

# **Segmentation of Lung Region in Computed Tomography (CT) Images**

by

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15377

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the  
Electrical & Electronics Engineering Programme

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BACHELOR OF ENGINEERING (Hons)

(ELECTRICAL & ELECTRONICS)

Approved by,

---

(DR. NORASHIKIN YAHYA)

Universiti Teknologi PETRONAS

TRONOH, PERAK

September 2015

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original contained herein have not been undertaken or done by unspecified sources or persons.

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HUSNA ADILA BINTI MOHD BOKERI

## **ABSTRACT**

Segmentation of lung region in lung CT scan images is an important pre-processing technique prior automatic detection and classification of emphysema disease. Well segmented lung allows correct selection of region of interest (ROI) and thereby improve the abnormality detection and classification of the lung. In this work, a lung segmentation algorithm for CT images is proposed and evaluated. The proposed method is uses Gaussian smoothing filter followed by thresholding to create binary mask for the lung region. Formally, the binary mask will only select the lung region and zero the all the regions surrounding the lung area. The binary mask can be set to either separate the left and right lung or to show both lungs simultaneously. The algorithm is tested on a database of lung CT scan images of emphysema patients. The database contains top, middle and bottom sections of the lung. Evaluation of the algorithm using 39 middle section lung CT scan images give 15.38% correct segmentation of the left & right lung. With 39 top and 37 bottom section lung images, the algorithm give yy43% and 82.05% correct segmentation of lung. These results show the good potential of the proposed algorithm for segmentation of the lung region in CT images.

## **ACKNOWLEDGEMENT**

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My utmost gratitude goes to my roommate, Nur Ashiqin binti Nor Shaharim for helping me to understand the MATLAB function and language. Not to forget, my parents who are very supportive, family members and friends. Their encouragement and motivation have been one of the key that strengthen me in enduring my final year in Universiti Teknologi PETRONAS (UTP). It is hoped that this project paper would give a better understanding on the image processing techniques.

**HUSNA ADILA BINTI MOHD BOKERI**

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## **ABBREVIATION & NOMENCLATURES**

COPD	: Chronic obstructive pulmonary disease
COLD	: Chronic obstructive lung disease
COAD	: Chronic obstructive airway disease
WHO	: World Health Organisation
PSE	: Paraseptal emphysema
PLE	: Panlobular emphysema
CLE	: Centrilobular emphysema
CAD	: Computer aided diagnosis
CT	: Computed Tomography
NT	: Normal tissue
LBP	: Local Binary Pattern
MRF	: Markov Random Field
ROI	: Region of Interest
UTP	: Universiti Teknologi PETRONAS
GPM	: Graph Positioning Method
ABM	: Adaptive Border Marching
AC	: Adaptive Clustering
MDM	: Mahalanobis Distance Measure
PNN	: Probabilistic Neural Network
LLB	: Lung Lobe Segmentation
SNR	: Signal to Noise Ratio
UTP	: Universiti Teknologi PETRONAS

# CHAPTER 1

## INTRODUCTION

### 1. INTRODUCTION

#### 1.1 Background of Study

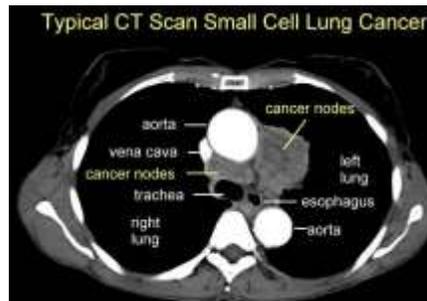


Figure 1: Thoracic CT scan showing the left and right lung and its surrounding region. (Trachea, spine and rib cage) [17]

Emphysema is part of chronic obstructive pulmonary disease (COPD). The other names for this disease are chronic obstructive lung disease (COLD) and chronic obstructive airway disease (COAD) [1]. Emphysema occurs due to confined airways that lead to the collapsed of the lung. Emphysema often occurs among smokers and a study conducted by the World Health Organization (WHO) had estimated nearly 10% of world population life span will be affected because of this disease in 2030.

There are several types of emphysema category which is Paraseptal Emphysema (PSE), Panlobular Emphysema (PLE) and Centrilobular Emphysema (CLE) [1]. Paraseptal Emphysema (PSE) can be determined from the destructions of distal airway

structures, alveolar sacs and alveolar ducts. For Panlobular Emphysema (PLE), the alveoli destroy uniformly and dominate the lower part of the lung. Meanwhile for Centrilobular Emphysema (CLE), it is common among the emphysema patients where most of the damages are occurred at the upper half of the lung.

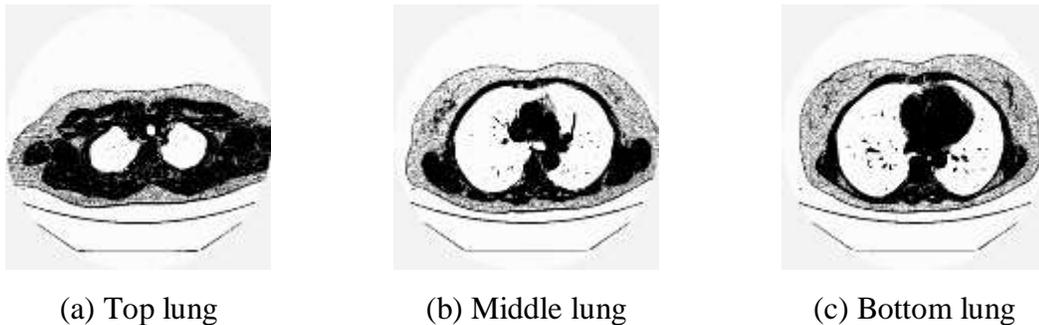


Figure 2: Lung CT scan images, (a) top slices, (b) middle slices and (c) bottom slices.

A typical look of lung CT scan images is shown in Figure 1. In general, the CT image comprises of the left and right lung and it surrounding region, heart, oesophagus, trachea, spine and rib cage. In CAD of emphysema, the focus will be on the lung region which can be categorized into PSE, PLE and CLE. Because only the lung region will be used to train the algorithm, lung segmentation is an important pre-processing stage of a CAD.

With the increment of emphysema patient, an accurate and reliable Computer Aided Diagnosis (CAD) is introduced to ease the physician's burden [9]. X-ray computed tomography (CT) images and mammogram images are one of the available solutions to diagnose this disease. In terms of ability preference, CT images are better compared to mammogram images [3]. From the images collected, textural analysis will be done to determine the severity of emphysema base on the morphological patterns.

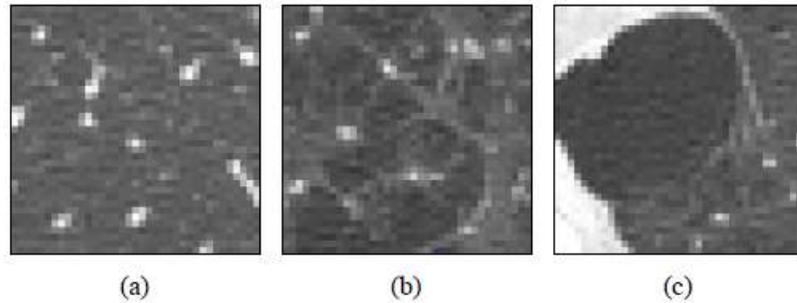


Figure 3: The lung tissue image of (a) NT, (b) CLE and (c) PSE in CT

In identifying the severity of the disease, the physician will classified the lung texture as PLE, PSE, CLE or normal tissue (NT) as shown in Figure 3. Textural analysis is done for emphysema detection. From the patches of lung slices, the lung morphology will be able to be examined. These images are then used for further image enhancement for better accuracy.

Various segmentation methods are used for emphysema detection. Methods like Local Binary Pattern (LBP), global thresholding, Markov Random Field (MRF), region growing etc. For this study, the preliminary of CT images will undergo image enhancement in terms of differentiating between the exterior of the lung and the lung tissue itself. The difference between pixel values in the image allows the system to distinguish between the lung exterior [6].

## 1.2 Problem Statement

Automatic detection and quantification of emphysema is important to medical practitioners in diagnosis of chronic obstructive pulmonary disease (COPD). The performance of computer aided detection (CAD) of COPD is highly dependent on the

accuracy of image segmentation, feature extraction and image classification. To enhance the segmentation image and obtaining the ROI, method like smoothing filter and image thresholding will be used in this work.

### **1.3 Objectives and scope of Study**

This project is relevant as it involves digital image processing technique where the knowledge requires are learned by Electrical & Electronics engineering student in Universiti Teknologi PETRONAS (UTP). As emphysema will affect the population in 20 years, this study will help to contribute in medical field. Feature analysis from the CT images will ease the physician in terms of determining the severity of COPD. Hence for better accuracy of CAD, segmentation technique that yielded high accuracy result is necessary.

This study is achievable in stipulated time because pixel comparison is widely used in image processing study. The algorithm can be work out as the calculation had been derived from the previous research. There are two objectives that need to be achieved after two semesters. The objectives are:

- To develop a lung segmentation algorithm for lung CT scan images based on thresholding method.
- To evaluate the performance of the proposed segmentation method of three sections, top, middle and bottom section of the lung CT images.

Image extraction applied in this research will isolates the lung tissue images with the lung exterior thus enhance the segmentation images. There are several methods used for extracting CT images for the emphysema classification. Those segmentation techniques are further discussed in the literature review.

### **1.3.1 Scope of study**

In this study we are learning about the Computed Tomography (CT) scan images of the lung. The purpose of this study is to conduct segmentation of lung regions for emphysema disease. There are various segmentation method used for segmentation methods. Thresholding method is one of commonly used method for segmentation. Other than this method, there are also methods such as Graph Positioning Method (GPM), Adaptive Border Marching (ABM) and Local Binary Patterns (LBP). In this study, our segmentation will be focusing on smoothing the image using smoothing filter. In this step, Gaussian function and Laplacian function will be applied for the boundary detection of the lung region. From the image obtain by using the smoothing filter, the study is continued by applying threshold method; a step in creating the binary mask. The last step will be segmenting the lung region by using a crop function that will create a cropping tools associated with the binary mask.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 Literature review**

There are several segmentation methods proposed by researchers in obtaining the region of interest (ROI). These techniques help to enhance the classification of emphysema patient's lung CT images. One of the common techniques that are widely used is thresholding method [2][5]. This method is divided into global thresholding and local thresholding. This method works by obtaining and analysing the threshold value of the images [5]. Histogram is build up for the purpose of obtaining comprehensive information regarding the images. For a better result, local thresholding are more preferred as it is more specific in calculating the threshold value by doing it locally [5].

In [4], Choong et. al used graph positioning method (GPM) in their study. The GPM performs by eliminating images with low similarities. By referring to the pixel value, the CT images will be analysed [4]. The segmentation involved three main stages; graph segregation, pixel value analysis and graph positioning. The graph positioning is based on pixel value, and the analysis part involves calculation of dissimilarities value. This process is repeated two times to ensure ROI is achieved [4].

In [5], Li et. al used adaptive clustering (AC) in refining the boundaries of ROI. Also, an edge detection algorithm is part of this technique in order to detect the discontinuity of grey level in the images. Phewit, Roberts, Sobel and Laplacian of Gaussian are example of standard operator used. In another paper, Elizabeth et. al use Mahalanobis distance measure (MDM) and Probabilistic Neural Network (PNN) in obtaining ROI [8]. The method gave accuracies of 96.49% and 98.19% for MDM and PNN, respectively.

In [8], segmentation based on Adaptive Border Marching (ABM) is proposed. It works by soothing the lung exterior using geometric method. Unfortunately, this method does not give accurate result where it slightly captures the lung exterior.

In [6], Ojala et. al. proposed Local Binary Patterns (LBP) for feature analysis. The method combines technique and statistical information in processing the image. In general, LBP uses similar concept to edge detection method [5] whereby both techniques compare the pixel value of the images. In LBP approach, the pixel located at the centre of the image is set as a reference. Then, it will obtain the threshold value of the rest of the image and sample it. The advantage of using this method is it can measure large sample size of image however, the main issue is in differentiating the ROI with the exterior since the lung affected with emphysema consist many dark area [6].

In [8], Kazuaki stated that by applying lung lobe segmentation (LLB) and discriminant analysis based on MDM, false negative rate can be reduced up to 18.7% and positive rate can be increases to 11.2%. This method is executed by using partial maximum intensity projection to prevent overlapping of images [9]. The process continue by using Otsu method, Euclidean distance transform (EDT) and morphological processing. The results are displayed in the form of 3-Dimension image. This method is favourable as it is suitable for patients with incomplete modulation but still it not suitable for patient with collapsed lung [9].

In [15], Chen et. al mention that automatic segmentation can be done by applying Gaussian Blurring technique to the CT images. This technique connects the isolated pixel clusters allowing the left and right lung region to be classified. For the ROI to be classified, this technique will turn the CT images into binary mask [15].

Hadad and Gedraite in [16], mention about the application of Gaussian blurring method. This method is suitable for image with lots of noise due to strong dependency on the variance of the Gaussian function instead of the signal to noise ratio (SNR) variance of the image itself. The flaw in this method is larger variance value will make the Gaussian filter to make the image blurry thus worsen the image [16]. This may lead

to less accuracy in segmenting the required ROI due to mask created based on the blurry image.

Enhancement of segmentation method, a pre-processing technique prior to CAD is necessary for a better life performance. From [2], [3], [4] and [5], threshold value technique is widely used as a preliminary step in enhancing the CT images. However, some changes are required for this study as the aim of this study is to extract the lung feature and classify it into its own category.

# CHAPTER 3

## METHODOLOGY

### 3.0 Methodology

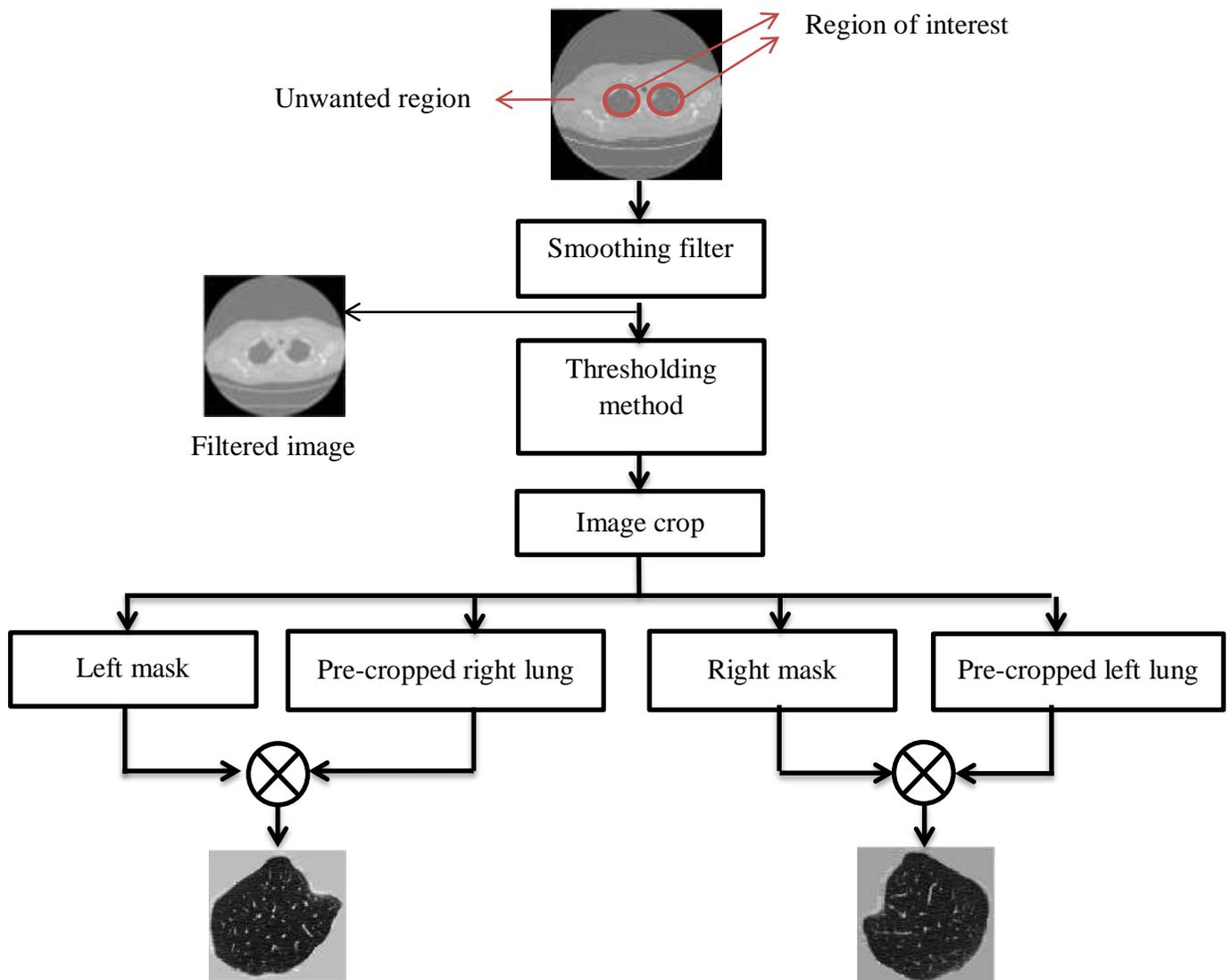


Figure 4: Proposed segmentation method

From Figure 4, slices of CT images from top, middle and bottom segment will be extracted from the lung images. The overall block diagram of the automatic lung segmentation is shown in Table 1. In this study, the process first involved smoothing the image. This is required in order to ease the thresholding method; a step in creating the binary mask. The binary mask obtained will then be superimposed to the original image and the ROI is cropped into left and right region of the lung.

### 3.1 Smoothing filter

For smoothing filter, Gaussian function,  $h(r)$ , that represents a convolution template is used. The formula used is:

$$h(r) = -e^{-\frac{r^2}{2\sigma^2}} \quad [7]$$

Where  $r^2 = y^2 + x^2$

$\sigma^2$  is the standard deviation

$x$  is the  $x$  – coordinates

$y$  is the  $y$  – coordinates

Next, Laplacian function is used to obtain the double-edge image. Below is the Laplacian function:

$$\nabla^2 h(r) = -\left[\frac{r^2 + \sigma^2}{\sigma^4}\right] e^{-\frac{r^2}{2\sigma^2}} \quad [7]$$

Double-edge image is necessary in this study as it helps in giving the edge direction instead of edge detection directly. Laplacian may not give the edge direction directly due to its sensitivity to noise.

A 2D convolution is done between the original image and an array of 10. This 2D convolution returns the central part of the convolution into the same size as the original image. From the filtered image, thresholding method is applied to create the binary mask.

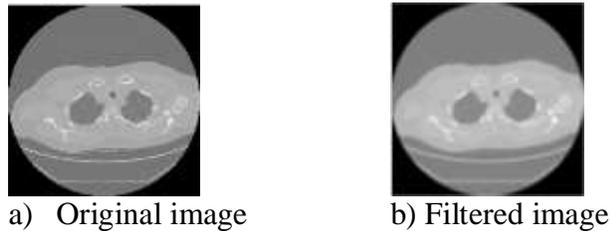


Figure 5: Image result from smoothing filter.

### 3.2 Thresholding method for creating binary mask

Thresholding method is a step in creating a binary mask. Binary mask generated is based on the following formula:

$$I(i, j) = \begin{cases} 0, & I(i, j) \leq \tau \\ 1, & \text{otherwise} \end{cases}$$

Where  $\tau$  is the *thresholding value*

‘bwareopen’ function is then used to removes all connected object in the image that has pixel value less than 100 for a better and cleaned image. For the next process which is cropping the image, the binary mask needs to be inverted by using the formula below:

$$I(i, i) = \begin{cases} 1, & i = 0 \\ 0, & i = 1 \end{cases}$$

This process is necessary for the detection of the ROI.

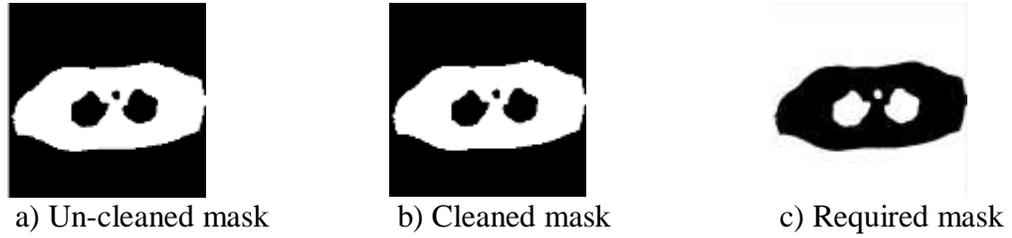


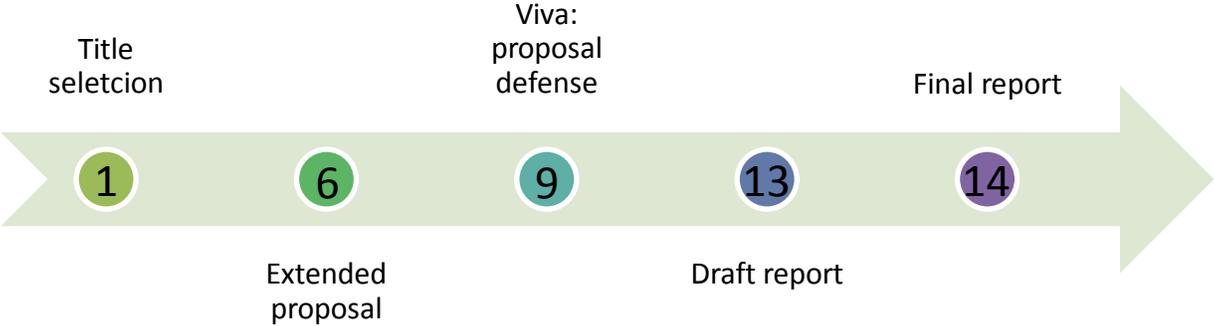
Figure 6: Results of thresholding method

### 3.3 Image crop

Bounding boxes are drawn from the required binary mask for differentiating the left and right region of the lung. The ROI are obtained from the original lung image by using the crop function that will create a cropping tools associated with the binary mask. For a cleaned image, 'bwareopen' function is used to filter pixel value less than 200 from the pre-cropped image.

**3.4 Milestone**

FYP 1:



FYP 2:



### 3.5 Gantt chart

FYP 1:

Activity	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Title selection	■														
Discussion with supervisor	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Research (segmentation method)	■	■	■	■	■	■									
Extended proposal preparation						■									
MATLAB							■	■	■	■	■	■	■	■	■
Proposal defence									■						
Submission of draft report														■	
Submission of interim report															■

FYP 2:

Activity	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Meeting with supervisor		■	■	■	■	■	■	■	■	■	■	■	■		
Application of the proposed method from FYP 1		■													
Filtering the CT scan images using smoothing filter			■												
Modification of the proposed method				■											
Creating binary mask from thresholding method					■										
Crop the lung into left and right region and obtaining the ROI						■									
Submission of progress report							■								
Pre-SEDEX poster presentation											■				
Submission of draft for final report													■		
Submission of technical report and final report														■	
VIVA															■

## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.0 RESULTS AND DISCUSSION

In this experiment we are able to obtain the segmented ROI of the left and right lung. The results obtained are as followed:

#### 4.1 Top images of the lung

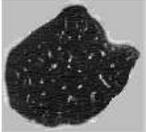
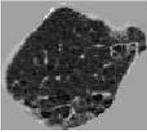
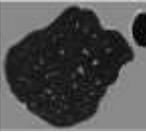
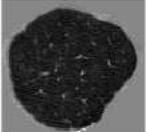
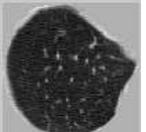
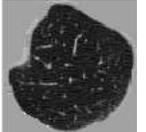
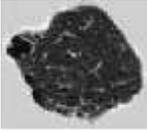
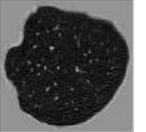
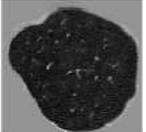
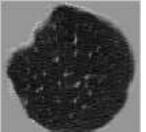
	Image 1	Image 2	Image 3	Image 4	Image 5
Left					
Right					

Table1: The segmented left lung images at the top row and right lung images at the bottom row for top section. From left to right; image 1 until image 5.

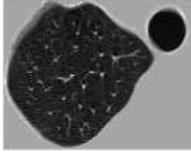
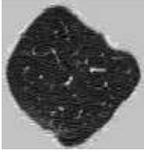
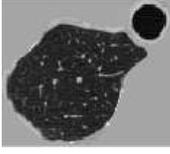
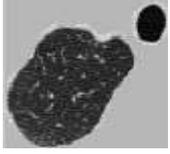
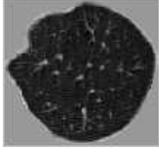
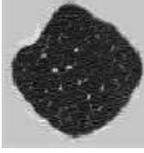
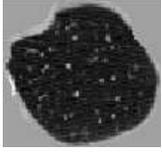
	<b>Image 6</b>	<b>Image 7</b>	<b>Image 8</b>	<b>Image 9</b>	<b>Image 10</b>
<b>Left</b>					
<b>Right</b>					

Table2: The segmented left lung images at the top row and right lung images at the bottom row for top section From left to right; Image 6 until Image 10.

39 top sections of lung CT scan images are tested. The accuracy of obtaining the ROI which is the lung images itself is 43%. Some of the region located at the centre of the lung is included. These things happen because the pixel value of the unwanted region is the same as the ROI; so the clean binary mask created had include the unwanted region as the part of the ROI.

## 4.2 Middle images of the lung

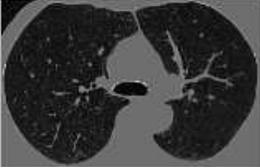
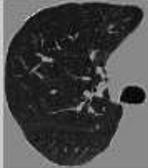
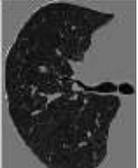
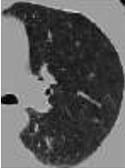
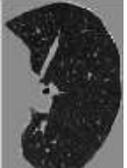
	Image 1	Image 2	Image 3	Image 4	Image 5
Left					
Right					

Table 3: The segmented left lung images at the top row and right lung images at the bottom row for middle section. From left to right; image 1 until image 5.

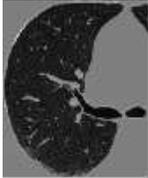
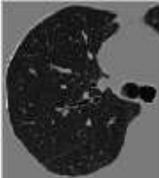
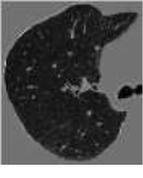
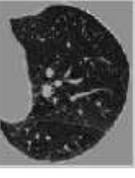
	Image 6	Image 7	Image 8	Image 9	Image 10
Left					
Right					

Table 4: The segmented left lung images at the top row and right lung images at the bottom row for middle section From left to right; Image 6 until Image 10.

For middle section of the lung, 39 images of lung CT scan images are tested. The unwanted region is included in the result due to the same pixel value between the ROI and the unwanted region. The accuracy for middle section is 15.38% because the only the perfect wanted region is count. The rest of the images include the unwanted region and also some part of either left or right lung region. This thing happen because of the bounding box created. Bounding box create a rectangular shape and if the blob detected is slightly slanted, it will create a rectangular blob that will include the other blob. Referring to Figure xx, the left and right lung region is situated closely together, so when the bounding box created, some part of either left or right lung will be included.

**4.3 Bottom images of the lung**

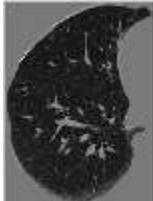
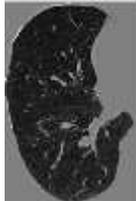
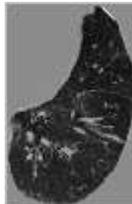
	Image 1	Image 2	Image 3	Image 4	Image 5
<b>Left</b>					
<b>Right</b>					

Table 5: The segmented left lung images at the top row and right lung images at the bottom row for bottom section. From left to right; image 1 until image 5.

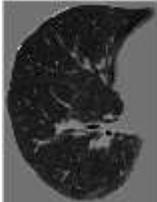
	Image 6	Image 7	Image 8	Image 9	Image 10
Left					
Right					

Table 6: The segmented left lung images at the top row and right lung images at the bottom row for bottom section From left to right; Image 6 until Image 10.

37 CT scan images are tested for bottom section of the lung. 82.05% of accuracy is achieved for this lung section. In the middle and bottom section of the lung result, we may obtain a full image of segmented lung region that include both left and right lung due to the binary mask created from the original image. Figure 7 show the steps of getting the complete lung image. The top end point of left and right lung region are connected together by referring to the binary mask created. In the original image, the pixel value may vary but after image filtering, the pixel intensity is reduced making both side of the lung looks connected. Therefore, during image cropping, the boundary box created detects the whole lung as it refers the location of the ROI based on the cleaned binary mask.

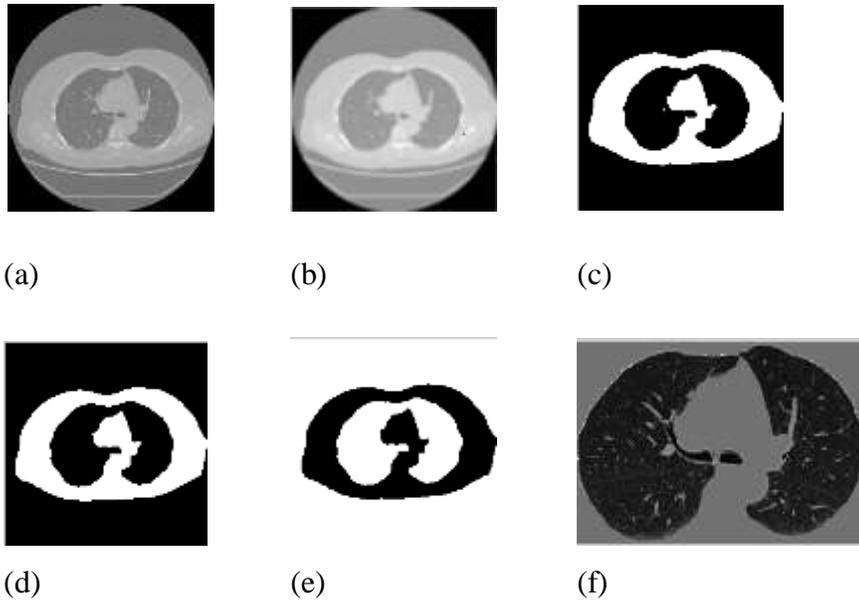


Figure 7: Image obtained in the steps of getting the clean binary mask. (a) original image. (b) filtered image. (c) inverted binary mask. (d) clean inverted binary mask. (e) clean binary mask. (f) Segmented ROI.

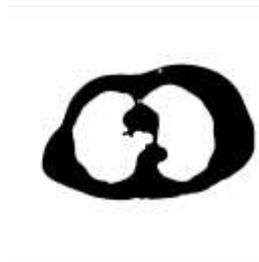


Figure 8: Cleaned binary image of result obtain in Table 4: Image 8

#### **4.4 Error in segmentation**

The presence of the unwanted region in the images can cause error to the segmented region. These error occur due to the same pixel value between the unwanted region and the ROI itself. Image filtering had reduced the intensity of image pixel value, giving an inaccurate edge detection for the ROI. Inaccurate edge detection will create a wrong binary mask where the binary mask is used to detect the location of the ROI.

Besides, when the segmented image may also include some part of either left or right region of the lung. The error occur due to the bounding box created earlier during the process of segmentation. Due to slanted blob detected from the binary mask, the bounding box will include either the left or right region of the lung as explain in 4.3 *Bottom images of the lung*.

## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATION**

A lung CT-scan images typically comprises of lungs as the region of interest as well as the other nearby organs; heart, oesophagus, spine and rib cage surrounding the lungs. In the diagnosis of emphysema, medical expert will focus on the lung pattern in order to classify the image into several stages of emphysema. The use of computer-aided diagnosis (CAD) is becoming more popular in the recent years as it can assist medical expert in diagnostic process, reduce diagnostic errors, and improve quantitative evaluation. One of the pre-processing processes for CAD is segmentation of region of interest (ROI) and in this case, the lung is the ROI before being inputted to CAD system.

In this work, a lung segmentation technique using thresholding method is developed and evaluated. The method combines Gaussian smoothing and thresholding to produce a binary mask that selects lung region and zero the surrounding region. Evaluation of the segmentation method was done on CT images of top, middle and bottom section of lung CT-scan images. Based on the conducted tests, the method gave 43%, 15.38% and 82.05% correct segmentation for top, middle and bottom images, respectively.

This shows a good potential of the proposed method in segmenting the lung region. Unfortunately, further improvement is necessary as some segmented images still include the unwanted regions having the same pixel value as the ROI. In addition to this, we still need to specify the location of the boundary box in order to obtain the correct lung images. Future extension on this work should look at developing automated techniques of selecting the threshold and the boundary box.

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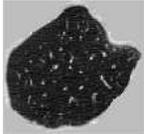
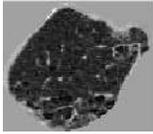
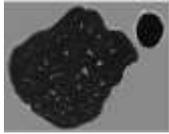
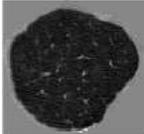
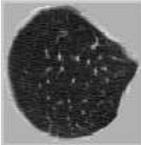
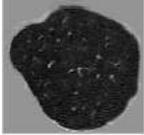
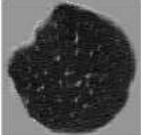
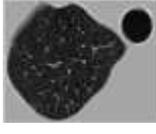
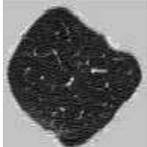
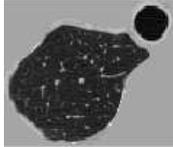
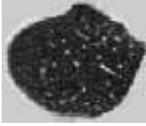
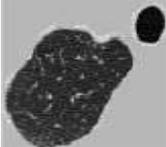
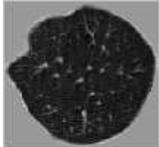
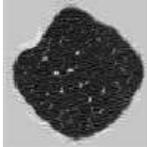
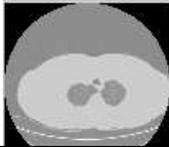
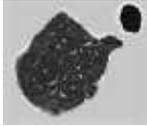
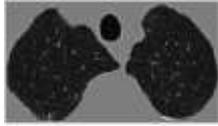
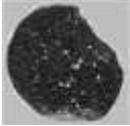
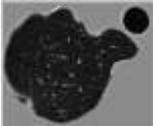
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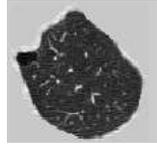
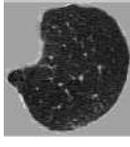
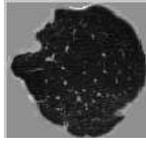
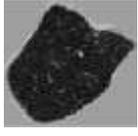
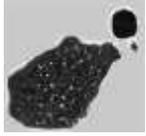
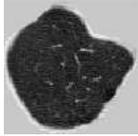
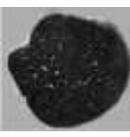
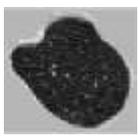
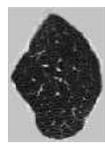
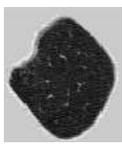
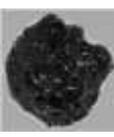
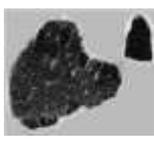
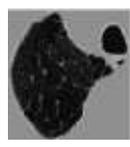
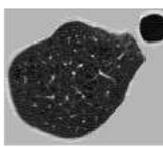
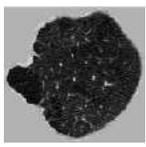
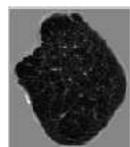
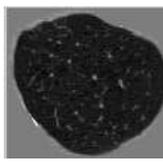
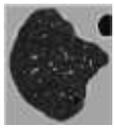
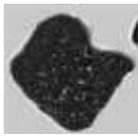
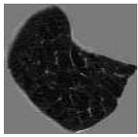
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**APPENDICES**

Result of lung segmentation for top, middle and bottom slices of the lungs:

**TOP SLICES:**

	Image 1	Image 2	Image 3	Image 4	Image 5
<b>Left</b>					
<b>Right</b>					
	Image 6	Image 7	Image 8	Image 9	Image 10
<b>Left</b>					
<b>Right</b>					
	Image 11	Image 12	Image 13	Image 14	Image 15
<b>Left</b>					

<b>Right</b>					
	<b>Image 16</b>	<b>Image 17</b>	<b>Image 18</b>	<b>Image 19</b>	<b>Image 20</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 21</b>	<b>Image 22</b>	<b>Image 23</b>	<b>Image 24</b>	<b>Image 25</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 26</b>	<b>Image 27</b>	<b>Image 28</b>	<b>Image 29</b>	<b>Image 30</b>
<b>Left</b>					

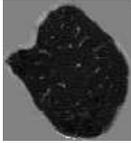
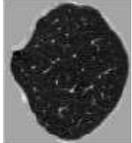
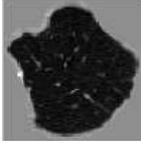
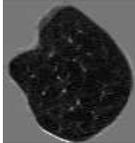
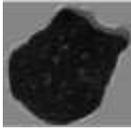
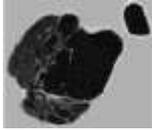
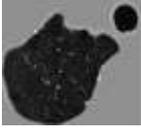
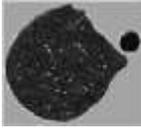
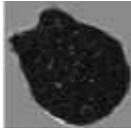
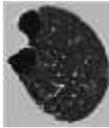
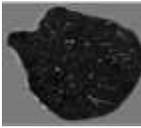
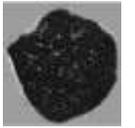
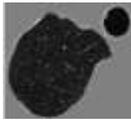
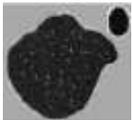
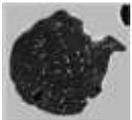
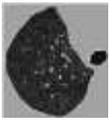
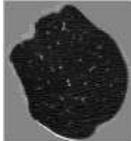
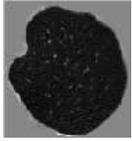
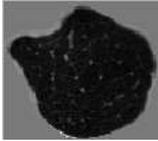
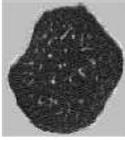
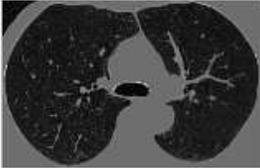
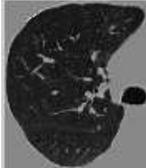
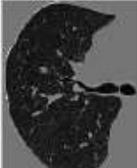
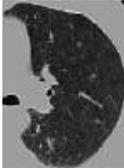
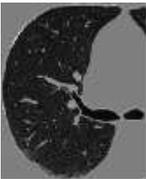
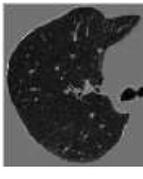
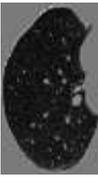
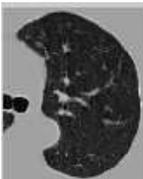
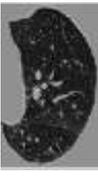
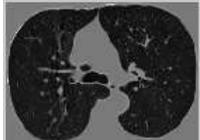
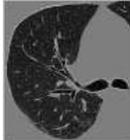
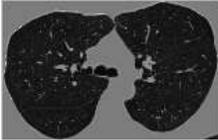
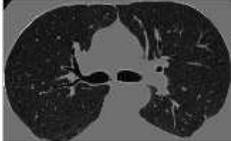
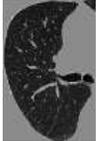
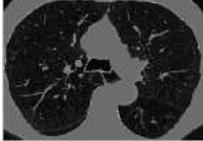
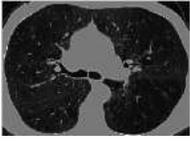
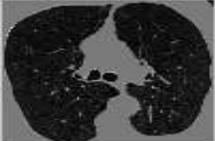
<b>Right</b>					
	<b>Image 31</b>	<b>Image 32</b>	<b>Image 33</b>	<b>Image 34</b>	<b>Image 35</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 36</b>	<b>Image 37</b>	<b>Image 38</b>	<b>Image 39</b>	
<b>Left</b>					
<b>Right</b>					

Table 7: The segmented left lung images and right lung for top section. All result of 39 images are shown above.

**MIDDLE SLICES:**

	Image 1	Image 2	Image 3	Image 4	Image 5
<b>Left</b>					
<b>Right</b>					
	Image 6	Image 7	Image 8	Image 9	Image 10
<b>Left</b>					
<b>Right</b>					
	Image 11	Image 12	Image 13	Image 14	Image 15
<b>Left</b>					

<b>Right</b>					
	<b>Image 16</b>	<b>Image 17</b>	<b>Image 18</b>	<b>Image 19</b>	<b>Image 20</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 21</b>	<b>Image 22</b>	<b>Image 23</b>	<b>Image 24</b>	<b>Image 25</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 26</b>	<b>Image 27</b>	<b>Image 28</b>	<b>Image 29</b>	<b>Image 30</b>

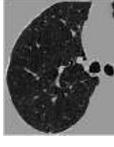
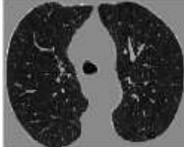
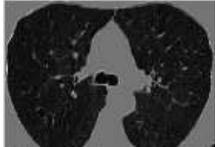
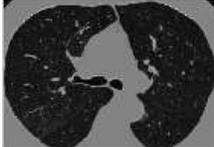
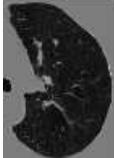
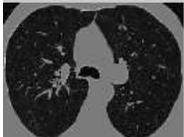
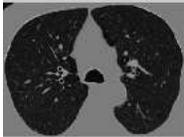
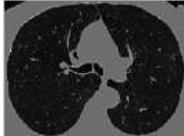
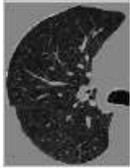
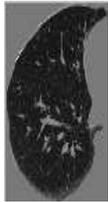
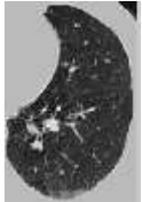
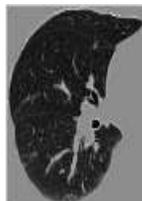
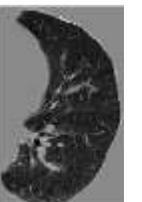
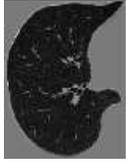
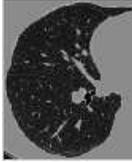
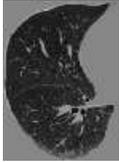
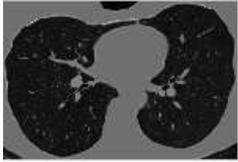
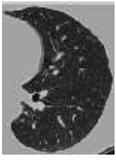
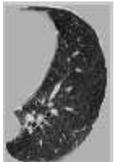
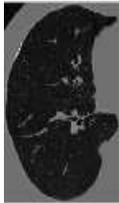
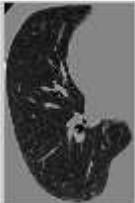
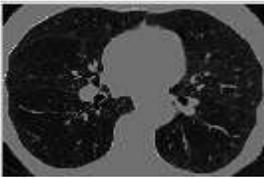
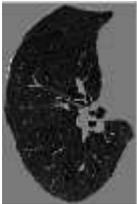
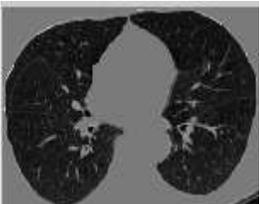
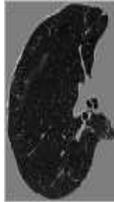
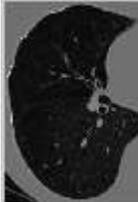
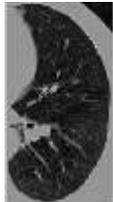
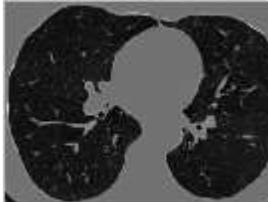
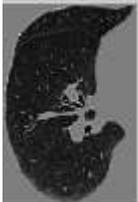
<b>Left</b>					
<b>Right</b>					
	<b>Image 31</b>	<b>Image 32</b>	<b>Image 33</b>	<b>Image 34</b>	<b>Image 35</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 36</b>	<b>Image 37</b>	<b>Image 38</b>	<b>Image 39</b>	
<b>Left</b>					
<b>Right</b>					

Table 8: The segmented left lung images and right lung for middle section. All result of 39 images are shown above.

**BOTTOM SLICES:**

	Image 1	Image 2	Image 3	Image 4	Image 5
<b>Left</b>					
<b>Right</b>					
	Image 6	Image 7	Image 8	Image 9	Image 10
<b>Left</b>					
<b>Right</b>					
	Image 11	Image 12	Image 13	Image 14	Image 15

<b>Left</b>						
<b>Right</b>						
	<b>Image 16</b>	<b>Image 17</b>	<b>Image 18</b>	<b>Image 19</b>	<b>Image 20</b>	
<b>Left</b>						
<b>Right</b>						
	<b>Image 21</b>	<b>Image 22</b>	<b>Image 23</b>	<b>Image 24</b>	<b>Image 25</b>	
<b>Left</b>						

<b>Right</b>					
	<b>Image 26</b>	<b>Image 27</b>	<b>Image 28</b>	<b>Image 29</b>	<b>Image 30</b>
<b>Left</b>					
<b>Right</b>					
	<b>Image 31</b>	<b>Image 32</b>	<b>Image 33</b>	<b>Image 34</b>	<b>Image 35</b>
<b>Left</b>		Null			

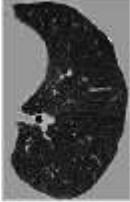
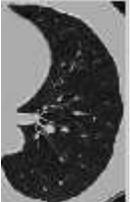
<b>Right</b>					
	<b>Image 36</b>	<b>Image 37</b>	<b>Image 38</b>	<b>Image 39</b>	
<b>Left</b>				Null	
<b>Right</b>					

Table 9: The segmented left lung images and right lung for bottom section. All result of 37 images are shown above.

The code used in this study is shown below. Every image has different bounding box value based on Table 30.

```
clc;clear all;close all
I = double(imread('A0002_bottom.tiff'));
figure;
subplot(2, 2, 1); imshow(I,[]); title('original image');
%%%%% filtering the image
kernel = ones(10)/10^2; % Create averaging window.
Io = conv2(I, kernel, 'same'); % Get means.
subplot(2, 2, 2); imshow(Io,[]); title('filtered image')
[r,c] = size(I);
%%%%% creating the binary mask
for i = 1:1:r
    for j = 1:1:c
        if Io(i,j)<=-41.9  %% latest value by adila
            Io(i,j)=0;
        else
            Io(i,j)=1;
        end
    end
end
maskn = Io;
%%%%Remove objects containing fewer than 100 pixels using bwareaopen
function.
maskc = bwareaopen(maskn,100);
subplot(2, 2, 3); imshow(maskn,[]);title('noisy inverted mask');
subplot(2, 2, 4); imshow(maskc,[]);title('cleaned inverted mask');
%%%%% invert the black to white
% maskc = invert(maskc);
for i = 1:1:r
    for j = 1:1:c

        if maskc(i,j)==1  %% latest value by adila
            maskc(i,j)=0;
        else
            maskc(i,j)=1;
        end
    end
end
figure; imshow(maskc,[]);title('correct mask');

prod = maskc.*I;
bw = bwlabel(maskc,8);
```

```

%%% create bounding box for crop function
stats = regionprops(bw, 'BoundingBox', 'Centroid');
bbl = stats(2).BoundingBox; %%%% box for left lung
bbr = stats(3).BoundingBox; %%%% box for right lung

LL = imcrop(I,bbl);
RL = imcrop(I,bbr);
figure;subplot(4,2,1); imshow(LL, []); title('Original left lung');
subplot(4,2,2); imshow(RL, []); title('Original Right lung');

LL = imcrop(prod,bbl);
RL = imcrop(prod,bbr);
subplot(4,2,3); imshow(LL, []); title('Noisy left lung');
subplot(4,2,4); imshow(RL, []); title('Noisy Right lung');

LM = imcrop(maskc,bbl);
LM = bwareaopen(LM,200);
RM = imcrop(maskc,bbr);
RM = bwareaopen(RM,200);
subplot(4,2,5);imshow(LM, []); title('Left mask');
subplot(4,2,6);imshow(RM, []); title('Right mask');

Lcrop = LL.*LM;
Rcrop = RL.*RM;
subplot(4,2,7); imshow(Lcrop, []); title('Cleaned Left L');
subplot(4,2,8); imshow(Rcrop, []); title('Cleaned Right L');

```

Image	File name	Bounding box value (left/right)		
		Top	Middle	Bottom
1	A0001	6/8	2/2	2/3
2	A0012	4/6	2/2	2/2
3	A0003	3/4	2/3	2/3
4	A0011	2/4	2/4	2/3
5	A0005	3/6	3/4	2/3
6	A0006	2/4	2/4	2/2
7	A0007	5/7	2/3	2/3
8	A0008	2/3	2/3	2/3
9	A0009	7/13	3/5	2/9
10	A0010	3/4	2/4	2/3
11	A0013	1/1	2/2	2/3
12	A0014	3/4	2/2	2/3
13	A0015	2/2	2/2	2/2
14	A0016	6/8	2/3	2/3
15	A0017	2/3	2/2	2/2

16	A0018	3/5	2/2	2/3
17	A0019	3/5	2/2	2/3
18	A0020	3/5	2/3	2/3
19	A0021	2/3	2/2	2/2
20	A0022	2/4	2/2	2/2
21	A0023	2/4	2/2	2/3
22	A0024	3/4	3/3	2/4
23	A0025	2/3	2/2	2/3
24	A0026	3/4	2/3	2/2
25	A0027	1/1	2/2	2/2
26	A0028	2/3	2/5	2/3
27	A0029	2/4	2/2	2/2
28	A0030	2/4	2/2	2/3
29	A0031	3/5	2/2	2/2
30	A0032	2/4	2/2	2/3
31	A0033	2/4	2/2	2/2
32	A0034	5/6	2/2	NULL

33	A0035	2/3	2/2	2/2
34	A0036	9/11	2/2	2/16
35	A0037	2/4	2/2	2/3
36	A0038	7/8	2/2	2/3
37	A0039	3/4	2/2	2/2
38	A0040	2/4	2/2	2/3
39	A0002	4/5	3/6	NULL

Table 30: Bounding box value required in the code for each image. The highlighted box gives a perfect left and right segmented image.