Fissure Enhancement and Segmentation Techniques on Chest CT Slices: A Review

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***Abstract* – Image processing is the branch of computer science which deals with images and their properties. This has a wide application in many fields. In medical field, many imaging modalities exist. Among them, Computer Tomography (CT) is an important imaging modality because the imaging and processing of CT is simple when compared to other imaging techniques. Segmentation in images extracts a particular portion of the image for more exact processing. For imaging lungs in vivo, CT is the most efficient technique. Here in this paper we are presenting a review on different techniques used for segmenting the lobar fissures.**

***Index Terms*–Image Segmentation, Human Lungs, Lobar Fissure, Fissure segmentation,**

I. INTRODUCTION

Medical imaging is the technology that evolved in 19nth century as the use of radiography and grows day by day. Now there are many imaging modalities exist in medical field for determining the possibility of a disease and to diagnose some diseases. Computer Tomography is one of the medical imaging modality which is widely used nowadays. It uses the conventional X-rays for image acquisition. CT takes the cross sectional images of the human body and the image quality of CT slices is more compared to other medical imaging like ultrasound scanning, MRI, etc. and another advantage of CT imaging is that the imaging time is less compared to MRI. For lung disease detection and analysis, CT is the primary imaging option.

In human body, the essential factor for being alive is oxygen. The sufficient amount of oxygen is supplied to our body by a process called breathing and the system which helps this breathing process is called respiratory system. During breathing, the oxygen is taken into the body and the unwanted carbon dioxide is left out of the body. The main part of this respiratory system is the lungs. Lungs are a pair of spongy type organ placed in the thoracic cavity of human body to either side of the heart. The lungs play a major role in all living organisms. In human, there are two lungs and they are primarily divided into five different lobes. The right lung is divided into three lobes and they are right upper lobe, middle lobe and right lower lobe. In left lung there are only two lobes called left upper lobe and left lower lobe. The physical boundaries called fissures and in right lung, the two fissures are oblique fissure and horizontal fissure whereas oblique fissure alone present in left lung. There are three major tubular systems which are supplied to the lungs. First one is responsible for the air transport in and out of the lung and is called bronchi or airway tree. Next is the pulmonary vein which carry purified blood to the body parts from lungs and the last one is the pulmonary artery which brings the deoxygenated blood to the lungs. There are separate tubular systems for each lobe and thus each lobe is working independently. These lobes are further divides into segments and they are divided into sub segment and so on.

As lung plays an important role in human body, any disease affecting lungs is life threatening. There are many diseases which affects the respiratory system and lung. Chronic Obstructive Pulmonary Diseases (COPD) which include chronic bronchitis and emphysema, asthma, lung cancer, lung metastasis, pneumonia, pulmonary embolism are some of the major disease which affects the lung. Any disease to the lung cause problem to the respiratory system. But the disease can be better treated and cured if detected at the early stage. So early detection and diagnosis of lung disease can reduce the fatality of diseases of this kind. For the detection, diagnosis, assessment and treatment planning, we need a radiological imaging and CT is the best choice for lung imaging.

The lung CT image are used for different purposes like the identification some diseases or planning the treatment and follow ups, etc. the main features that can be extracted for analysis are the vessels, fissures, lobes, segments and the sub segments. And the volumetric analysis is another advantage of lung CT imaging. For analyzing the above said features, we first have to extract them and for that we need some segmentation techniques for segmenting these structures. The first step of almost all lung CT analysis is the segmentation of lung field because the lung field includes only half of the portion of the image and segmenting this lung field will reduce the effort of the entire process. So it is called a prerequisite segmentation to other pulmonary segmentation techniques.

In this paper, some of the techniques used for segmenting the pulmonary fissures are discussed and before that some methods for segmenting the lungs from the CT is presented.

II. LUNG SEGMENTATION

The segmentation of lungs from the chest CT is the prerequisite segmentation for almost all other processes. It is like the pre processing step. There exist many techniques for

segmenting the lung field from the lung CT which is an essential prerequisite segmentation for the analysis of lung image. Iterative thresholding is a method for segmenting lungs [1]. Labeling and cropping of image is used along with iterative thresholding. First iterative thresholding is done to find the region of interest. In this process, the threshold is set to anew value in each iteration and this process converges when there is no change in the successive thresholds. After this, labeling is applied for getting the foreground and background and cropping applied for getting the lung field.

A fuzzy based method is described in the work of C.Karthikeyan *et al* [2]. In this paper, they said about the fuzzy c means clustering for segmenting lungs. First the fuzzy c means clustering is applied to the chest CT slices and obtains two clusters. One includes body pixels and other with non body pixels. The cluster with body pixels is taken. Some morphological operations are applied for the removal of background and the resultant image is sliced vertically through centre and the left and right lung are segmented. Finally a morphological operation, opening followed by closing, is applied for smoothing the result.

Shiying Hu *et al* [3] presented a fully automatic method for lung segmentation. It is used for extracting lungs from the 3D lung CT images. In this, there are three steps for the lung segmentation. First step is identifying the lung region by applying gray level thresholding. Thresholding is nothing but selecting a value as threshold and based on that value the image is segmented. Then the left and right lungs are separated. For this a dynamic programming is used by identifying the anterior and posterior junctions. This is the second step and the last step is smoothing the irregular boundaries by applying some morphological operations.

Region growing along with thresholding is used in [4] proposed by Anna Fabijaska. Here the chest CT is binarized using a global threshold and this global threshold is determined by Otsu method. The low intensity regions as lungs, airways, surrounding air are made to 1 and other body pixels are made to 0. Then this image is supplied for the 3D region growing algorithm. It starts with a seed point at the centre of the trachea and uses 4-connected white pixels.

Another three stage segmentation technique is proposed by Asem M. Ali, Ayman S. El-Bazand Aly A. Farag [5]. Here image signal modelling and initial labelling is the first step. In the second stage the spatial interaction between the neighbouring pixels is identified using analytically estimated potentials for Potts model parameter. Final stage is the formulation of the energy functions from the previous stages.

Nihad Mesanovic *et al* [6] presented another technique for lung segmentation using region growing. Here firstly the CT slices are applied with histogram thresholding. Histogram thresholding is one of the simplest segmentation techniques in image processing. In this method, we first plot the histogram of the image and by analysing this histogram we obtain a threshold from this histogram. And based on this threshold the image will be segmented. In this paper also they used the histogram thresholding for getting the binary image. Then using the same threshold, region growing is applied and sobel edge detector is applied for getting the edges. Applying morphological filling in this edge detected image result a binary mask of the lung region. Then multiplying this binary mask with the original lung image will give the lung field.

III. FISSURE SEGMENTATION

As we discussed before, fissures are the physical boundaries of the pulmonary lobes. In lung image analysis, the fissures and their segmentation have a great importance. Since lungs are divided into lobes, we need to know the exact boundaries of these lobes for the correct disease analysis, treatment planning, surgical planning and follow ups. In the case lung cancer, it is first caught on the anterior segment of the right upper lobe and tuberculosis is first affects posterior segment of the upper lobes. So in these cases the exact boundary of the lobes should be known. Since fissures are the boundaries of lobes, fissure identification and segmentation has much significance. But the segmentation of fissures are so challenging because there are many other features like vessels with the same intensity of fissure. So we first have to enhance the fissure by applying some filters. And then only we can segment the fissure correctly. The fissure is segmented using the assumption that there are less vascular structures at the fissure area and there will be different vascular and airway sub tree for each lobe. The Many techniques and methods are exists for this fissure segmentation and fissure enhancement and some of them are discussed here briefly.

A. *Fissure Enhancement Methods*

For enhancing the pulmonary fissures, there exist some methods. They are briefed below.

1. *First Derivative based Fissure Filter:* This method [7] uses the advantage of structure tensor. Structure tensor is made from the image points where we consider the gray value derivative around each point. The fissures are plane like structure and thus for this plane like structures, it is expected a simple neighborhood and this is characterized by one prominent gradient and two vanishing gradient. Using this and the properties of tensor matrix, the fissure pixels are enhanced.
2. *Second Derivative based Fissure Filter:* The fissure smoothing is done here using the property of plane like structures, i.e. there will be one strong curvature perpendicular to the plane and two vanishing curvature parallel to the plane. Here the fissure is a planar structure. Then using the properties of Hessian matrix, the fissure is enhanced [7].
3. *Supervised Enhancement Filter:* As the name indicates, it is a supervised technique. Here training and testing take place. Some voxels from the training images are taken and some features are extracted to train the classifier. Then the testing voxels are tested with the classifiers which decide the voxels should be labeled enhanced or not. The selection of training feature is a challenging task [8].
4. *Unsupervised Enhancement Filter:* This method depends on the first order or second order image information. [8] Uses the second order gradient matrix is used and it is the Hessian matrix. The curvature of the voxels is found using the Eigen value analysis of the Hessian matrix.

5. *Single phase Supervised Filtering:* Here the training set is taken from both positive and negative classes. And then the features for classification will be extracted for these two class voxels. For fissure enhancement, the positive class of voxels is selected by a user in which the voxels are appeared to be belonging to the fissure and the negative class includes randomly selected voxels elsewhere from the image [8].
6. *Multiphase Supervised Filtering:* Multiphase filtering is used for avoiding the false response from the single voxel. In this method, it is started with single phase supervised filtering and then another supervised filter is designed and takes features from both images, i.e. the original one and the previous output. It increases the efficiency of enhancement and also it speeds up the process [8].

B. Fissure Segmentation Methods

We have seen some methods for enhancing the lung fissure. Now let's have a look into the techniques that can be used for segmenting the fissures. Zhang *et al*. [9] presented an atlas based method for fissure segmentation. Here, the atlas of fissure is used for initialising the fissure detection. Then a ridgeness measure is calculated for enhancing the fissure region and then a fuzzy logic system is applied to get the fissure.

Kuhnigk *et al*. [10] presented a system for fissure segmentation using the property that the presence of vascular structures is less at the fissure region. So using this, a distance measure is calculated and the fissure is extracted using this distance measure and original CT value. Then iterative watershed transformation is applied for segmenting the lobes of the lungs.

The concept of ridge map is used by Jingbin Wang *et al* [11] for fissure segmentation. Using this ridge map the fissure structure is enhanced and then a curve growing process is used for segmentation. This curve growing method is modelled by Bayesian network and is uses the features from ridge map and the known property of fissure like the shape of the fissure.

Vikram Appia *et al* [12] developed a method using minimal path approach and it is semi automatic system. In this method, an energy function is derived such a way that the integral over the fissure will be global minimum. This algorithm minimises the energy function based the user defined points. The fissure is the infimum path between the user defined point and the non fissure pixel.

IV. CONCLUSION

The lung imaging has a great significance in medical imaging. We mostly use CT images for lung disease analysis and treatment planning. The analysis of chest CT needs the segmentation of different structures like fissure, airways, bronchi, lobes etc. the segmentation of lungs from the chest CT is as the pre processing for almost all thoracic CT analysis.

Another important feature of lung CT is the lobar fissures. They are the physical boundary of the lobes. So segmentation and enhancement of fissure has a great importance. This paper discussed the methods used for segmenting the lungs form chest CT. The techniques for enhancing and segmenting the lobar fissures are also discussed. All the methods are discussed very briefly.

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