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Segmentation of differential structures on computed tomography images for diagnosis lung-related diseases

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ABSTRACT

Computer-aided diagnostics (CAD) systems for automatic detection of lung cancer or lung-related diseases have highly depended on the segmentation accuracy of differential structures from computed tomography (CT) scan images. By detection of differential structures such as right/left Lungs, lung nodules, human airways and pulmonary trees, the new segmentation algorithm (PropSeg) is proposed. The PropSeg method is developed based on four major phases such as pre-processing, detection of candidate regions, segmentation, and post-processing. The pre-processing step is performed to enhance by reconstruction of an input image into the 4 frequency subbands through discrete wavelet transform (DWT) and un-sharp energy mask (UEM). The 3 levels of fuzzy c-means (FCM) clustering is used to detect candidate regions by an integration of local energy constraints (LEC) and variational level set (VLS) method is then utilized to segment differential regions. Moreover, the post-processing step is performed by morphological edge detection to enhance the results of segmentation. The system is tested with manually draw radiologist contours on the 220 images by using statistical measures. The performance of PropSeg is also compared with other four state-of-the-art segmentation methods. The achieve results show that the PropSeg system is outperformed compared to other techniques and it is favorable for automatic diagnosis of lung cancer or to detect lung-related diseases.

1. Introduction

Lung cancer is affecting more than 27% and according to the estimation of 2015 [1], 221,200 new cases and 158,040 deaths are reported. Early detection of lung cancer is very important to increase the human survival rate and radiologists are widely using computed tomography (CT) [2] imaging tool. In spite of lung cancer, there are also lung-related diseases such lung cancer, signs of pulmonary hypertension, shortness of breath (dyspnea), Fatigue, and Chest pressure. To improve the diagnostic accuracy of radiologists, the automatic computer-aided detection (CAD) systems [3–7] are developed as the manual interpretation of lung structures is a time-consuming task. Even though the visual inspection of CT scan is perfect but the assessment of the likelihood of malignancy of nodules is difficult and only 50% of nodules resected at surgery are benign. Therefore, the radiologists need to specify additional information to improve the detection and classification accuracy of nodules. The computer-aided detection (CAD) tools are needed to develop for categorizing between normal and abnormal lung tissue that may improve the radiologist's ability. However, the detection of pulmonary small nodules from volumetric CT scans is also difficult task [8], and therefore, lots of CAD tools are developed to compensate this problem.

The comparative study of CAD tools suggests [9] that the accurately segmentation and recognition of lung tissues are still a problematic task. The segmentation of differential structures [10] is the first and important step for CAD system to classify lung cancer. The detection of differential structures such as right/left Lungs, lung nodules, human airway and pulmonary tree are important to find out the lung-related or even lung cancer diseases. Furthermore, the accuracy of automatic CAD tools depends on upon the segmentation of these structures from HRCT scan images. Therefore in this paper, the segmentation of right/left Lungs, lung nodules, human airway and pulmonary tree structures from HRCT scan images are focused on increasing the automatic diagnostic accuracy of CAD system. However, in the past, many researchers have mainly segmented these differential structures in different studies and there is no single study that designs one system for segmentation of all these structures from HRCT scan images. Consequently, the new segmentation algorithm is proposed to delineate these differential

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structures. In Section 2, the related work is reviewed especially for segmentation of lungs and nodules.

2. Literature review

The scientists have mostly used these segmentation techniques such as Fuzzy C-means (FCM) clustering, Morphological Edge-detection, Level sets, watershed and active contours to segment lung nodules or right/left lung from HRCT scan images. However, there is no single study that developed a complete segmentation system to detect all differential structures such as right/left Lungs, lung nodules, human airways and pulmonary trees from HRCT scan images. The description of these state-of-the-art segmentation methods is briefly described in the following paragraphs.

In Ref. [11], active contours (AC), watershed and Markov random field (MRF) methods were combined to segment only lung nodules from computed tomography images. In fact, the authors were manually selected region-of-interest from each HRCT image and then apply these segmentation techniques. They utilized a dataset containing 32 lung lesions with one radiologist's delineated contours and achieved the mean overlap ratios was 69%. In Ref. [12], the authors introduced the nodules shape in a variational framework for segmentation of lung nodules. To determine background and nodule, a nonparametric density approach was also performed. The authors claimed that this approach segmented any size of lung nodule regardless of their locations when tested on 742 nodules. The authors reported that this approach was successful with a rate more than 94%.

Whereas in Ref. [13], the level set (LS) method and morphological edge-detection algorithms were used to segment vessels and lung nodules into three level of intensity. The author developed this technique based on 50 HRCT scans images. By developing a segmentation technique into three levels of the intensity, the authors did not compare his technique and there were no reported results. A different approach was developed in Ref. [14] to isolate the lung nodules with the automatically selection of seed points in region growing algorithm. In fact, this segmentation approach was designed to delineate the focal areas in lung nodules but the authors have not mentioned any statistical results and no comparisons were found.

The local binary pattern (LBP) technique was used in Ref. [15] to segment lung nodules from CT scan images. They tested the system by using two general datasets of CT images and indicated that the segmentation of lung nodules using LBP method was helpful for the finding compared to the watershed method. The authors mentioned the 98% accuracy of segmentation of lung nodules in some HRCT scan images. Similarly in Ref. [16], the lung nodules were segmented based on multi-level thresholding process, morphological edge detection along with the feature extraction methods. The authors tested their segmentation system on 233 HRCT scan images and they got 92.6% segmentation accuracy rate on 403 juxtapleural nodules. Moreover, this segmentation accuracy was compared with manually segmented reference standards done by a radiologist. Especially in Ref. [17], the automatic method was proposed to detect juxtapleural nodules. They used chain coding method with SVM classifier to obtain smooth lung border without over-segmentation and tested on 233 scan image obtained from LIDC public dataset. The lungs are segmented from CT scan images by utilizing of mean shift (MS) [18] clustering algorithm along with the geometric property. They obtained best accuracy and speed compared to the past studies and showed that the automatic delineation of lungs was a difficult task due to the presence of high dense abnormalities. The proposed algorithm has achieved Dice Similarity Coefficient (DSC) of 0.9854 ± 0.0288, the sensitivity of 0.9771 ± 0.0433 and specificity of 0.on 43 subjects.

In Ref. [19], one operator is manually selected seed point and then used an ensemble of segmentation methods to delineate the lung nodules from CT scan images. To evaluate the performance, they used 129 images with the similarity index (SI) measure and compared with the level setting (LS) and graph cut methods. They achieved 93% of SI accuracy for segmentation of nodules. On 229 HRCT scan images, the similarity index(SI) was 78.29% achieved when compared with expert radiologist manual borders and also, the authors compared with two algorithms such as level set and the skeleton graph cut algorithms obtaining an average SI of 63.77% and 63.76%, respectively. The segmentation of all types of nodules on internal and external attachment was proposed in [20] and 891 nodules were used to test this system. The author concluded that this segmentation method is more reliable compared to others to classify for all types of pulmonary nodules based on internal texture.

In Ref. [21], the active contour (AC) approach was also used to segment lung nodules. In the first step, the lung area is delineated by AC approach along with to transfer isolated nodules. Afterward, the support vector machine (SVM) classifier is utilized to detect the lung nodules such as lung wall, parenchyma, bronchioles, and nodules. At the end, the performance of this method was compared with other techniques through detection of lung nodules and achieved an overall detection rate of 89%.

The past works put forwarded that these types of segmentation algorithms are detected lungs or nodules from CT scan images. The authors are also combined segmentation techniques with the mathematical edge-detection, FCM or LS methods to only detect lungs or nodules. Furthermore, these studies did not focus on segmentation of other important structures such as human airways or pulmonary trees from lungs. The detection of all structures is difficult task as shown in Fig. 1. For example in Fig. 1, there is no threshold value that can segment these structures. A novel optimal thresholding algorithm is presented in this paper to segment all differential structures from the HRCT images.

3. System architecture

The system architecture of the proposed segmentation of differential structures from CT scan images is presented in Fig. 2. The information of utilized data set is briefly defined in Section 3.1. Section 3.2 represents the preprocessing method to enhance the contrast of lung CT scan images. The candidate regions of differential structures are represented in Section 3.3. From these candidate regions, the segmentation step is performed, which is clarified in Section 3.4. In Section 3.5, the differential structures are segmented using post-processing. The results and evaluations are performed in Section 4 and at last, this paper accomplishes result mention in Section 5.

3.1. Acquisition of dataset

To test and compare the segmentation algorithms, a dataset of CT scans were acquired from the Lung Imaging Database Consortium (LIDC) and Image Database Resource Initiative (IDRI) [22]. The LIDC/IDRI Database contains 1018 cases in this dataset. The scan cases were captured by different CT scanners. In fact, these scans were captured by Siemens and General Electric CT scanners with x-ray tube current exposure ranging from 75 mA to 344 mA. All the CT scan images are stored in DICOM format with the size of pixels (512×512). The challenges present in the LIDC-IDRI (nodules<; 3 mm and nodules with 3–30 mm diametric size). From all these images, the 220 CT slices are selected for evaluating the segmentation methods. However the manual boundaries of lung nodules from this dataset are utilized to test the performance of segmenta-