Automatic Extraction of Gound-glass Opacities on Lung CT Images by Histogram Analysis

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Abstract: In recent yeas, studies on computer aided diagnosis (CAD) using image analysis on CT images have been conducted with respect to various diseases. Extracting ground-glass opacities (GGO) on lung CT images is one of such subjects, though it has not found an established method yet. If the region of ground-glass opacities is large on CT images, it can be detected without much difficulty. On the other hand, if the region is small, it is still difficult to find it exactly. In the latter case, increasing overlooking possibility cannot be avoided according to smaller size of the region. To solve this difficulty, this paper proposes an automatic technique for extracting ground-glass opacities on lung CT images employing some statistical parameters of a gray level histogram and a differential histogram. The proposed technique is applied to some lung CT images in the performed experiment. The results are shown with discussion on future work.

Keywords: Ground-glass opacity, CT images, Histogram analysis, CAD

1. INTRODUCTION

In recent years, various imaging techniques have been introduced into medical fields as useful tools for providing helpful information in visual inspections by doctors. For example, ultrasound images, magnetic resonance images, moire topographic images, and X-ray computed tomography, etc., are those already established imaging techniques. Accordingly many related image processing techniques have been developed and reported with respect to these images. In X-ray CT images, several approaches have been reported to date for segmenting lung cancer regions. Most of them need a small number of knowledge-based schemes based on fuzzy logic or 3-D structure of blood vessel. But there haven't been proposed effective techniques yet for analyzing lung images.

There are many disease of the lung. For example, pneumonia, lung cancer and pulmonary emphysema, etc. There are many kind of pneumonia. For example, interstitial pneumonia, carinii pneumonia, and bronchopneumonia, etc. In these diseases of the lung, interstitial pneumonia and initial state of lung asbestosis, etc., show ground-glass opacities as a symptom of the lung disease. Ground-glass opacity is a light gray shadow in which we can recognize blood vessels. If the area GGO occupies is large on the CT image, the laesio part can be extracted comparatively easily. However, the possibility to overlook the light gray shadow becomes higher when GGO exists as a small area.

There is no practical method of extracting ground-glass opacity regions from lung CT images yet. It is therefore required to devise an efficient algorithm for analyzing lung images and specifying ground-glass opacity regions from the images. This paper presents a technique for performing the analysis over lung CT images.

2. PROPOSED TECHNIQUE

2.1. Parameters and procedures

We define the mean value, the variance, the skewness and the kurtosis of a histogram as feature parameters of ground-glass opacities. The skewness is the third momentum and is a parameter showing the extent of how distorted the distribution of a histogram is from symmetric distribution. On the other hand, the kurtosis is the forth momentum and is a parameter which shows the extent of how the distribution of the histogram spreads irrespective of a symmetric or an asymmetric distribution.

The proposed technique is separated into 3 main steps. In the first place, we extract regions of interests (ROIs) on the lung region from the given CT slice images. In the second place, candidate regions for ground-glass opacities are extracted based on the mean value and the variance of a gray level histogram of the processed image. Finally, a ground-glass opacity region is identified from the candidate regions based on the skewness and the kurtosis of a differential histogram of the image. Flow of the process is shown in Fig.1.

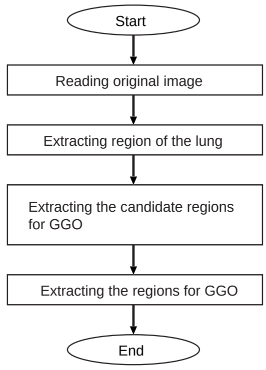


Fig. 1. Configuration of the developed blimp system

2.2. Extracting the region of the lung

There are black regions in the periphery of the lung CT images. Since these regions are not necessary for GGO analysis, they are eliminated in the first place. Gray levels of the black regions are simply changed from 0 to 255 representing white level.

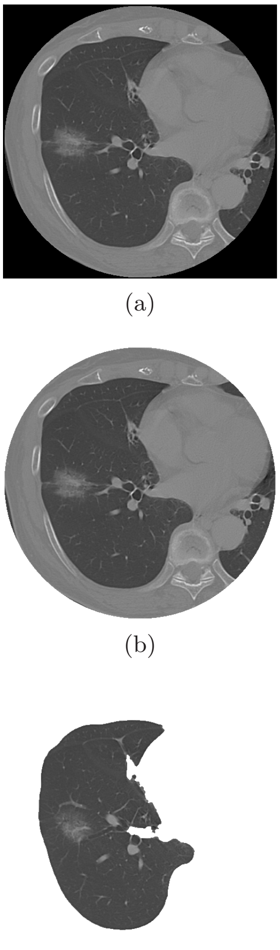
After eliminating outer black regions, we apply median filtering, binarization, and labeling to the CT images. When we apply labeling to the CT images, the largest black area is regarded as a lung region. The result of extracting the lung region is shown in Fig.2.

2.3. Extracting the candidate regions for ground-glass opacities

We make gray level histogram of ground-glass opacities for each CT image which can possibly be recognized as having ground-glass opacities regions. The mean value and the variance for normalized gray level histogram $P(i)$ are given by the following equations;

$$\mu = \sum_{i=0}^{n-1} iP(i) \quad (1)$$

$$\sigma^2 = \sum_{i=0}^{n-1} (i-\mu)^2 P(i) \quad (2)$$



(a) (b) (c)

Fig. 2. Extracting lung regions: (a) The original image; (b) Elimination of outer black regions; and (c) Extracted lung region.

The range of distribution of the mean value and the variance for ground-glass opacities are decided by using Eqs. (1) and (2). If the mean value and the variance of the n × n local area on an extracted lung region stay within the range of the distribution obtained from Eqs. (1) and (2), location of the center pixel in the local area is marked as the pixel included in the candidate regions for ground-glass opacities.

2.4. Extracting the regions for ground-glass opacities

We make differential histogram of ground-glass opacities for each CT image which can possibly be recognized as containing ground-glass opacities pixels. The skewness S and the kurtosis K for a normalized differential histogram $P(i)$ are given as follows;

$$S = \frac{1}{\sigma^3} \sum_{i=0}^{n-1} (i-\mu)^3 P(i) \quad (3)$$

$$K = \frac{1}{\sigma^4} \sum_{i=0}^{n-1} (i-\mu)^4 P(i) \quad (4)$$

where μ and σ are defined by Eqs. (1) and (2), respectively.

The range of distribution of the skewness and the kurtosis for ground-glass opacities are decided by using Eqs. (3) and (4). If the skewness and the kurtosis in the candidate regions are within the range of the distribution obtained from Eqs. (3) and (4), the regions are regarded as a ground-glass opacities region.

3. EXPERIMENTAL RESULT

3.1. Decision to the range of the distribution for feature parameters

We made an experiment employing 4 cases containing 64 CT slices. Case1, case2, case3, and case4 contained 10 slices, 29 slices, 15 slices and 10 slices, respectively. We fed lung CT images into PC and transferred them to EWS (PC-Linux: Pentium 400MHz) using Ethernet and performed the experiment on the workstation. The image size and the gray levels are 512 × 512 and 256, respectively. In the experiment for extracting candidate GGO regions, we used the mask of 51 × 51 pixels. This mask size was determined experimentally.

The ranges of the distribution for the mean value, the variance, the skewness, and the kurtosis are decided by experiment as follows;

$$\begin{aligned} 82 &< \mu < 113 & (5)\\ 137 &< \sigma^2 < 500 & (6)\\ -0.000013 &< S < 0.000903 & (7)\\ 0.000002 &< K < 0.00042 & (8) \end{aligned}$$

Figure 3 shows examples of differential histograms for a ground-glass opacity region, and a normal region. Figure 4 shows results of the four cases based on the presented method.

4. DISCUSSION

In order to extract candidate region of ground-glass opacity, we use mask of 51 $\times$ 51 size. If the mask size is smaller, the regions having pixel values over the mean value do not satisfy Eq. (5) and the regions of ground-glass opacity are divided into some regions. It is therefore a comparatively large mask becomes necessary. In the performed experiment, the optimum mask size was experimentally determined. In the employed cases, there are large shadow and small shadow. We find that the region of ground-glass opacity is extracted independently to the size of the shadow. But there are some cases where the regions including normal regions are extracted. This fact claims that the mask size should be larger.

In order to extract regions of ground-glass opacity, we defined the skewness and the kurtosis as feature parameters. The histograms of ground-glass opacity have almost the shape of normal distribution because differences of gray levels between pixels in the ground-glass opacity regions are not so large as described above. On the other hand, normal regions and the blood vessel regions are no differences in gray levels between pixels. Therefore, we think that the regions of ground-glass opacity and the normal regions show different shape of differential histogram as shown in Fig. 3.

5. CONCLUSIONS

We proposed an algorithm by which ROIs were extracted from CT images of a lung and the ground-glass opacity regions were identified from the extracted ROIs. As a result, lung regions were extracted automatically on all slices. Ground-glass opacity regions were also extracted automatically, but low contrast regions containing ground-glass opacity regions were not identified exactly. This needs further investigation. An improved method should be applied to a larger number of lung images.

References

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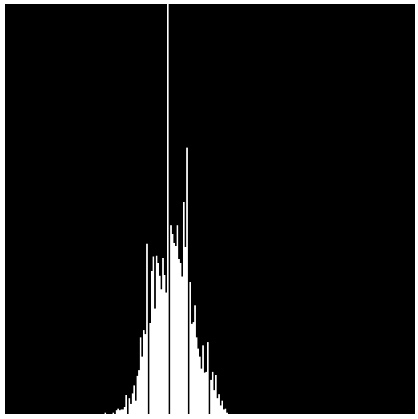
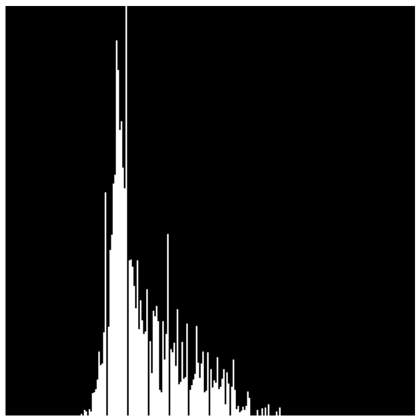
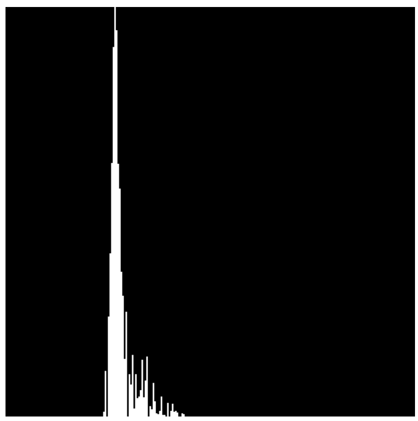


(a)



(b)



(c)

Fig. 3. Examples of differential histogram: (a) A histogram on the region of GGO; (b) A histogram on the normal region; and (c) A histogram on the normal region including a blood vessel region.

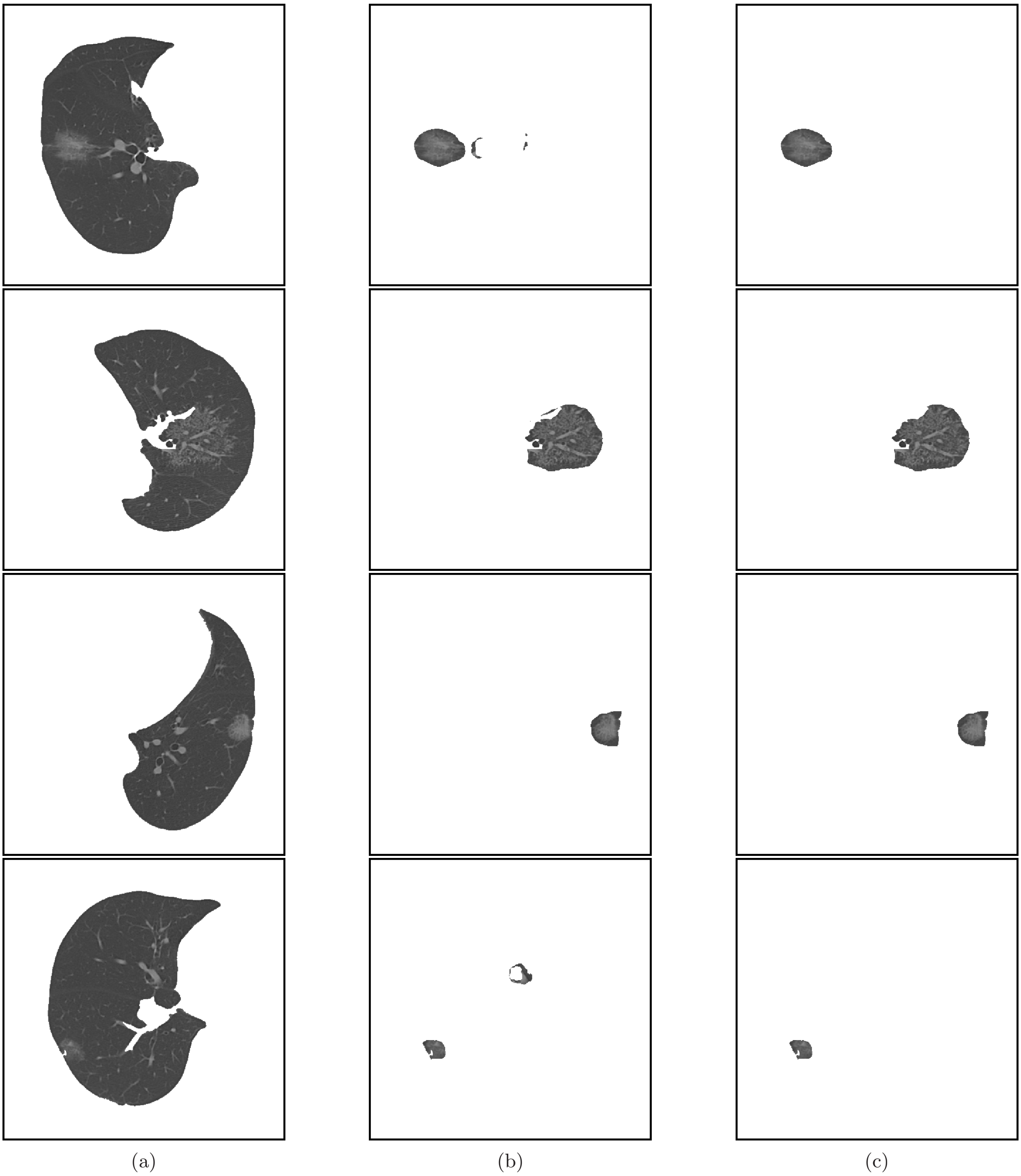


Fig. 4. Results of extraction: (a) Images of the lung; (b) Candidate regions of ground-glass opacity; and (c) Regions of ground-glass opacity.