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A Survey on Lung Segmentation Methods

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Abstract

Lung diseases are the deadliest disease in the world. The computer aided detection system in lung diseases needed accurate lung segmentation to preplan the pulmonary treatment and surgeries. The researchers undergone the lung segmentation need a deep study and understanding of the traditional and recent papers developed in the lung segmentation field so that they can continue their research journey in an efficient way with successful outcomes. The need of reviewing the research papers is now a most wanted one for researches so this paper makes a survey on recent trends of pulmonary lung segmentation. Seven recent papers are carried out to analyze the performance characterization of themselves. The working methods, purpose for development, name of algorithm and drawbacks of the method are taken into consideration for the survey work. The tables and charts are drawn based on the reviewed papers. The study of lung segmentation research is more helpful to new and fresh researchers who are committed their research in lung segmentation.

Keywords: Computer Aided Detection, pulmonary lung segmentation

INTRODUCTION

Tomographic imaging modalities contribute an important role in diagnosis, treatment, and research of lung cancer. The anatomic structure of human lungs has five separate partitions which are known as lobes. The boundaries of these lobes are called as lobar fissures. Lung cancer is the main cause of cancer death for both men and women [1].

Lung cancer is the advancement of lung tissue and is responsible for 1.2 million deaths annually. The living organism cells are normally divided and grown in a controlled manner. When this control process is lost and the lung tissue starts expanding will results in the lung cancer diseases. It is caused by mainly the cigarette smoking habit among both men and women [2].

Current research influences that the factor with the greatest impact on risk of lung cancer is the exposure to inhaled carcinogens. The main cause of this is due to air pollution tobacco smoke. The removal of diseased lung lobes by the surgery is considered as important for the treatment of lung cancer. In recent clinical arrangements, radiologists read two dimensional computed tomography images of lung cavities for the planning of lung surgery. The early detection of lung cancer is difficult because the symptoms are appearing only at the advanced stages. Several techniques are adapted by physicians to diagnose the lung cancer which includes chest radiograph, sputum cytological examination [3]. Recently, the medical researchers have proven that the sputum cell analysis can assist the fruitful diagnosis of lung cancer. The analysis of sputum images can be used in the process of finding tuberculosis [4]. We use computed aided detection system for automatic detection and diagnosis of pulmonary nodules on CT image [5]. These are different types of future extraction including color or gray level histogram, texture, shape, spatial relationships and semantic features [6]. Abnormal lung tissues are often characterized by specific texture in CT images that help to identify a specific diagnosis [7].

In computer point of view, segmentation is referred as the process of partitioning digital images into multiple sets of pixels. Each of the pixels in a region is similar with respect to the computed property such as color, intensity or texture. Adjacent region are significantly changing based on the same characteristics [8][9][10]. The diseased-lung segmentation and diseased-tissue segmentation are related problems. So the Computer-aided cancer treatment planning such as surgery, Radiation treatment and Quantitative assessment of lung cancer masses requires robust lung segmentation methods [21].

a. Active shape model approach based lung segmentation

Tomographic imaging modalities occupy an important contribution in diagnosis, treatment, and analysis of lung cancer. This paper [19] offers fully automated method lung segmentation for high density pathologies. The robust ASM (Active shape model) is the chief component employed with this paper.

The existing methods with ACM required a manual initialization so that they followed only semi automation. This limitation is solved in this paper using a new rib detection method which is used for initialization. This method is can be adopted for both normal or contrast enhanced CT scans and here the left and right lungs are handled individually. The main concepts employed in this method are given below:

- Lung Model Generation
- Automated Model Initialization
- ASM Matching
- Constrained Optimal Surface Finding

First, the ribs are detected to maintain the place-initialization for ASM [20] in the lung image. Second, a robust ASM (RASM) method is used as matching algorithm to produce the lung segmentation in the case of diseased lungs. Third, the constraint optimal surface finding concept is played to obtain refined lung segmentation.

This paper presents a new way for lung segmentation for computer-aided lung image auto diagnosis. The computation time is well reduced because of large shape models and parallel implementation. This approach can also suitable for other imaging modalities by using the RASM based matching cost function. This RASM based lung segmentation can be generally applicable and fit for large shape models.

b. Iterative threshold and shape based lung segmentation

The paper [17] segments the human lungs based on the fusion of shape information with an advantage of iterative threshold. The shape prior effectively uses the intensity information to get the maximum data utilization. The features such as orientation, major & minor ellipse lengths, Eccentricity and centroid locations for the right and left lung fields are calculated and a statistical model of a lung is constructed using a large database. The proper threshold value is computed by optimization via Iterative process. The Mahalanobis distance [18], method is used to make similarity between the statistical model and the binary image. The post processing step refined the contour of binarization output using the ASM method. The major level implementation of this paper is to maximize information utilization by successfully combining intensity information with shape priors. The major steps of this method as follows:

- Lung field statistical model
- Optimising iterative binarisation
- Postprocessing

This algorithm is cannot separate the lung tissues overlapping with the heart due to the different intensity characteristics.

c. Incremental Constrained Nonnegative Matrix Factorization based lung segmentation

The paper [11] presents a method to segment the human lung which may help to develop fully automated lung lobe segmentation. In this paper a sequence of Computed Tomographic images are used to develop the lung separation process. The Lola lung database is utilized for this research method to get accurate results for human lungs.

The nonnegative matrix factorization technique is adopted in this method to obtain better segmentation. It extracts voxel-wise vectorial features quantifying high-order spatial signal dependencies for image separation [12], [13], [14], [20]. The Nonnegative matrix factorization is a tool for dimensionality reduction in image analysis using three components such as feature extraction, clustering and classification. Its advantage is dealing with piecewise-homogeneous vectorial properties of pixels. It can be used unsupervised learning of basis features with few control parameters. A few characteristic basis features related with each ROI are extracted and then the initial pixel/voxelwise vectors (related with highly relevant features) are projected onto the feature space.

The Incremental constrained NMF (ICNMF) algorithm is used to segment the 3D Lung Segmentation and the first step of it is a preprocessing step which involves the Removal background of an input lung image. The region growing method is used to remove the background. Then r-dimensional voxelwise projection vectors in the matrix H are obtained. The K-means algorithm is implemented to segment the image and the K Value is assigned through the pixel wise descriptors. The difference of Frobenius norms of brightness in lung and chest segments is computed. The final segmentation is obtained by the 3D connected components.

This lung segmentation process combines the INMF and CNMF as ICNMF [11]. The estimation of basis and projection matrices is optimized in a incremental way with the usage of Frobenius norms to reach the smoothness and sparseness. This method can also be used for 2D lung image segmentation and it can be used for both the synthetic and real lung image segmentation. The LOLA11 challenge which is formed by variety of scanners, scanning protocols and restructuring parameters, is faced by this method and it generates better results.

d. Adaptive Appearance-Guided Shape Modeling based lung segmentation

The method presented in [16], handles the lung segmentation process using Adaptive appearance guided shape modeling. This learnable MGRF integrates two visual appearance sub-models with an adaptive lung shape sub-model.

This method can be applicable to both normal and pathological lungs from chest CT images which are acquired by various types of sensors. This framework integrates an adaptive shape prior with easy-to-learn first-order visual appearance models and a 2nd-order 3D MGRF-based model of spatial voxel interactions. This method introduces a probabilistic map accounting for region labels and surrounded pixel intensities. The main steps of this method are follows:

- Adaptive probabilistic shape prior
- Gaussian scale space (GSS) smoothing
- First-order appearance (intensity) modeling
- Modeling pairwise spatial interactions of lung labels
- Joint MGRF model of 3D chest CT images
- Classification using majority voting

The Lola11 competition verifies this method and announced that this method gains 98% accuracy in segmentation of lungs at expert level. Any Cad System can accept this method for early detection of lung nodules provides an accurate identification in the search space.

e. Hierarchical Lung Field Segmentation

The author Yeqin Shao et al. denoted a method for lung field segmentation with better accuracy. This method meets the challenging part of such as shape variation and boundary ambiguity segment a chest radiograph in accurate manner. The proposed method of this paper works based on the technology namely 'joint shape and appearance sparse learning'. The major divisions of this lung segmentation procedure include the following sub modules.

- Initial shape which is close to lung boundary can be generated based on shape initialization
- The high shape variations can be adjusted through local sparse shape composition models.
- The lung boundary ambiguity can be solved by local appearance models using sparse representation at lung boundaries.
- Lung segmentation is obtained with the help of a hierarchical deformable segmentation framework.

The data set used in this method is PA chest radiograph which is a public data set. In the step one process, an initial shape that is coincide with anatomical land mark localization is derived to get a true patient specific shape. In step 2 procedure, the whole lung shape is separated into enough level of segments to sparsely compose by the reference

segments of the referred training samples to add the flexible shape composition. In the step three process, split and cluster the lung boundary into many segments of resembled characteristics t solve the shape deformation. In the fourth step, the hierarchical segmentation criteria are added with the shape and appearance information to offer a powerful segmentation. This paper can be thought as a tool for pulmonary disease diagnosis and hemodialysis treatment. The drawback of this method is that the boundary being nodules affects the lung segmentation.

f. Generic approach based lung segmentation

A pathological lung segmentation process to assist medical diagnosis is captured in the paper [23] via considering the neighbor prior constraints and a pathology recognition system. This algorithm is developed to solve a challenge lies in lung segmentation like failure cases when dense pathologies exists, because lung pathologies hold appearances different from the normal lung tissue. This paper provides a generic solution for lung segmentation issues from CT images. The two stages of this framework first compute the fuzzy connectedness and next make a refinement process. The notification of notable volume difference announces the occurrence of pathology. The pathology indication insists the action of the second stage, in which texture based features are utilized to find abnormal patterns. The output of these two segmentation result is further refined by a neighboring anatomy guided segmentation concepts. This method is widely tested by 400 CT scans with the occurrence of wide level of abnormalities. The drawback of this method is its high complexity.

g. Structured Edge detector based lung segmentation

The author Wei Yang et al. releases a method for lung segmentation in chest radiographs to aid the pathologists. This method is the preprocessing step of an automatic processing chest radiographs. The source technology of this lung segmentation is made of an advanced boundary separator called as structured edge detector (SED). A training process is undergone to make study about lung boundaries, which are already manually outlined. An ultra-metric contour map (UCM) is generated from the masked and marked boundary maps whereas the highest confident contours exist in UCM are considered as lung contours. This method makes a real time segmentation of lung in standard PA, CXRs for practical applications. This work first detects lung boundaries and the outcome is a boundary map oriented segmentation results. The SED is trained upon the manually outlined lung fields which draws lung boundaries efficiently. The ultra-metric contour map is derived with the help of trained SED and marker controlled watershed transform (MWT) [25]. The name of the proposed method is SEDUCM. The drawback of this method is a possibility of false boundary responses from SED. The another drawback is large training samples are required to train up the SED. This method is suitable to simplify analyzing approaches of CXRs.

ANALYSIS AND DISCUSSION

The comparison of lung segmentation techniques and the pre, post processing and the contribution techniques are given in the tables 1 and 2.

Table 1: Brief comparison of lung segmentation technique

Algorithm	Preprocessing availability	Enhancement technique	Post processing availability	Post processing technique	Post processing main contribution
Dawood	No	Not reported	Yes	ASM technique	Iterative binarization
Shanhui	Yes	Lung model generation	Yes	Constrained optimal surface finding	RASM
Yeqin shae	Yes	Robust shape initialization	No	Not reported	Shape and appearance sparse learning
Awais	No	Not reported	Yes	Refinement of lung segmentation	Rib-cage based lung volume estimation
Ehsan	No	Not reported	No	Not reported	ICNMF based visual appearance model
Ahmed	Yes	GSS filteration	No	Not reported	MGRF
Wei yang	Yes	Guided filters	Yes	Highest confidence contour extraction	Structured edge detector

Table 2: Brief comparison of Pre-processing, Post-processing and Main contribution techniques

Algorithm	Year	Reference	Input	Implementation	Database	Segmentation Technique
Dawood	2011	[17]	Chest radiograph	Matlab	JSRT	Fusing shape information in iterative thresholding
Shanhui	2012	[19]	CT	Not reported	Own database	Active shape model approach
Yeqin shae	2014	[22]	Chest radiograph	Matlab	Own database	Hierarchical Technique
Awais	2014	[23]	CT	Not reported	Clinic database	Generic approach
Ehsan	2015	[11]	CT	Not reported	Lola 11	Incremental constrained non negative matrix factorization
Ahmed	2017	[16]	CT	Not reported	VESSEL 12 and Lola 11	Adaptive appearances guided shape modelling
Wei yang	2017	[24]	Chest radiograph	Matlab	JSRT	SED based boundary maps

CONCLUSION

This review paper analyzes both early and recent publications of the lung segmentation category. The techniques described have been much popular among research software and used in medical practice. The objective of this review is to introduce the recent trends in lung segmentation. The review makes that the all proposed methods are having its own level of accuracy. Segmentation accuracy is important factor pathologists and it should led to more precise. The accuracy of the lung segmentation algorithms should be erected to higher value to meet the current diagnosis issues. This review can be thought as a high level knowledge guide for the lung segmentation algorithms. Among the preferred seven methods the structured edge detector based lung segmentation yields high accuracy. Finally, a suggestion is raised out that the search of more effective and accurate CAD for lung cancer detection will remain an active research area. Thus, we expect that our method will be of significant benefit for the quantification of lung diseases.

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