# Automated Detection System for Pulmonary Emphysema on 3D Chest Images

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## ABSTRACT

An automatic extraction of pulmonary emphysema area on 3-D chest CT images was performed using an adaptive thresholding technique. We proposed a method to estimate the ratio of the emphysema area to the whole lung volume. We employed 32 cases (15 normal and 17 abnormal) which had been already diagnosed by radiologists prior to the study. The ratio in all the normal cases was less than 0.02, and in abnormal cases, it ranged from 0.01 to 0.26. The effectiveness of our approach was confirmed through the results of the present study.

Keywords: 3-D chest CT images, emphysema, computer-aided diagnosis

## 1. INTRODUCTION

Pulmonary emphysema is mainly caused by long-term smoking, and medical treatments is difficult since, in worse cases, the structure of the lung is damaged irreversibly. In such those cases, the most effective remedy is to arrest the development of the diseases. However, methods for quantitative analysis of pulmonary emphysema have not yet been established. Such an analysis would enable well-trained radiologists to interpret the changes in the CT scans of the patients over a period of time. Some quantitative analyses [1] have already been reported, but the number of such studies is very small.

The purpose of this study was to develop an automated measurement technique to estimate the ratio of the pulmonary emphysema regions to the lung volume for assessing the degree of lesion development using 3D chest CT images. The degree of the disease was assesed subjectively by well-trained radiologists, since the quantitative analysis of the ratio (abnormal region volume / whole lung volume) was not performed. In clinical opinions, the emphysema areas were described as low attenuation areas (LAA) on CT scans. Our technique for calculating the ratio was based on the region extraction of LAA and volume measurement of the whole lung area except the bronchus regions.

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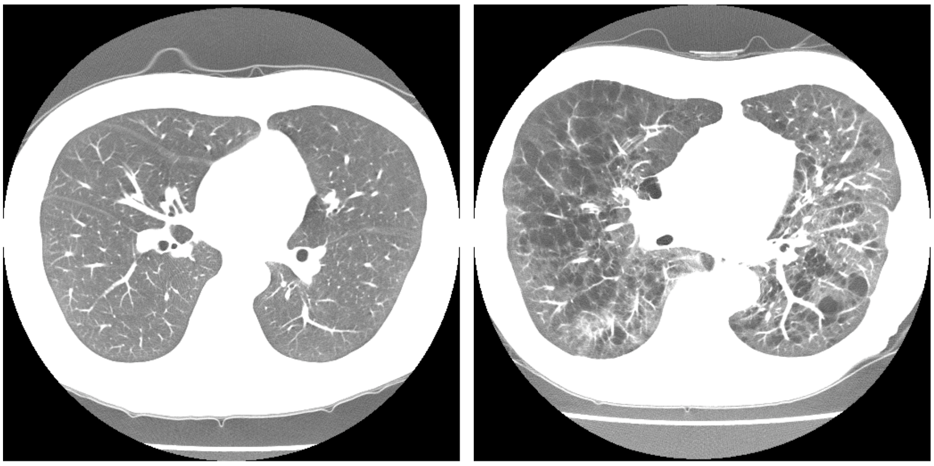
## 2. MATERIALS AND METHODS

### 2.1. Emphysema and CT value

Figure 1 (a) and (b) show a normal lung scan and an abnormal one, respectively. The lung area in Fig. 1 (a) shows a homogenous density, while Fig. 1 (b) includes a dark area called LAA. The CT value within LAA was approximated by the CT value of air, but this CT value was slightly higher than that of the air CT because of artifacts from the born or other organs surrounding the lung. We proposed a threshold technique for changing the binarization value according to the scan position, based on these variations in air CT values, so that the values inside the bronchus assume a very important role to estimate the CT values of LAA at the same scan.



(a) (b)

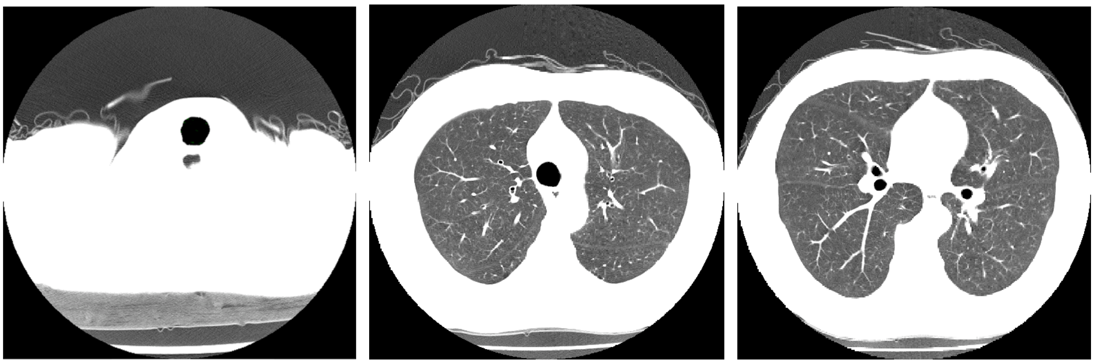
Fig.1: Difference between normal and abnormal (emphysema) lung scan.
(a) Normal lung field (b) Abnormal lung field with dark area (LAA)

### 2.2. Algorithm outline

The measurement approach consists of the following steps:

(1) Extraction of whole lung area (WLA)
(2) Extraction of bronchus regions
(3) Determination of low attenuation area (LAA)
(4) Removal of false-positive areas
(5) Determination of the LAA/WLA ratio

In step (1), the WLA area was simply determined by applying the thresholding technique to differentiate the lung area from the whole chest area. Most of the vessels, bones, and other organs on the scan were removed in this step. In step (2), the bronchus regions within the lungarea determined in the previous step, were also removed by the thresholding technique and the region growing technique in 3D space. The bronchus areas were shown as small air regions with round shapes surrounded by thin walls. However, their volume had to be removed from abnormal volumes. Figure 2 shows the extracted regions in three scans. Figure 2(a) shows the upper lung area including the start region (black area), and Figs. 2 (b) and (c) show the bronchus regions (black area) in the middle area of the lung. In step (3), the determination of LAA was also based on the thresholding technique but its value changed according to the position of the lung fields because of the variations in CT values depending on the area and the degree of diseases. However, the LAA had a CT value similar to that of air. Figure 3 shows the extracted area of the trachea. The size of the area was reduced when compared with the original tracheal regions on CT scans because the boundary area was blurred. In step (4), very small LAA areas within 5-voxel-region were removed as false-positive areas from the candidates in the previous step. These small regions could contain the actual LAA, but the precise measurements of these small lesions could not be determined by this approach. The black arrow in Fig. 4 shows a typical false-positive area. These areas were eliminated by calculating the CT value along the peripheral regions because they were surrounded by thin walls similar to the normal lung structures of the bronchus. Finally, the volume [mm3] of LAA regions in step (4) was divided by the volume [mm3] of the whole lung area (WLA) in step (2) to determine the ratio of LAA.



(a) (b) (c)

Fig.2: Tracheal and bronchus area (in black) extracted by region growing methods
(a) Upper scan of the lung area
(b) Middle scan with the tracheal region
(c) Middle scan with the bronchus regions

## 3. RESULTS

We employed 32 cases (15 normal and 17 abnormal) diagnosed by radiologists prior to the study. The abnormal cases were graded according to the degree of the diseases into three categories (moderate, intermediate, and severe) All cases were examined at the same hospital. The slice thickness and the reconstruction interval were 2.0mm and 2.0mm, respectively. The pixel size and the number of scans were changed from 0.546 to 0.625mm and from 105 to 161 scans, respectively based on the lung size of the patients.

With regard to the results of this study, the ratio in all normal cases were less than 0.02, and in abnormal cases, it ranged from 0.01 to 0.26. Figure 6 shows the comparison between the ratios [%] of the cases of emphysema and normal cases. The t-study showed that the difference between the two groups was statistically significant ($p<0.01$). A tendency for severe cases to have a larger value of the ratio such as more than 15%, was observerd. On the other hand, intermediate or moderate cases had a smaller ratio when compared with that of severe cases.

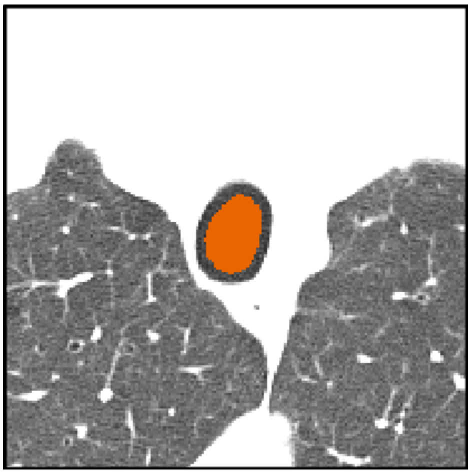


Fig.3: Tracheal region for determining the threshold value after reducing the original trachea area.

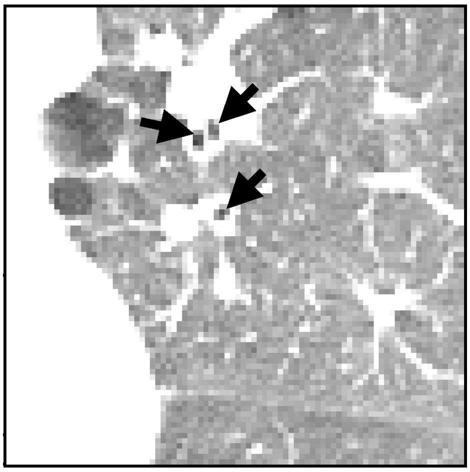
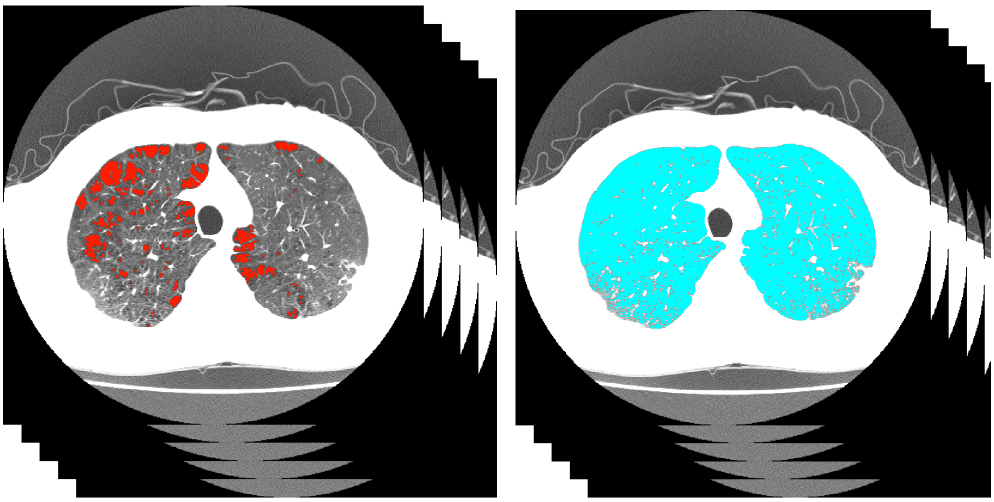


Fig.4 : Small bronchus regions (with black arrow). These areas have to be eliminated as false-positive areas



(a) (b)

Fig.5: Detected LAA area and whole lung fields.
(a) LAA area (b) Lung fields except bronchus regions

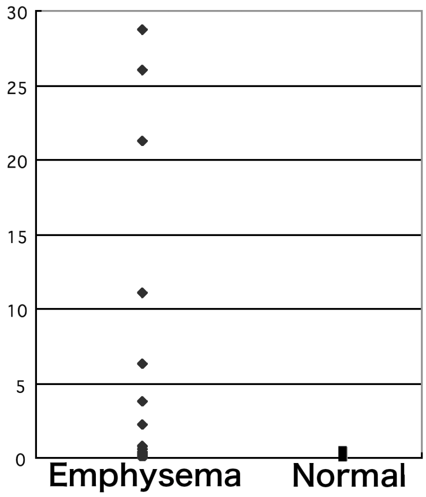



Fig6: LAA/WLA [%] distributions of normal and emphysema groups.

## 4. CONCLUSIONS

We have developed a quantitative measurement technique for pulmonary emphysema on 3D chest CT images. The performance of this technique was estimated by employing 32 cases diagnosed and graded by radiologists prior to the study. Although the number of cases we employed was not large, the effectiveness of our approach was confirmed throuth the results.

## ACKNOWLEDGEMENTS

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## REFERENCE

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