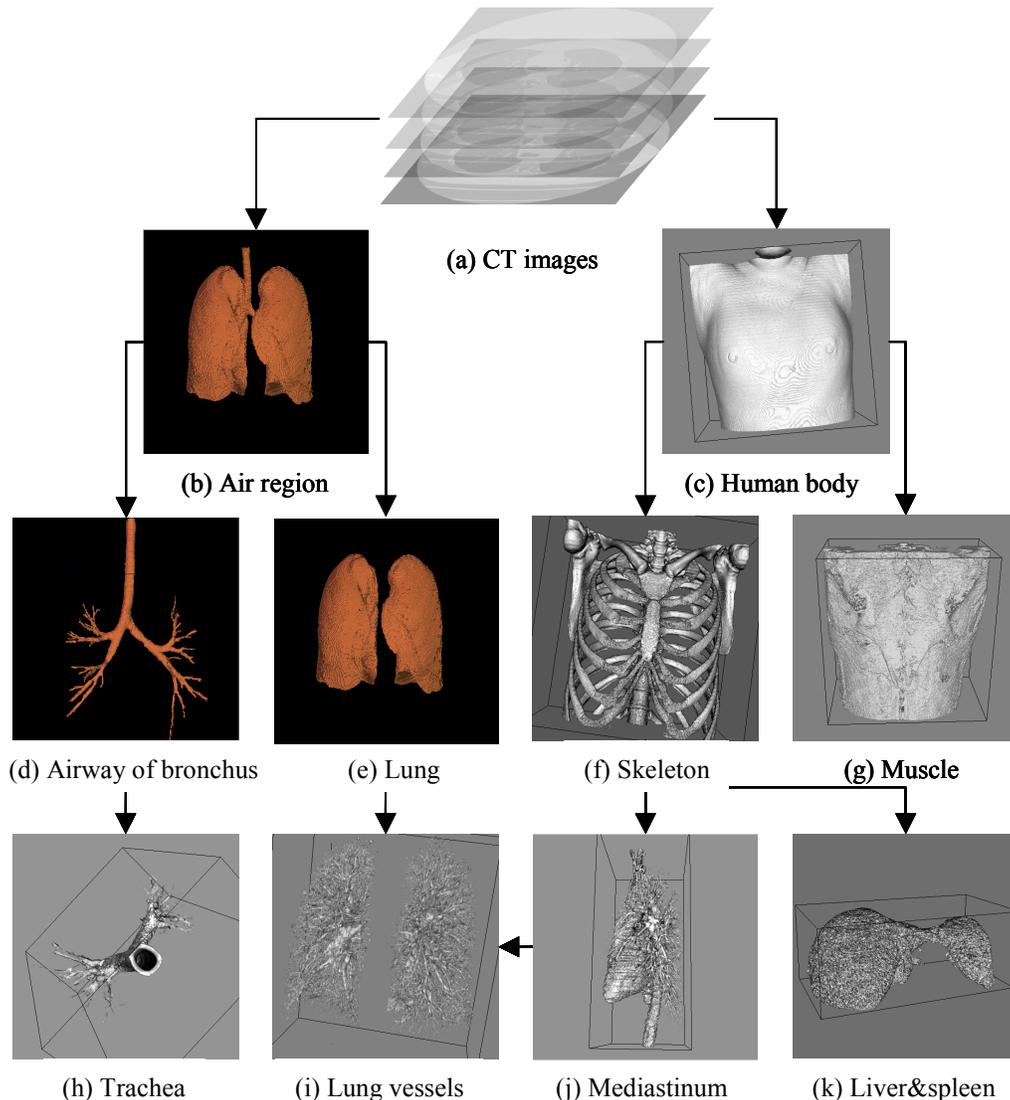(h) Trachea (i) Lung vessels (j) Mediastinum (k) Liver&spleen

Fig. 1: The processing flow for organ region recognitions from CT images.

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 [Fig.1(f, j, k)]. In fact, a 3D region growing process [12] has been applied to extract bone, liver, and mediastinum regions sequentially using the initial skeleton regions as the seed points.

The trachea region [Fig.1 (h)] is extracted using the information of the density value and Euclidean distance [13] 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 [Fig.1 (i)]. 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.

3. Generating 2D simulated chest radiograms from CT images

We integrated CT values of pixels along rays casting through an entire volume to produce a 2D image resembling conventional chest radiograms. By adjusting the projection coefficient of each organ before the 2D projection process, we can easily estimate influence of a special organ such as skeleton or emphasize the influence of a special organ such as bronchus. This function is useful to help doctor to recognize a special organ correctly from traditional chest radiograms. By selecting the projection volume in CT image, we can generate a chest radiogram only for an interesting region such as lung regions. In addition to average projection method used above, maximum projection (MIP) method is also used to generate 2-D chest radiograms. Although the density distributions in such images are quite different from real chest radiograms, the interpretation of the chest radiograms using such simulated images may be more effective because the obscurity caused by the overlap of organs and tissues in a volume can be greatly reduced which is impossible in real chest radiograms.

4. Experimental results

We applied this system to generate 2-D simulated chest radiogram from real 3D chest CT images. six patient cases of multi-slice CT images were used in the experiment and each of them covers the entire human chest region. The property of the images is about 512x512x512 (voxel) digital format with density resolution of 12 bits and spatial resolution of 0.625x0.625x0.5 (mm^3), which were obtained by a Helical CT scanner "LightSpeed Ultra" of GE Medical Systems Corporation. With the recognition results, The human structure can be shown from body surface to the internal organs as illustrated in Fig.2. A series of simulated chest radiograms was generated as shown in
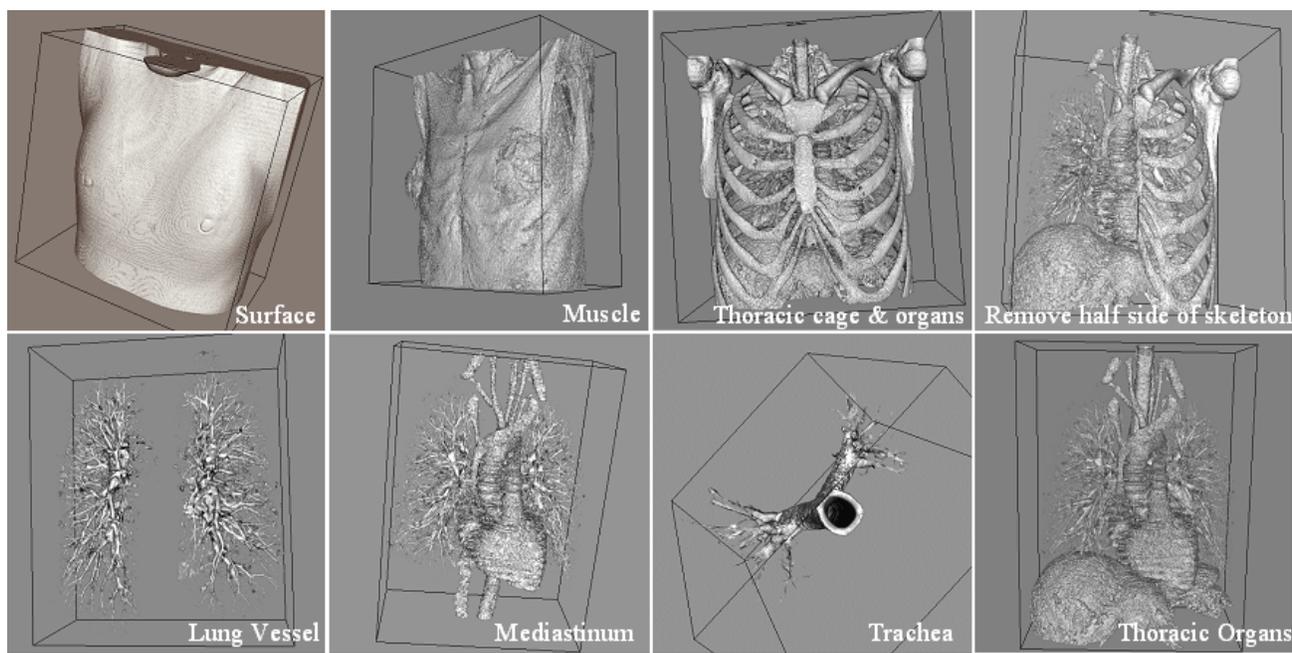

Fig. 2: 3D views of human organ recognition results.

Fig.3. From those images, we can get following results: (1) simulated chest radiogram [Fig.3 (a)] generated by our system is quite close to the real chest radiogram. (2) Using our system, we can easily make a virtual "contrast media" efficacy to enhance an interesting organ region such as trachea [Fig.3 (b)] or lung vessels [Fig.3 (e, f)]. (3) Our system can make virtual "energy subtraction" efficacy in chest radiogram easily [Fig.3 (c)], in which the result image is as well as the real one [3, 4]. (4) By limiting the projection volume [within lung, Fig.3 (d)], the overlapping problems of organ regions can be solved perfectly.

5. Conclusion

We found that our system could extract the thoracic organ regions successfully from multi-slice chest CT images. From the preliminary results, we confirmed that each target organ region has been recognized correctly. We also confirmed that simulated chest radiograms is very close to the real chest radiogram, that means it was possible to generate the chest radiogram using high-resolution CT images. By adjusting the parameters, we can easily estimate or emphasize the influence of a special organ in simulated chest radiograms; it is helpful for trainee doctors to understand the human structure from 2D chest radiography images in image-diagnosis (interpretation) training.

6. Acknowledgements

(a) 2-D projection of human chest   (b) Emphasizing trachea region   (c) Deleting skeleton region

(d) 2D projection of lung region   (e) MIP within lung region   (f) MIP of left lung (heart=>left side)
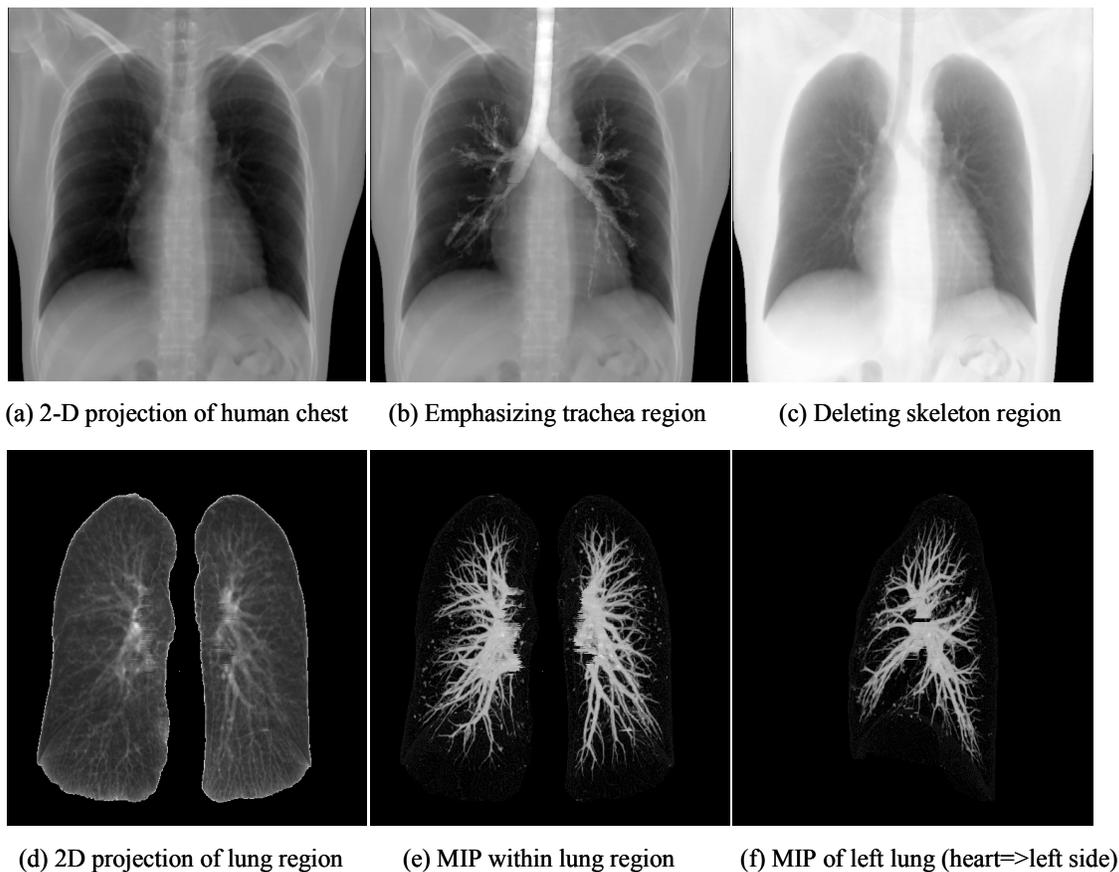
Fig. 3: 2-D simulated chest radiograms generated from CT images.

References:

[1] E. Samei, W. Eyler, and L. Baron: "Chapter 12. Effects of Anatomical Structure on Signal Detection", In Handbook of Medical Imaging: Volume 1. Physics and Psychophysics, eds. by J. Beutel, H.L. Kundel, and R.L. Van Metter, SPIE Press, Bellingham, Washington, pp.655-682, 2000.

[2] H. Kundel and G. Revesz, In Optimization of Chest Radiography, HHS Publication No.80-8124, FDA, Rockville, MD, pp.16-21, 1980.

[3] W. Ito, K. Shimura, N. Nakajima, M. Ishida, and H. Kato: Improvement of Detection in Computed Radiography by new Single-exposure Dual-energy Subtraction, Proc. of SPIE (Medical Imaging VI: Image Processing), Vol. 1652, pp.386-396, 1992.

[4] S. Kido, J. Ikezoe, H. Naito, J. Arisawa, S. Tamura, T. Kozuka, W. Ito, K. Shimura, and H. Kato: "Clinical Evaluation of Pulmonary Nodules with Single-exposure Dual-energy Subtraction Chest Radiography with an Iterative Noise-reduction Algorithm", Radiology, Vol. 194, No. 2, pp.407-412, 1995.

[5] K. Doi, H. MacMahon, S. Katsuragawa, R.M. Nishikawa, and Y. Jiang: "Computer-aided Diagnosis in Radiology: Potential and Pitfalls", European Journal of Radiology, Vol. 31, pp. 97-109, 1999.

[6] http://www.kansai.mss.co.jp/CADProj/

[7] X. Zhou, T. Hara, H. Fujita, Y. Ida, K. Katada, and K. Matsumoto: "Extraction and Recognition of the Thoracic Organs Based on 3D CT Images and Its Application", Proc. of the 16th International Congress and Exhibition of Computer Assisted Radiology and Surgery 2002, Springer, Germany, pp.776-781, 2002.

[8] X. Zhou, T. Hara, H. Fujita, Y. Ida, K. Katada, and K. Matsumoto: "Generating Simulated Two-dimensional Chest Radiograms Based on High-resolution Multi-slice Chest CT Images", Radiology, Vol. 225(P), Proc. of the 88th Scientific Assembly and Annual Meeting of RSNA, pp.757-758, 2002.

[9] H. Fujita, X. Zhou, T. Hara, T. Kiryu, R. Yokoyama, H. Hoshi, "A Virtual Interpretation Training System for Chest Radiograms Using High-resolution Multi-slice CT images", Proc. of the 9th International Conference on Virtual Systems and Multimedia(VSMM), VSMM and 3Dmt Center, pp.622-628, 2003.

[10] X. Zhou, T. Hara, H. Fujita, R. Yokoyama, M. Sato, T. Kiryu, and H. Hoshi: "Preliminary Examinations of Automated Tissues and Organs Recognition from Multi-slice Torso CT Images", Medical Imaging and Information Sciences, Vol.20, No.1, pp.44-47, 2003, in Japanese.

[11] X. Zhou, S. Kobayashi, T. Hayashi, N. Murata, T. Hara, H. Fujita, R. Yokoyama, T. Kiryu, H. Hoshi, and M. Sato: "Lung Structure Recognition: A Further Study of Thoracic Organ Recognitions Based on CT Images", Proc. of the 17th International Congress and Exhibition of Computer Assisted Radiology and Surgery 2003, Elsevier Science B.V., Netherlands, pp.1025-1030, 2003.

[12] K. Mori, J. Hasegawa, J. Toriwaki, H. Anno, and K. Katada, "Automated Extraction of Bronchus Area from Three Dimensional X-ray CT Images", Technical Report of Institute of Electronics, Information and Communication Engineers, PRU93-149, pp.49-55, 1994, in Japanese.

[13] T. Saito and J. Toriwaki, "Euclidean Distance Transformation for Three Dimensional Digital Images", Trans. of Institute of Electronics, Information and Communication Engineers, Vol. J76-D-II, No.3, pp.445-453, 1993, in Japanese.