SOFTWARE DEVELOPMENT FOR THREE DIMENSIONAL VISUALIZATION OF LUNG ON COMPUTED TOMOGRAPHY SCANS USING ACTIVE SHAPE MODEL AND VOLUME RENDERING

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ABSTRACT

Lungs are respiratory apparatus in humans and some animals. Lung specialists and radiologists usually only see image of Computer Tomography Scans (CT Scans) with naked eye to detect abnormalities of lungs. This procedure is considered to be ineffective. Purpose of this research is to develop applications for 3-D visualization of lungs on CT Scans. This study is divided into two steps. The first is lung segmentation using active shape model (ASM). Second is a 3-D visualization of lung using volume rendering. Results of our study show that segmentation approach with an Active Shape Model has accuracy 96.8%, sensitivity 88.2% and specificity 99.1%.

Keywords: *Active Shape Model, Computer Tomography (CT), Volume Rendering.*

1. INTRODUCTION

In past three decades, medical technology has been using imaging sensors or scanners that produce high-resolution images such as x-ray, Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), which is very useful to help diagnose a disease [1]-[2]. To get a good and accurate diagnosis, performed by observing one by one anatomical slice of the CT image [3]-[5]. This means, process of manual diagnosis is difficult and results are not accurate [6]. This is becaused each CT image is observed, there are still other organ tissues.

Lung is a 3-D object, lack of a well-integrated application, making medical staff should observe data set 2-D CT for to diagnosis of lung abnormalities [7]. Because of need for information that can be read in detail, therefore required an application that can transform an image data set of lung 2-D into a 3-D visualization, that can help physician to diagnose lung abnormalities in lung.

Purpose of this research is to develop an application for segmentation and 3-D visualization of lung CT images. In this study is divided into two

steps First is to segment lung which aims to separate image of lung with surrounding tissue using active shape models. Second is 3-D visualization of lung using volume rendering.

Studies on nodule detection [8]-[14] have been carried out. In these studies, detection of abnormalities (nodules) of lung, consists of two steps, namely segmentation of candidate nodules, and classification process to determine nodule. Nodule candidate detection starts with segmentation of lung. Campadelli [8] segments on the postero-anterior chest radiographs using consecutive multiscale methods.To detects the most visible lung edges by means of the first derivatives of Gaussian filters. Edges are detected is lung border. Sousa [10] performs lung segmentation using two steps. First, torax extraction using region growing and the second lung extraction using thresholding. Dolej [12] perform lung segmentation using thresholding. Iakovidis [13] perform lung segmentation using Active Shape Models (ASM) from postero-anterior (PA) chest radiograph images. First, image of PA chest radiographs performed threshold process. The second process is the segmentation of left and

right lung boundary using ASM. Furthermore, reduction of first process to second process.

Segmentation of lungs CT images is not an easy process. This is because lungs CT image there are objects that are not part of lung. Method used for segmentation of lung in this study were active shape models. Active Shape Models are used in this study is ASM of Cootes et al. [15]. ASM uses a statistical model to shape appearance, derived from determination of landmark on outline of object. Model using some images in training set that has been marked correctly. Model uses some images in training set where correct landmarks of object have been defined. After aligning shape by Procrustes algorithm, shape variations are described using Linear Principle Component Analysis (PCA). PCA analysis results in a model including a statistical model of both edge profiles and shape [16]-[17].

To find object using ASM mean shape is placed on approximate correct position in an unseen image. Algorithm tries to fit mean shape to object edges in unseen image by finding best fit within edge profile of each landmark and then moves landmark to best fit of edge. This procedure is repeated for each landmark and finally a new shape is generated. Since this new shape may not look like correct shape, each model parameter is limited to less than 3 times of standard deviations of that parameter resulting from shape variations in training set. This iterative process is stopped after a predefined number of iterations.

For 3-D visualization of lung image using volume rendering. First, a set of 2-D CT images of lung are stacked in this order. Results of first step, segmentation process is then performed to obtain results of 3-D visualization of lungs such as original shape. To test accuracy of segmentation method, then results are compared with manual segmentation of groundtruth.

2. MATERIALS AND METHOD
2.1. Materials

Data used is lung CT images from 20 patients. Orientation of slices is axial with one patient taken one slice. We also use 24 slices of one patient, so that total of all slices were used in experiments is 44 slices. Imaging was performed using Thosiba TCT 300S**,** one of facilities owned by Bethesda Hospital, Yogyakarta. Image size of 505x427 pixels, and a thickness of 0.5 - 10 mm.
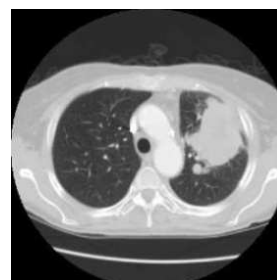

Figure 1. Examples of Abnormal Lung CT Image With Axial Slices

2.2. User Interface Software Development

User interface is developed consisting of 8 processes. These processes are: browse, lung segmentation, left and right lung visualization, Left and right lung visualization, 3-D visualization of lung, and 3-D visualization of lung lesions. User interface is developed can be seen in Figure 3.

2.3. Lung Segmentation Software Development Using ASM

Steps of Lung Segmentation Using Active Shape Model (ASM) can be explained as follows:

2.3.1. Shape model

First step is to establish a model using position of landmarks on training data. There are three steps to create a model of shape:

1. Procrustes Analysis

Procrustes analysis [18] is a form of statistical shape analysis used to analyze a collection of shapes. In this case, shapes are equalized by removing translational, rotational and scaling components. A brief description of stages to align shapes and can be explained as follows:

a. Translational

Calculate center of mass for each shape:

$$\bar{x}=\frac{x_1+\ldots+x_n}{n}, \bar{y}=\frac{y_1+\ldots+y_n}{n}, \bar{z}=\frac{z_1+\ldots+z_n}{n}, \bar{w}=\frac{w_1+\ldots+w_n}{n} \quad (1)$$

Translate each shape to its center of mass: $(x',y') \mapsto (x-\bar{x}, y-\bar{y}), (z',w') \mapsto (z-\bar{z}, w-\bar{w})$

$$(2)$$

b. Scaling

Calculate scaling for each shape using L2-norm:

$$ScaleX = \sqrt{x_1'^2 + y_1'^2 + x_2'^2 + y_2'^2 + \ldots + x_n'^2 + y_n'^2}$$

$$ScaleZ = \sqrt{z_1'^2 + w_1'^2 + z_2'^2 + w_2'^2 + \ldots + z_n'^2 + w_n'^2} \quad (3)$$
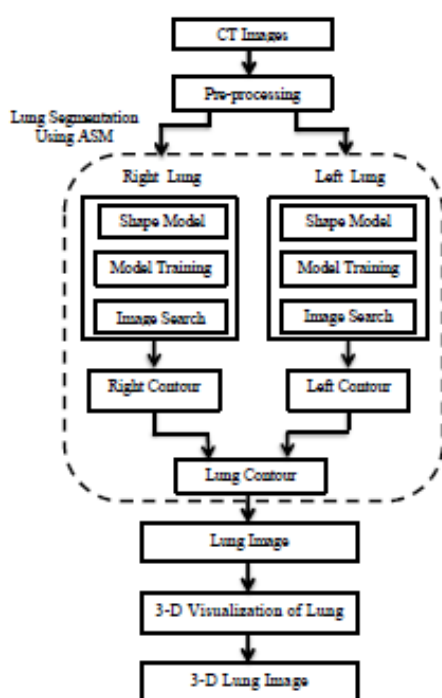
$$X' = \frac{X'}{ScaleX}, Z' = \frac{Z'}{ScaleZ} \quad (4)$$

Figure 2. Proposed Method for 3-D Visualization of Lung.

c. Rotation

Construct and as following

$$\underline{X} = \begin{pmatrix} x'_1 & x'_2 & \dots & x'_n \\ y'_1 & y'_2 & \dots & y'_n \end{pmatrix},$$

$$\underline{Z} = \begin{pmatrix} z'_1 & z'_2 & \dots & z'_n \\ w'_1 & w'_2 & \dots & w'_n \end{pmatrix} \tag{5}$$

Calculate Singular Value Decomposition (SVD) for and find U, S, V.

The rotation matrix(R) to match $\underline{Z}$ to $\underline{X}$ is:

$$R = V * U^T = \begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix} \tag{6}$$

Calculate $Z_{rotasi} = R * \underline{Z}$. (7)

2. Shape Alignment

Shapes of objects in training set are different in scaling, rotation and translation. In order to construct a stable shape model, these differences must be removed. Standard approach is to align all shapes to mean shape and continue this procedure till mean shape does not change in two consequent iterations

3. Principle Component Analysist (PCA)

PCA is a linear orthogonal transformation transmitting data set to a new coordinate system as first greatest variance in data is assigned to first

dimension. Principal components are eigenvectors of covariance matrix.

2.3.2. Model training

This section explains how to find gray level information of each landmark using images in training set. It is generally possible to consider all areas around landmark but traditional ASM only considers a line crossing landmark. This line for ith landmark has   length and can be bisector line of angle between and landmarks.

2.3.3. Image search

In this step, an initial estimation of shape is manually applied to an unseen image. Initial shape should hit object edges in unseen image and at same time be reasonably short. Then ASM uses edge profile and the covariance matrix of the mean normalized derivatives generated in last stage to find best movement. Steps for image search can be explained as follows:

a. Initial Shape Estimation

At first, user should choose a shape as initial shape. This shape is better to be as close as desired object in image. If X_i is the initial shape, it can be considered as translation, rotation and scaling of a reference shape.

b. Changes of Pose and Model Parameters

In order to reach an acceptable result, initial shape must be modified by changing pose and model parameters. Steps to change pose and model parameters can be explained as follows: first, calculate pose parameters changes, second, calculate model parameters changes. After changing pose parameters, remaining adjustments can be done using model parameters modifications.

c. Calculate Each Landmark Movement

As can be seen last equations are independent and there is no relation between it and desired object in unseen image. For enabling this connection edge profile of each landmark in initial shape must be calculated.

2.4. Software Development For 3-D Visualization of Lung Using Volume Rendering.

Input file is a set of 2-D images are contained in same folder. A set of 2-D lung CT images will be loaded and displayed on screen. Volume Rendering is a step in which process is carried out to reconstruct a set of lungs 2-D image to 3-D. First, a set of 2-D images will be stacked in accordance with order. Of volume is created, segmentation process will be carried out to obtain results of 3-D image visualization approaching its original form.

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Segmentation process is done by determining Opacity Transfer Function and Color Transfer Function. Opacity Transfer Function defines value of opacity or transparency of each voxel contained in volume is formed. While Color Transfer Function defines value of Red, Green, Blue (RGB) of each voxel contained in volume is formed. After that, determine other properties of volume required. Final step is connecting Reader, Mapper, and Actor, so volume can be displayed on-screen form. Steps of proposed method for 3-D visualization of lungs can be described in Figure 2.

3. ACCURACY, SENSITIVITY AND SPECIFICITY.

To calculate accuracy, sensitivity and specificity of proposed segmentation method, done by adding image of segmentation result using ASM with segmentation result by groundtruth. Furthermore, detected pixels grouped into 4 groups: TP (true positive), TN (true negative), FP (false positives) and FN (false negative). TP is a lung pixels detected correctly. TN is not lung pixels identified correctly. FP is not lung pixels identified as lung pixels. While FN was not detected lung pixels. Then to test performance of proposed segmentation method, by calculating accuracy, sensitivity and specificity. Accuracy shows the performance of proposed method. Sensitivity indicates proportion of lung pixels correctly detected. While specificity indicates proportion of pixels not lung detected as a lung. Equation of accuracy, sensitivity and specificity were as follows:

$$Akurasi = \frac{TP+TN}{TP+FP+FN+TN} \qquad (8)$$

$$Sensitivitas = \frac{TP}{TP+FN} \qquad (9)$$

$$Spesifisitas = \frac{TN}{TN+FP} \qquad (10)$$

4. EXPERIMENT AND RESULTS

Software for 3-D visualization of lung starts by displaying Main Menu as shown in figure 3. Main menu consists of eight buttons. Browse button is used to view location of CT data. Segmentation Button is used to segment lung. Left Lung Visualization Button is used for visualization of left lung. Right Lung Visualization Button is used for visualization of right lung. Left Lesion Visualization Button is used for 3-D visualization of abnormalities left lung. Right Lesion Visualization Button is used for 3-D visualization of abnormalities right lung.
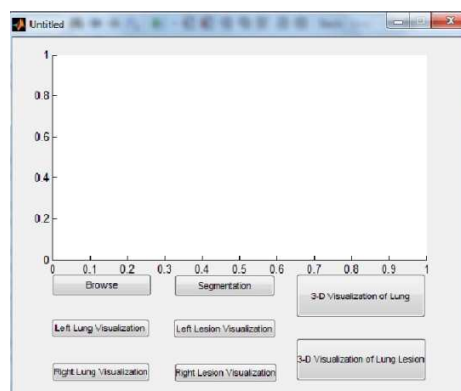

Figure 3. Main Menu

3-D Visualization of Lung Button is used for visualization of lung. 3-D Visualization of Lung Lesions Button is used to abnormalities lung visualize.

If Segmentation Button is pressed, will perform lung segmentation process. Segmentation process can be performed per slice or many at once. Figure 4 below are examples of segmentation process into 29 slices with a great shape abnormalities.
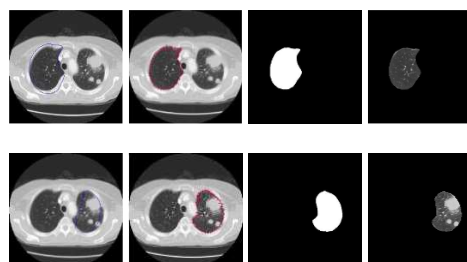

Figure 4. ASM Segmentation Process.
Upper, From Left to Right is Right Lung Segmentation,
Bottom, From Left to Right is Left Lung Segmentation
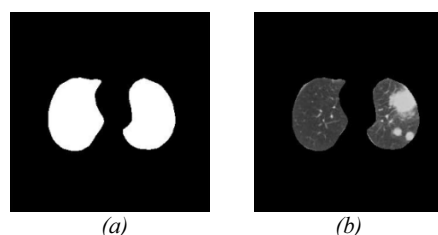

(a)   *(b)*
Figure 5. (a) Lungs Contour, (b).
Final Lung Image.

To test accuracy of ASM method, we examined CT images of patients consisting of 24 slices, as shown in Figure 6.`
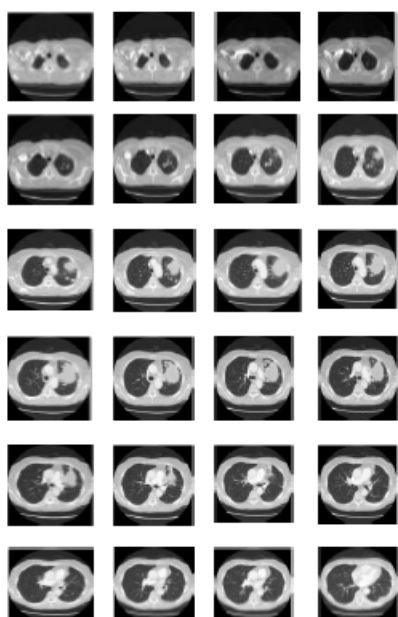
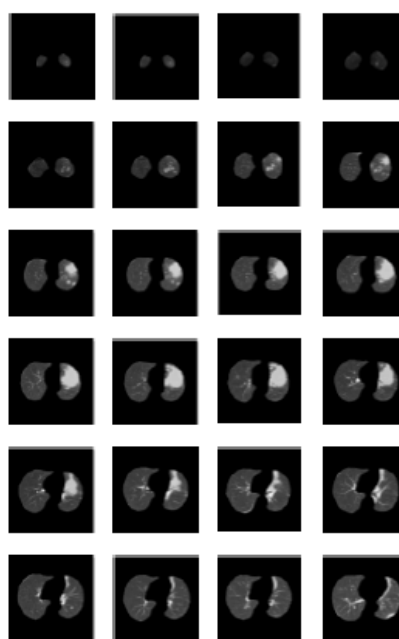*Figure 6. Sequential Original Lung CT image*

Results of segmentation using ASM produces lung contour as shown in Figure 7.
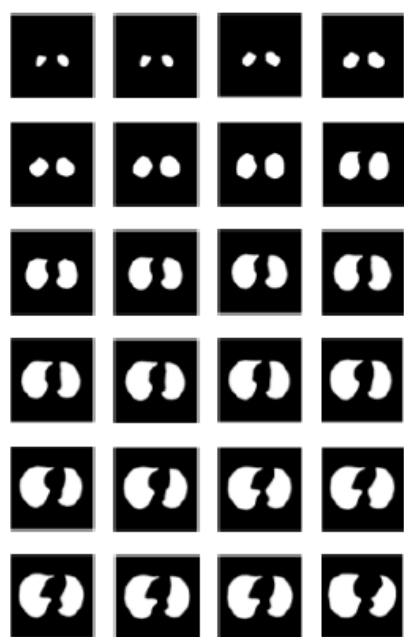

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Figure 7. Lung Contour Image Segmentation Results with ASM

Figure 8 below is final lung image. Final lung derived from multiplication of original lung CT image with contours of segmentation with ASM. This images will be visualized 3-D.

Figure 8. Final Lung Images

Results of final lungs images 3-D visualization from figure 8, can be seen in figure 9 below.
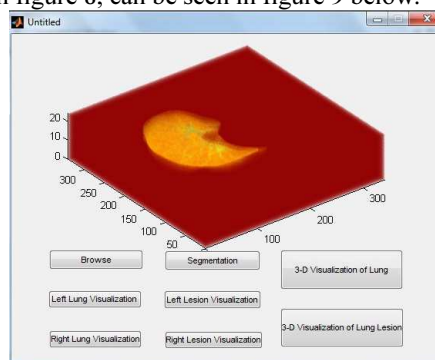

Figure 9. Results of Right Lung 3-D Visualization

Figure 9 shows results of 3-D visualization of right lung, whereas in figure 10 shows results of visualization of left lung.
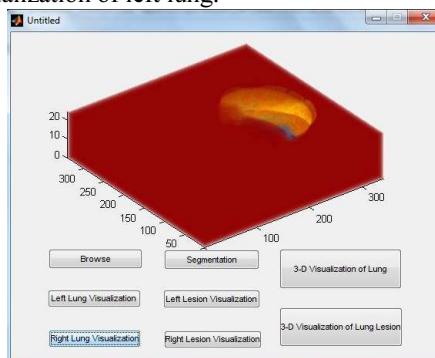

Figure 10. Results of 3-D Visualization Left Lung

Figure 11 shows result of 3-D visualization of lungs, whereas in Figure 12 shows a visualization of lung rotated.
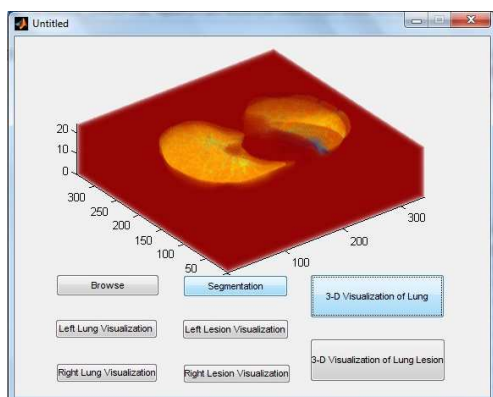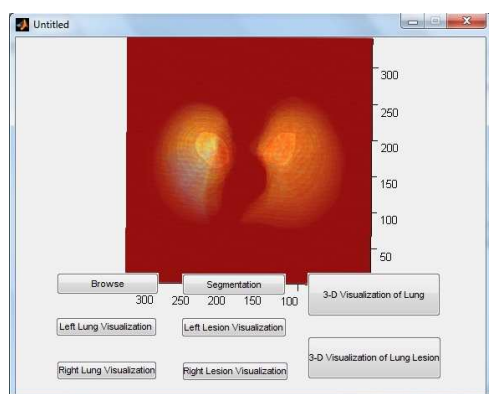

Figure 11. 3-D Visualization of Lung

Figure 12. 3-D Visualization of Rotated Lung

Figure 13 shows results of lesion (abnormality) lung 3-D visualization, whereas in Figure 14 shows visualization of lung lesions were rotated.
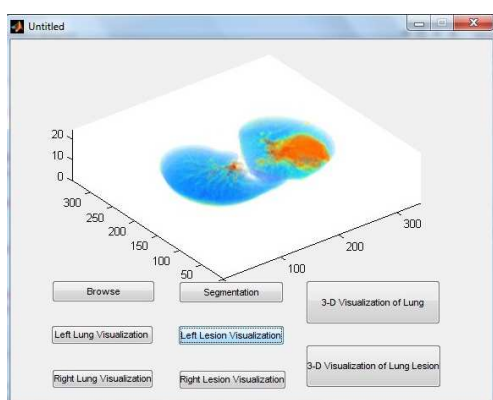
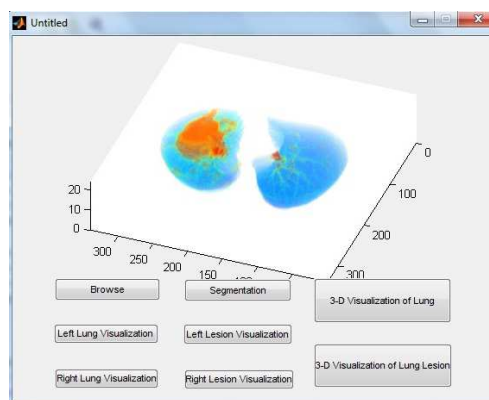

Figure 13. 3-D visualization of Lung Lesions

Figure 14. 3-D Visualization of Rotated Lung Lesions

Experimental results using 44 slice CT scans of 20 patients can be seen that ASM method has high accuracy for segmentation of lung fields,, especially lung containing abnormalities (nodules). Lung segmentation results with ASM has an accuracy 96.8,%, sensitivity 88.2% and specificity 99.1%.

5. CONCLUSION

ASM segmentation method is suitable to segment lung containing abnormalities (nodules). Lung segmentation results are very influential in 3-D visualization process. Lung shape in 3-D format, causing lung image can be seen more clearly, and can be seen from all directions. It can be helpful to radiologists in performing CT image readings, especially the lungs, and can assist in diagnosis process.

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