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# 3D DEFORMABLE MODELING OF PLEURAL EFFUSION SEGMENTATION ON CT IMAGES

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## ABSTRACT

Pleural effusion is the excess fluid within the pleural space. Detection of pleural effusion helps in the diagnosis of diseases. We develop a method to segment and measure the volume of pleural effusion using chest CT scan images. The method is based on guided filtering, unaffected and entire lung segmentation, B-Spline curve fitting algorithm and 3D deformable modeling. For the three dimensional view of the pleural effusion, 3D deformable modeling is applied. The method is tested in three different images and it showed better accurate results.

***IndexTerms*—**Guided filtering, B-Spline curve fitting algorithm, 3D deformable modeling

## 1. INTRODUCTION

A pleural effusion is an abnormal amount of fluid within the lung. Pleural effusions can result from many medical conditions such as congestive heart failure, pneumonia, or metastatic cancer. They have also been identified as prognostic indicators, for example, for acute pancreatitis. The pleura is a thin membrane that lines the surface of the lungs and the inside of the chest wall outside the lungs. The visceral pleura cover the lungs and the parietal pleura run along the inside of the chest wall. Pleural effusions are usually categorized as transudates or exudates based on laboratory characteristics of the fluid. Transudate effusions are caused by some combination of increased hydrostatic pressure and decreased plasma oncotic pressure. Exudative effusions are caused by local processes leading to increased capillary permeability resulting in exudation of fluid, cells, protein and other serum constituents. As fluid accumulates in the cavity, it compresses the nearby lung, reducing the lung function.

There are many methods for the detection of pleural effusion, including X-ray film, CT scan, and US. Chest X-ray film: a Plain X-ray film of the chest is one of the first step in identifying a pleural effusion. Pleural effusions appear on chest X-rays as white space at the bottom of the lung. If a pleural effusion is likely, additional X-ray films can be taken while a person lies on her side. In an X-ray film called decubitus, these can show if the fluid flows freely within the chest. Computed tomography (CT scan): A CT scanner takes multiple X-rays, and inside of the chest images are constructed by a computer. Compared to chest X-rays, CT scan is more efficient and it produces more detailed information about pleural effusions and many other lung abnormalities. In most of the cases, the accuracy of CT makes it the better choice. Ultrasound: A probe placed against the skin reflects high-energy sound waves off structures in the chest, creating images on a video screen. Ultrasound can helps to identify whether pleural effusions are free-flowing.

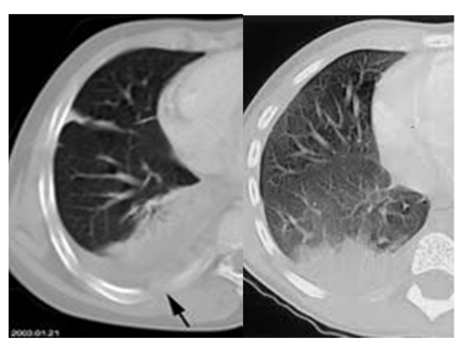


**Figure.1 Examples of CT scan of PE**

This work presents a method to segment and measure the volume of pleural effusion using chest CT scan images. This program is useful for the diagnosis of diseases.

## 2. MATERIALS AND METHODS

***CT Scan Images***

A chest computed tomography (CT) scan, is a painless, non-invasive test. It creates precise pictures of the structures in your chest, such as your lungs. "Non-invasive" means that no surgery is done and no instruments are inserted into your body. The chest CT scanning machine takes many pictures of the lungs and the inside of the chest.

A computer processes these pictures and they can be viewed on a screen or printed on film. The computer can also stack the pictures to create a very detailed, three-dimensional (3D) model of organs. Sometimes, a substance called contrast dye is injected into a vein in your arm for the CT scan. This substance highlights the areas of your chest, which helps in creating a clearer image.

***Method Overview***

Given a CT scan, pre-processing is done at first to reduce and remove noise. Then it identifies the unaffected part of the lung using a 3D region growing method. The entire lung is then segmented using B-Spline curve fitting algorithm. Thus the pleural space is segmented by global matching of the unaffected and the entire lung.

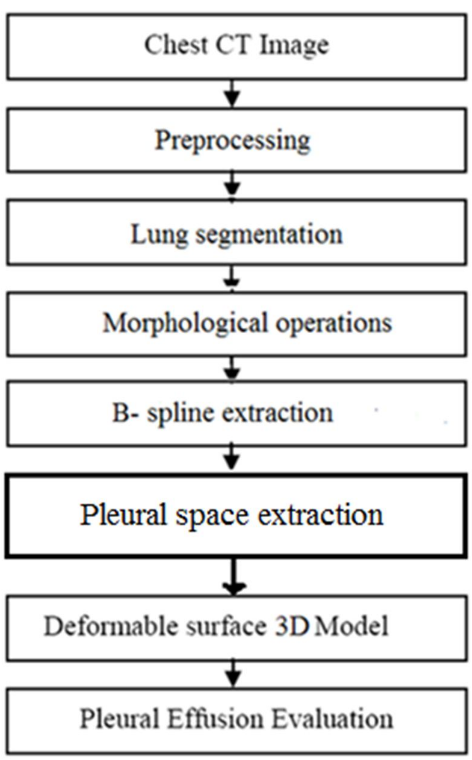



**Figure.2 Schematic of the PE segmentation process**

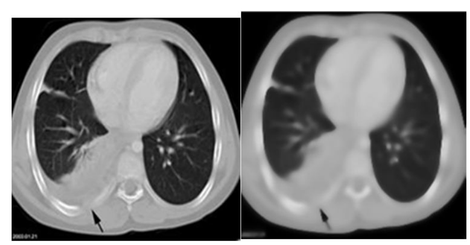
After that a 3D deformable model is applied to refine the boundary of the PE and pleural effusion can be evaluated. The details of the process are described in the following sections.

1) *Preprocessing*:It is done for reducing and removing the noise in the image. Guided filter is used here, it is it is one of the fastest edge preserving filter and has better behaviour near edges. It is a non-iterative filter. Guided filter computes the filtering output by considering the contents of the guidance image. It is like a bilateral filter.

The filtering output at a pixel *i* is given as a weighted average:

$$= \sum \quad ( ) \qquad (1)$$

This involves guidance image I, an input image p, and an output image q. Both *i* and *j* are pixel indexes. It provides many applications like denoising, texture decomposition image, smoothing / sharpening, HDR compression, image obstruction, optical flow estimation, image super resolution, feather smoothing etc. the result of the guided filter is shown in Fig. 2(b)



(a) (b)

**Figure. 3. (a) Input image (b) pre-processing output**

2) *Lung Segmentation*:Otsu's method is used for the determination of lung threshold. It performs clustering based image thresholding. The algorithm assumes the image contains foreground and background classes of pixels. Then calculates the optimum threshold separating two classes so that their combined spread is minimal. For the rough segmentation of lungs 3D region growing method is used. Region growing is useful and simple but sophisticated method for image segmentation. Combining region growing with accurate edge detection improves the image segmentation quality. The output of the lung segmentation is shown in fig. 4(a).

*3) Mathematical morphology:*The two basic morphological operationssuch as dilation and erosion are applied. Dilation allows objects to expand. It fills in small holes and connects disjoint objects. Erosion shrinks objects by etching away their boundaries.

Dilation:

$$[\ (\ )](\ ) = \max_{\in (\ )} (\ +\ ) \qquad (2)$$

Erosion:

$$[\in\ (\ )](\ ) = \min_{\in (\ )} (\ +\ ) \qquad (3)$$

Erosion followed by dilation is also used to eliminate all pixels in the region which are very small to contain the structuring element, called opening.

$$(\ ) = \ (\ (\ )) \qquad (4)$$

Dilation followed by erosion fills in small holes and closing gaps, called closing.

$$(\ ) = \ (\ (\ )) \qquad (5)$$

After the morphological process, the obtained result is shown in fig. 4(b).

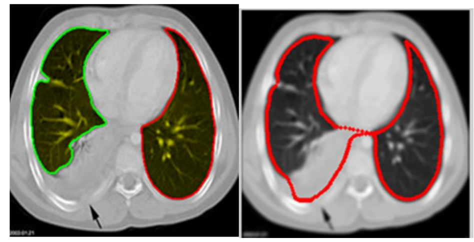
(a) (b)

**Figure.4. (a) Lung Segmentation (b) Mathematical Morphology**

4) *B-Spline extraction:* In this method it has to place uniform control points and then the B-spline is redrawn as the control point's weights are adjusted. As the points are placed in the axes, the b-spline of specified order is drawn progressively. Control points addition can be terminated by pressing enter, esc or right mouse button. The B-spline function is given by:

$$(\ ) = \sum \ (\ ) \qquad (6)$$

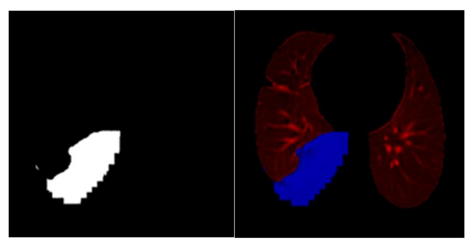
Where Pi is the control points. B-spline has finer shape control. The B-Spline curve requires more information and therefore it provides more flexibility. The position of the control points can be changed without changing the shape of the whole curve.



(a) (b)

**Figure.5. (a) unaffected lung segmentation (b) entirelung segmentation**

5) *Pleural space extraction*:The pleural space extraction is done by global matching of two images of the lung such as unaffected lung and entire lung. By removing the unaffected lung part from the entire lung, the pleural space can be obtained. The unaffected lung segmentation is done by the region growing mechanism. And the entire lung segmentation is done by using the B-Spline curve fitting algorithm. The unaffected lung is shown in the fig. 5(a) and the entire lung is shown in the fig. 5(b). The extracted pleural space is shown in the fig 6(a).



(a) (b)

**Figure.6. (a) Pleural space (b) Entire lung region with pleural space highlighted.**

6) *Deformable surface 3D model:*The deformable surface model is then applied to refine the boundary of the PE. The use of deformable surface model is faster. The 3D surface is defined as a series of 2D planar curves and it ensures smooth and coherent surface between image slices. The isosurface command computes isosurface data from the volume data V at the isosurface value specified in isovalue. That is, the isosurface connects points that have the specified value much the way contour lines connect points of equal elevation. The arrays X, Y, and Z define the coordinates for the volume V. The structure contains the faces and vertices of the isosurface, which can be passed directly to the patch command. The three dimensional representation of pleural space is shown in the fig.7.

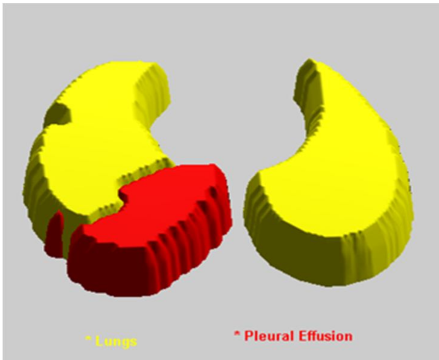
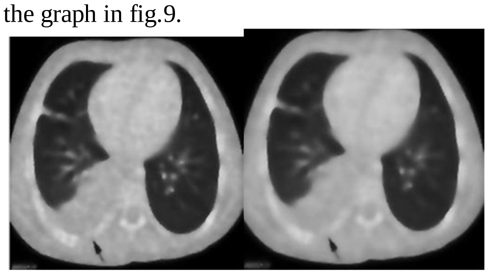



**Figure. 7. 3D deformable model of pleural effusion**

## 3. RESULT AND ANALYSIS

A method to segment and measure the volume of pleural effusion using chest CT image is proposed. In this a guided filter is used in the pre-processing stage. But in the existing stage anisotropic diffusion filter was used for the same. Guided filter is the fastest edge preserving filter and is very accurate. It is very effective and efficient than anisotropic diffusion filter. It shows better behavior near the edges. It is more generic than smoothing and is a non-iterative filter. It computes the filtering output by considering the contents of the guidance image.The fig. 8(a) shows the output of anisotropic diffusion filter and fig.8(b) shows the output of guided filter. Comparison of both the filters is shown in the graph in fig.9.



(a) (b)

**Figure.8 (a) output of anisotropic filter (b) output of guided filter.**

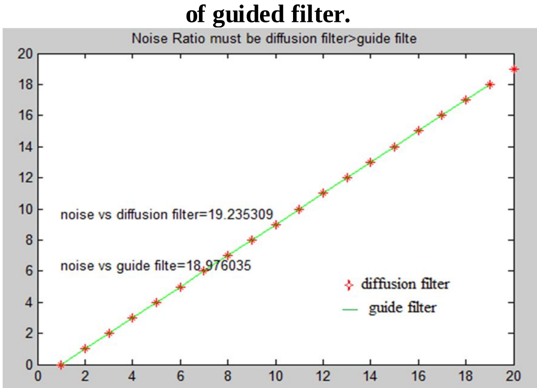



**Figure. 9 Comparison of diffusion filters and guided filter**

The pleural space extraction is done by B-Spline curve fitting algorithm. It mainly performs unaffected lung segmentation and the entire lung segmentation. By comparing both the images, the pleural space can be obtained. But in the existing stage, Bezier surface fitting algorithm was used. It extracts the parietal pleura and visceral pleura for pleural space segmentation. The proposed method is more accurate than the existing scheme, because the B-spline curve provides more flexibility. In B-spline, the position of the control points can be changed without globally changing the shape of the whole curve. It has finer shape control. The curve requires more information and is easier to control.

The 3D deformable model used in this program provides a three dimensional view of the pleural space, which give better representation of the size of the pleural effusion. Instead of representing only in the 2D format, 3D view helps to have more information about the size and shape of the pleural effusion.

The results show that the proposed method to segment and measure the volume of pleural effusion is more effective and efficient than existing method.

## 4. CONCLUSION AND FUTURE WORK

The program works best for the pleural effusion of any shape. The method is quiet simple but it incorporates several advanced image processing techniques. Some specific models were used in this method because of their availability and effectiveness. B-Spline curve fitting algorithm is used for the entire lung segmentation. It provides more flexibility and is very easier to control. The position of the control points can be changed without changing the shape of the whole curve. B-spline curve requires more information therefore it is more efficient and accurate. The obtained pleural space is converted to 3D by using the 3D deformable modeling. This model is faster and is a more robust segmentation technique. To proceed on as the future work, vector field convolution (VFC) can be done.

We have made a program which can be used clinically for the diagnosis of diseases. This program produces the data which shows the pleural effusion size in the lungs. It is very efficient and is convenient to include it in the clinical workflow.

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