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Lung Segmentation Using Prediction-Based Segmentation Improvement for Chest Tomosynthesis

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Abstract

Chest radiography which is the most common imaging method for lung is difficult to distinguish the lung vessels and nodules due to characteristics of representing the chest in a single image and shading occurred by organs. Computed Tomography(CT) scan has excellent lung nodule detection sensitivity because it produces chest images as volume data, but it has a large amount of exposure dose and is expensive. Chest tomosynthesis which generates volume data through continuous shooting comes to the forefront as an early lung cancer screening method with high lung nodule detection sensitivity than chest radiography and low-dose than CT image. However, chest tomosynthesis is difficult to have computer-based automatic segmentation because of blurring occurred while generating the image. Therefore, we propose prediction-based segmentation improvement method based on the central slices with less blurring after performing lung segmentation using region-growing. Using the proposed method, it is to improve the lung segmentation performance by improving the incorrect segmentation results on the outer slices where many blurring occurs. The experiment results showed the improvement of incorrectly segmented lung region.

Keywords: *Biomedical image processing, image segmentation, tomosynthsis, lung segmentation*

1. Introduction

Since lung cancer has the highest mortality rate among cancers, the early screening is important [1,2]. Of chest imaging methods, chest radiography is the typical early screening method with low-dose of radiation and low cost. Chest radiography, which displays the chest into a single image by penetrating X-ray to the human body, has shading caused by anatomical structures such as ribs and heart. In addition, chest radiographic image consists of a single image, so it is difficult to distinguish lung vessels and nodules. By contrast, since Computed Tomography (CT) image generates the body image into volume data, the detection sensitivity is higher than lung nodule detection using chest radiographic image. The U.S. National Cancer Institute (NCI) published the research results that using CT as an early screening for lung cancer lowered the probability of dying with lung cancer than using chest radiography [3]. However, CT scan has a higher level of radiation dose affecting on patients

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during scanning and is costly. To overcome these disadvantages, currently chest Low-Dose CT (LDCT) is used for early screening of lung cancer, but the issues of medical radiation dose caused by CT scan have been raised continuously.

Tomosynthesis can improve the performance of lung nodule detection using volume data. As well as, tomosynthesis has low-dose to patients than CT scan and can be taken at a lower cost. In fact, in various clinical trials chest tomosynthesis showed 3 times more improved lung nodule detection sensitivity than conventional chest radiographic image. Although it has improved detection sensitivity than chest radiographic image, it has problem that more images should be reviewed by radiologists than conventional chest radiographic images. When compared to CT images, chest tomosynthesis has 30% less detection sensitivity of lung nodules [4]. Recently, through various studies Computer-Aided Diagnosis(CAD) system showed the results of improved detection sensitivity of lung nodules in radiography and CT scan by assisting the specialists. Studies have been carried out to make advantage of chest tomosynthesis as an early screening by applying it to CAD which can use volume data and has less exposure dose than CT [5].

Lung segmentation process in chest tomosynthesis is an important step for utilizing CAD. Accurate lung segmentation can remove surrounding tissues of lung and tissues irrelevant to lung, and can reduce computational complexity and false-positive rate in the lung nodule detection process. However, chest tomosynthesis is a projection image penetrated to the body through X-ray, so the lung segmentation is difficult under the effect of blurring and shading of the ribs. These problems occur more as it moves outward from the central slice of image dataset and this causes the decreased segmentation performance of outer slice compared to the central slice. Therefore, this paper proposed the method to predict the segmentation results of the outer slice using the segmentation information of the central slices which have less blurring than the outer slices in order to improve the accuracy of lung segmentation in chest Tomosynthesis. First, lung segmentation of dataset was performed using region-growing method. Then, after setting the central slice as a reference slice, the method to improve the lung segmentation performance was studied by improving incorrect segmentation results occurred in the outer slice through generating predicted segmentation information.

This paper is organized as follows. In Section 2, chest tomosynthesis is described. Explanation for the proposed prediction-based segmentation improvement method is given in Section 3. Experiment result is given in Section 4 and conclusion for this paper is made in Section 5.

2. Chest Tomosyntehsis

Tomosynthesis is a compound word of “Tomography” and “Synthesis” [6]. This method can reconstruct the coronal plane which has random height from the single topography. Tomosynthesis published by Ziedses in 1938 was widely applied to the clinical medicine as an image intensifier mounting system by Miller *et al.* in 1971. But, there was a problem of blurred images by image variation and narrow contrast ratio because the input fluorescent screen of image intensifier was a curved surface, and the use of image intensifier has been drastically reduced due to the spread of Magnetic Resonance Imaging (MRI) and Multi slice CT and subsequent development of three-dimensional and Multi-Planar Reformation(MPR) imaging technology. With the recent development of X-ray image detector, Flat Panel Detector(FPD) with high-sensitivity and high-resolution power was attached to the fluoroscopic device, and thus, it was possible to have low-dose of digital tomosynthesis that can obtain multiple clear tomographic images with one time continuous shooting. In addition, it was able to detect with less X-ray dose than CT scan and as the image reconstruction processing is possible, its utilization has been increased in regions such as orthopedics. Also, studies on applying it to the diagnostic process of patient are carried out rapidly [7, 8].

Figure 1 shows the basic elements of chest tomosynthesis. A computer-controlled motorized tube crane moves the X-ray tube to a series of positions along a vertical path, acquiring a projection image on a FPD at each position. Control circuitry handles the tube mover, digital detector, and X-ray generator. A reconstruction workstation produces the tomosynthesis reconstructed images [9].

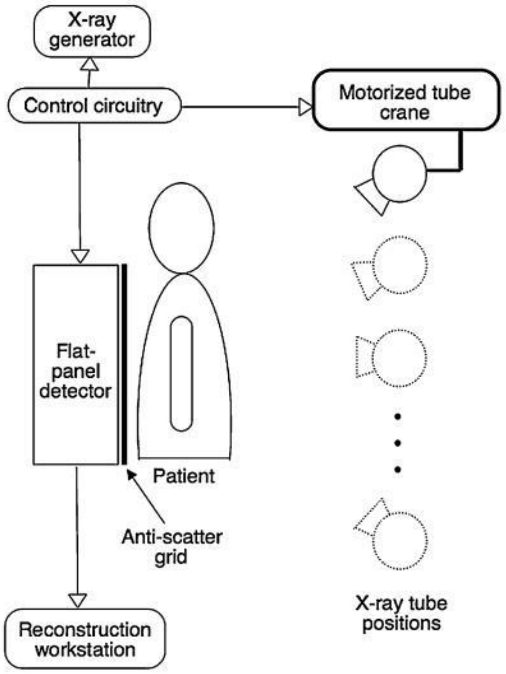

Figure 1. Basic Components of a Chest Tomosynthesis Device

3. Proposed Chest Tomosynthesis Segmentation

This paper proposed the segmentation method of lung region in chest tomosynthesis. The proposed lung segmentation method of chest tomosynthiesis is shown in Figure 2.

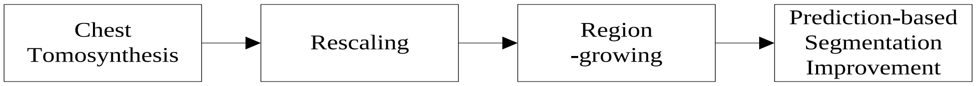

Figure 2. Proposed Lung Segmentation Method for Chest Tomosynthesis

First, after rescaling the input chest tomosynthesis, region-growing method is performed for lung segmentation. And finally, the lung segmentation is finished by performing prediction-based segmentation improvement. The prediction-based segmentation improvement process reduces the segmentation error caused by blurring occurred in chest tomosynthesis and improves the segmentation performance.

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3.1. Rescaling the Original Image

The first step of lung segmentation, the processing to reduce the resolution of chest tomosynthesis is performed. The original resolution of chest tomosynthesis is 1,965 × 1,942. Lung in chest tomosynthesis occupies a very large region. The reduced resolution has a small influence on the accuracy of lung segmentation. With the reduction of resolution, the processing time spent on lung segmentation process can also be reduced. In this paper, the resolutions of images were reduced to 491 x 485 using average masks with a size of 4 x 4 of the original images.

3.2. Segmentation Using Region-Growing Method

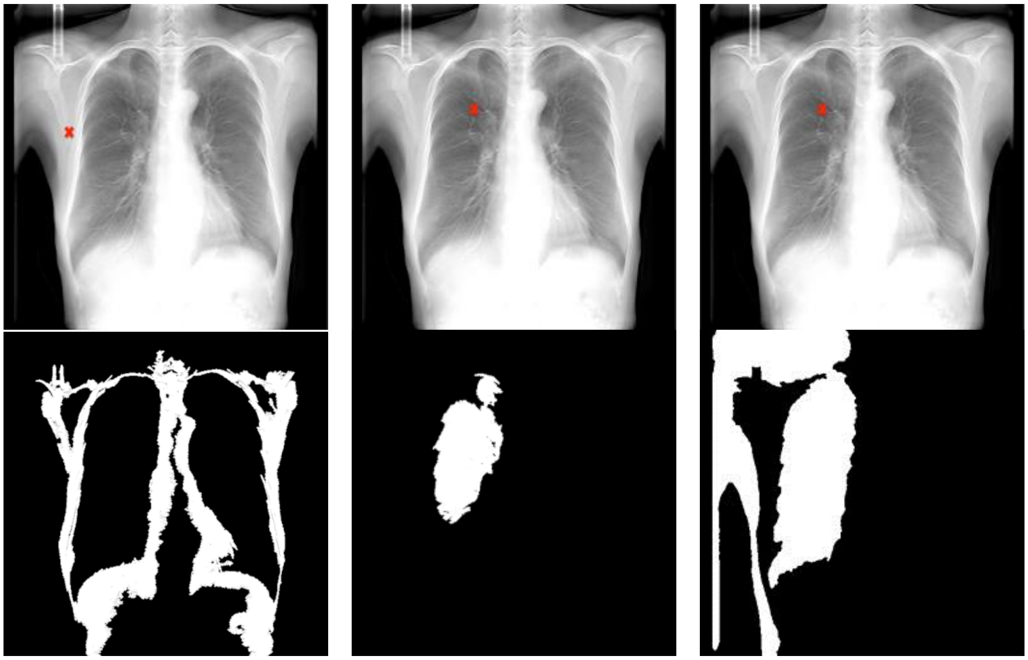
(a) Incorrect Seed Position (b) Incorrect Seed Value (c) Blurring

Figure 3. The Errors of Region-Growing Method

Region-growing method, which is one of algorithms for region segmentation, is to divide the total region of image at last by expanding regions with similar characteristics to the reference region which is the seed. With this method, the efficient region segmentation is possible in images with a lot of noise that are difficult to extract the contour region. Region-growing expands the region when the absolute value of difference between I_{seed}, initially set as a seed and image $I(i,j)$ is less than threshold value T, it identifies as the region with same characteristics and otherwise, it identifies as a different region as shown in following equation.

$$R(i,j) = \begin{cases} if \ \ |I(i,j) - I_{seed}| < T & 1 \\ \quad otherwise & 0 \end{cases} \tag{1}$$

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The segmentation results of region-growing method will vary depending on the threshold *T* for initial seed position, reference brightness value, and similar pixel selection. If the initial seed is set in the position that is not included in lung, lung segmentation will not be performed. If the initial seed value is set too bright or too dark value or *T* is set too high or too low, the lung region is over segmented or will not be segmented completely as shown in Figure 3. In addition, if it is used in the image which its contours are not clear due to blurring, the region leak occurs.

3.3. Predication-based Segmentation Improvement Method

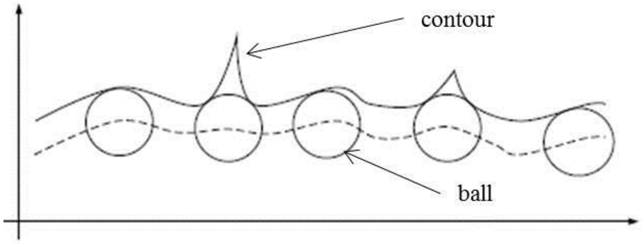

Figure 4. The Surface Generated by the Rolling-Ball

Since the contour of lung segmentation results obtained through region-growing method has a small groove, it doesn't have a naturally connected look. In order to obtain the smooth lung segmentation contour, the reconstruction process is required. In this paper, the reconstruction was performed filling small grooves of the initial lung segmentation contours by applying the rolling-ball algorithm. The rolling-ball algorithm, known as top-hat transform, is a geometric filter that fills the empty space of image. The ball used in the image moves along the contours of an object as shown in Figure 4, and fills the empty space which is not suitable for geometric shape [10].

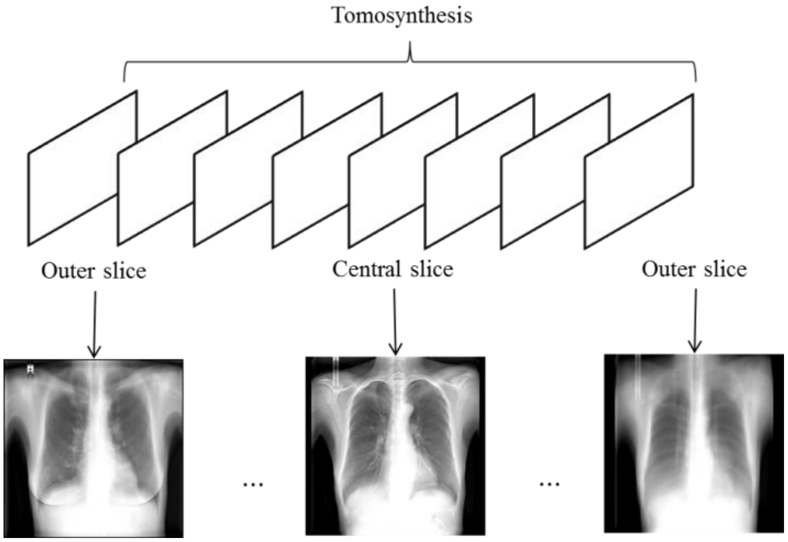

Figure 5. Dataset of Chest Tomosynthesis

Chest tomosynthesis, which is a projection image, has blurring in the image generation process. This blurring increases as the central slice of chest tomosynthesis moves toward the outer slice as shown in Figure 5. As the blurring increases, the contours of lung are unclear, leading to cause a lot of errors in lung segmentation using region-growing method. For this reason, it is difficult to perform the same quality of lung segmentation in entire dataset. Therefore, we propose the prediction-based segmentation improvement method which can perform the accurate segmentation even in outer slice where a lot of blurring occurs during the prediction-based segmentation improvement process. The flow chart of the proposed prediction-based segmentation improvement method is shown in Figure 6.

The prediction-based segmentation improvement method predicts the segmentation type of next slice using two reference slices. Moreover, the prediction-based segmentation improvement method is performed by combining predicted results and the initial segmentation results through initial segmentation process. To generate the predicted results, the reference slice is required. As shown in Figure 5, the central slice of chest tomosynthesis has less blurring than the outer slice, so it is possible to have accurate segmentation in the central slice compared to the outer slice. Since the reference slice affects on the result of prediction slice, the central slice which has less blurring should be selected and used.

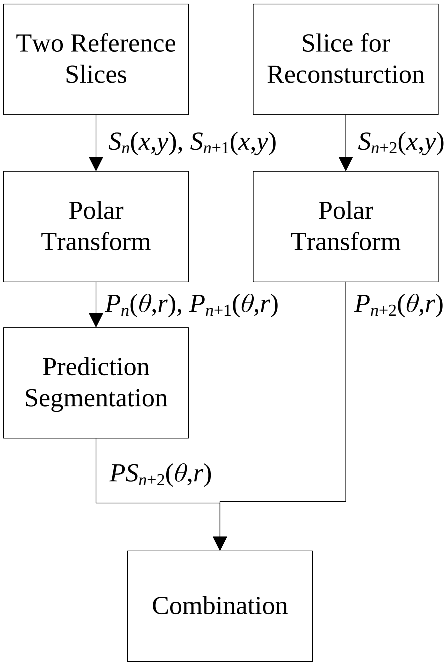

Figure 6. The Flowchart of Prediction-Based Segmentation Improvement

In order to generate the prediction slice, it needs to select the corresponding anchor point in contours of region existed between two reference slices. In this paper, polar space coordinate was used for selecting the anchor point and generating the prediction slice. Polar space coordinate is also an effective coordinate to dynamic programming.

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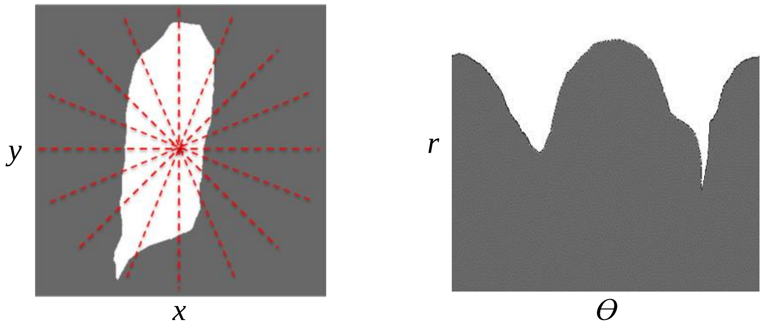


(a) Cartesian Space Coordinates (b) Polar Space Coordinates

Figure 7. Polar Space Coordinate Transform

To convert Cartesian space coordinates into polar space coordinates, it is represented in Figure 7(a) when setting the center coordinate and calculating the image angle *Θ* and distance *r* information as shown in Figure 7(b). The anchor points are generated depending on the angle of polar space coordinates and the contour coordinate with the same angle will be the matched pair. In polar transform the Cartesian space coordinates are converted into *r* and *Θ* relative to the origin of coordinate system, where:

$$x = r\cos\theta \qquad y = r\sin\theta \tag{2}$$

On basis of (2), we describe transform equation as follows:

$$r = \sqrt{x^2 + y^2} \qquad \theta = \arctan\frac{y}{x} \tag{3}$$

Where (x,y) are the coordinates in Cartesian space, (Θ,r) are coordinates in polar space.

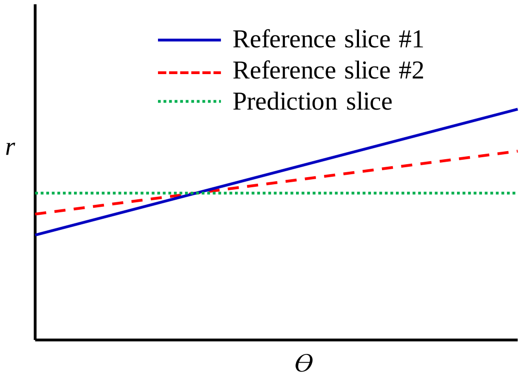


Figure 8. The Prediction Slice Generated by the Reference Slices

After converting two reference slices to polar coordinate and overlapping it to the same coordinate system, it will only be partially expressed in the form of Figure 8. While searching the horizontal axis sequentially, the value changes of reference slices are calculated in the vertical axis. When using polar coordinates, it can create the new contour location of the next slice depending on the changes of contour location in reference slices. The segmentation information is improved by combining contour location generated in this way with the contour information of slices to be improved. To combine the initial segmentation slice *S* and prediction slice *PS*, the distance of anchor points of two slices is used. First, after converting the initial slice *S* and prediction slice *PS* to polar coordinate as in the generation process of prediction slices, it is overlapped to the same coordinate system. The same Θ will be the matched pair of anchor points. And the final segmentation result *F* is generated by calculating the vertical axis coordinate differences of matched pairs as in the following equation:

$$F(\theta) = \begin{cases} S(\theta) & if \ |PS(\theta) - S(\theta)| < th \\ PS(\theta) & otherwise \end{cases} \tag{4}$$

4. Experimental Results

In this paper, the lung segmentation method was studied in chest tomosynthesis. The chest tomosynthesis used in the experiment has a resolution of 1,965 x 1,942. For obtaining the images, VolumeRAD of GE Healthcare Ltd., a CsI/a-Si flat panel detector system was used. In this equipment, X-ray tube worked continuously from -17.5 degrees to +17.5 degrees of vertical angle around recession site of normal right angle for 11 seconds and 60 projection images were obtained between -15 degrees and +15 degrees of tube angle. Images were reconstructed for about 54 coronal images with 5 mm thickness without overlapping and the shooting condition was 125 kVp, AEC speed 100, 1:10 dose ratio, 320 mA, 10 mSec, and 0.2 mm Cu filter. In this case, the simulated effective dose using measured entrance skin dose and Mont Carlo simulation technique was reported 0.92 mGy and 0.12 mSv [11].

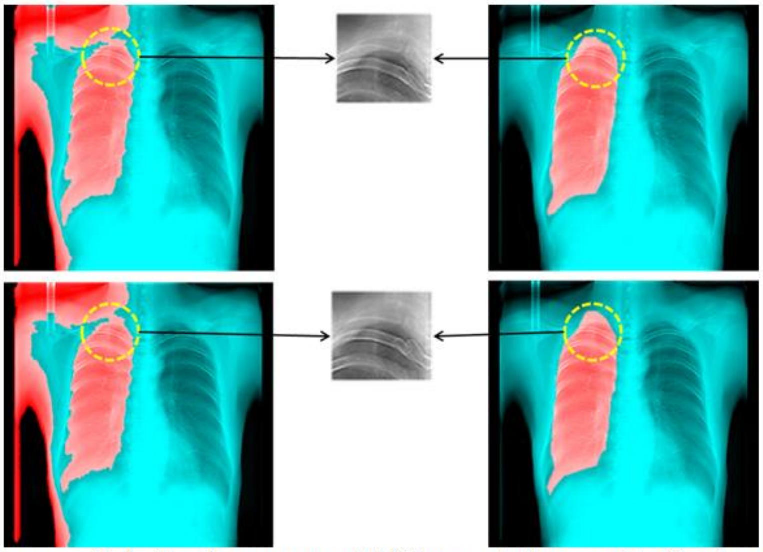
Lung segmentation was performed by applying region-growing method after rescaling chest tomosynthesis. In order to look the segmented contour by region-growing method natural, the lung contours were reconstructed by applying rolling-ball algorithm in the segmented lung region. And the lung segmentation performance was improved by applying the proposed prediction-based segmentation improvement. In this paper, the initial seed value was specified through user input.

(a) Chest Tomosynthesis (b) Region-growing Results (c) Rolling-ball Results

Figure 9. Representation of Region-Growing and Rolling-Ball Results

If segmentation using region-growing method is performed, lung region is missing in the lung contour region due to shading of the ribs occurred in chest tomosynthesis, generating uneven surface as shown in Figure 9(b). The lung region is brightened by shading of organ parts so sometimes the lung regions are not segmented. When applying rolling-ball algorithm to results of segmentation using region-growing method like in Figure 9(c), it can reduce errors caused by shading of the ribs and organs occurred in the lung contour.

The lung contour information is not clear in chest tomosynthesis because blurring occurred in the outer slices compared to the central slices. Therefore, as shown in Figure 10(a) in the segmentation results using region-growing method, the region leak occurred and the accurate lung region was not segmented. Some parts of lung contours have the small brightness difference due to blurring, leading to the region leak in this region as shown in Figure 10(a). In a small region marked as a circle in Figure 10(a) causes large errors due to the leak. If the threshold value is reduced to prevent the leak in region-growing method, the segmentation of other regions would not be performed sufficiently. However, as described earlier, the leak is generated prominently in the outer slices than the central slices. In other words, the possibility of the leak is less likely in the central slices and the segmentation performance in the central slices is higher compared to that of the outer slices.



(a) Segmentation results before improvement (b) Segmentation results after improvement

This paper proposed the prediction-based segmentation improvement method using these characteristics. The prediction segmentation information is generated using the central slices in the beginning. And the incorrect segmentation results in the outer slices are improved using the generated segmentation information. Figure 10(b) shows the result of applying the prediction-based segmentation improvement method proposed in this paper. In contrast to the initial segmentation results in Figure 10(a), it showed that the part with the region leak occurred by blurring was removed. The unclear contour information caused by blurring are reconstructed through the prediction-based segmentation improvement method.

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5. Conclusions

Chest tomosynthesis is a medical imaging which has volume data, low-dose and low cost than CT scans. Currently, studies to apply chest tomosynthesis to early screening in chest region are in progress. However, chest tomosynthesis has problems of shading by the ribs and blurring occurring during the image generating process. These problems occur more in the outer slices than the central slices, degrading the lung segmentation performance. Lung segmentation affects on the performance of medical image analysis using CAD. Therefore, in this paper the method was studied to improve the segmentation performance of the slices which blurring has occurred. As a result of experimenting the proposed method, it could improve the errors caused by region leak and region segmentation errors occurred by unclear contour values.

The future plan is to perform the lung segmentation in chest tomosynthesis dataset and to carry out the studies to solve the lung segmentation errors caused by shading of the ribs.

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