Extraction of Lung Cancer Area in Digital CT Images

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Abstract

In recent years the quoit filter processing, that is a kind of filtering processing of mathematical morphology, has been developed as a technique to automatically extract the candidates of lung cancer lesion by a lung cancer examination system using X-rays CT, but there are some problems such as low process speed and the extraction accuracy. In this study we proposed some new image recognition methods for the purpose of raising identification rate by the image processing technique as a remedy of these problems. Firstly we analyze the characteristics of sample images of the lung cancer and confirmed the effectiveness of the methods we propose.

Introduction

In recent Japan the death toll by the lung cancer showed a tendency of remarkable increase and became the first place of the male death cause in 1993. Discovery of the early cancer by lung cancer group medical examination is the best measures and becomes the most important process in the medical examination and treatment now to deal with this situation. This lung cancer is classified in squamous cancer (a little less than 40%), gladular cancer (about 40%). Since the squamous cancer occurs at the big bronchus which is near the hilum of a lung, subjective symptoms such as a cough or the bloody phlegm appear from the early days. Therefore early detection is possible by the expectoration cytodiagnosis inspection or endoscopic inspection. The construction of LSCT, Lung cancer Screening system by CT, based on X-rays CT with higher ability for small lung cancer detection in comparison with the conventional roentgenography has been tried. And the trial of the patrol examination by the examination car of the LSCT deployment is performed now and attracts attention as new means of medical examination for the small lung cancer .

But the burden of the doctor who did reading shadow with about 30 slices per checker became heavier. It has been reported that about 30% of the lungs tumor of the chest measured by LSCT has been overlooked. Therefore image processing by CAD, Computer-Aided Diagnosis, has importance as a tool which reduces the doctors' burden. The study of the method which automatically extracts candidate lesions in the CT images and shows only the found section of the images to the doctor is being developed. In this study some methods of lung cancer recognition is proposed to discover lung cancer at early stage with higher identification rate.

Automatic recognition method for a candidate lesion

The quoit filter processing, which we call Q-filter processing, is a kind of filtering handling of mathematical morphology developed for the automatic extraction of the candidate lesion. Lesion shadow is solitary, and the Q-filter specifically reacts for solitary shadow. In this report, we show some experimental results of the extraction with the case that a blood vessel and a lesion overlap each other. By using Q-filter together with GWDT we can extract a lesion of every size without being affected by neighboring shadow.

Binarization methods

Binarization is a process which convert grayscale images into black/white images. Let us denote the density value of a pixel (x, y) of a grayscale image as $f(x, y)$, and the threshold value by T. Then binarization of the image will be performed as the operation shown in eq.(1) or eq.(2) in general. In (1), pixels with density value T or above are converted into black, and those with brightness value less than T are converted into white. In (2), pixels with density value between T_L and T_H are converted into black, and others are converted into white. We show this operation conceptually in Fig. 1.

$$f_T(x,y)=\begin{cases}1 & f(x,y)\geq T\\ 0 & f(x,y)<T\end{cases} \quad (1)$$

$$f_T(x,y)=\begin{cases}1 & T_L\leq f(x,y)\leq T_H\\ 0 & others\end{cases} \quad (2)$$

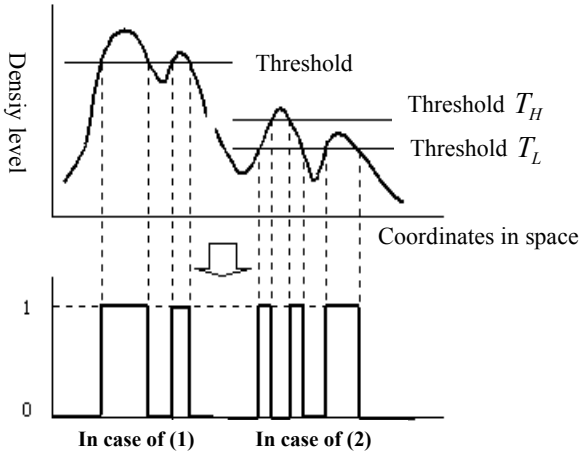


Figure 1. *Conception diagram of binarization*

Expansion-contraction methods

The process of converting the density value of all the neighboring pixels of the background into 0 is called contraction and the process of converting those into 1 is called expansion. These two processes are not commutative. When an image is expanded after contracted, small dents and holes will be removed,

whereas when it is contracted after expanded, small projections and isolated dots will be removed. We can use this method to remove the noise of figures or to detect an abnormal point of figures (see Fig. 2).

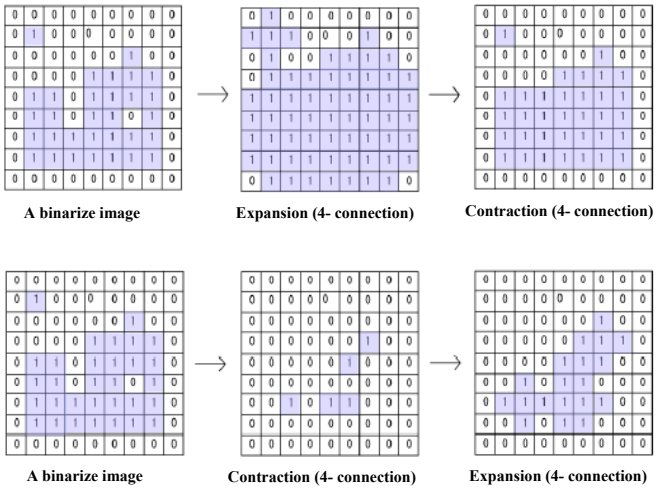


Figure 2. *The shrinkage and a conception diagram of the expansion*

Emphasis of the lesion shadow by GWDT

When a blood vessel shadow and a lesion shadow overlap each other on a two-dimensional image, we apply the gray weighted distance transform, which we call GWDT, to emphasize the focus region beforehand as preprocessing. By this processing there rises a big difference in density value between blood vessel and the focus region, so that extraction by the Q-filter becomes more effective.

Here, as a transfer function, a gamma correction is adopted, as shown in Fig. 3, and S character curve is obtained. For example, we multiply the gamma value more than 1 by the tone value of an input dot if it is more than the mean value. The tone value of an input dot which is less than the mean value is multiplied by gamma < 1.

As shown in Fig. 3, maximum value of an input is set to max and the minimum value is set to min. The range of an effective range will be set to 0-Max (usually 255), and min-max will be elongated now by 0-Max. It asks for a transfer function as follows.

The general formula of concentration conversion:

$$y = Max\left(\frac{x}{Max}\right)^{\gamma} \tag{3}$$

where

γ<1 when making it brighter,

γ>1 when making it darker.

Definition of Q-filter and its physical meaning

The shape of a cancer focus is near to a sphere, and X-rays absorption factor is higher than neighboring lung organizations and this is reflected on radiographic film additively and supposes that it is displayed as kindred spirit circle exclusivity shadow. A Q-filter is defined as the following.

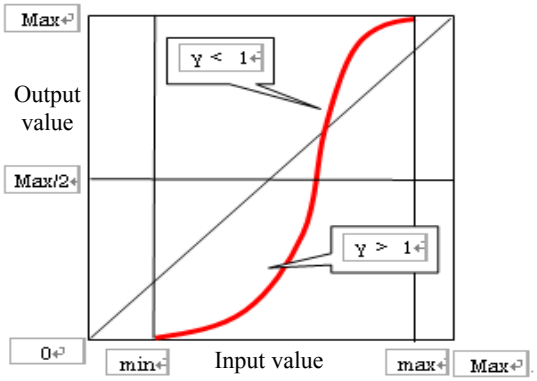


Figure 3. *Gamma correction*

$$q(x,y) = (f \oplus D)(x,y) - (f \oplus R)(x,y) \tag{4}$$

$$(f \oplus D)(x,y) = \max_{(x_1,y_1)\in K_D} \{f(x-x_1, y-y_1) + D(x_1,y_1)\} \tag{5}$$

$$(f \oplus R)(x,y) = \max_{(x_1,y_1)\in K_R} \{f(x-x_1, y-y_1) + R(x_1,y_1)\} \tag{6}$$

where,

$f(x,y)$: input image,

$q(x,y)$: output image,

$D(x,y)$: disk type filter function,

$R(x,y)$: ring type filter function,

K_D: domain of the disk type filter,

K_R: domain of the ring type filter.

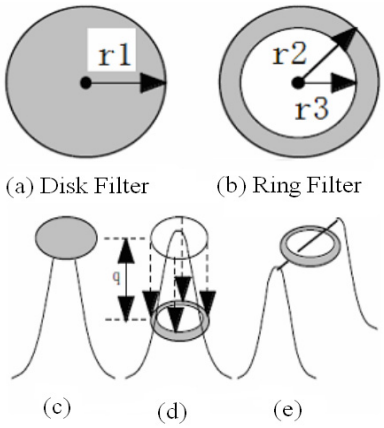


Figure 4. *Concept of Q-filter*

Here the filter functions $D(x,y)$ and $R(x,y)$ are defined as the following.

$$D(x,y) = \begin{cases} 0, & x^2+y^2 < r_1^2 \\ -\infty, & others \end{cases} \tag{7}$$

$$R(x,y) = \begin{cases} 0, & r_2^2 \le x^2+y^2 \le r_3^2 \\ -\infty, & others \end{cases} \tag{8}$$

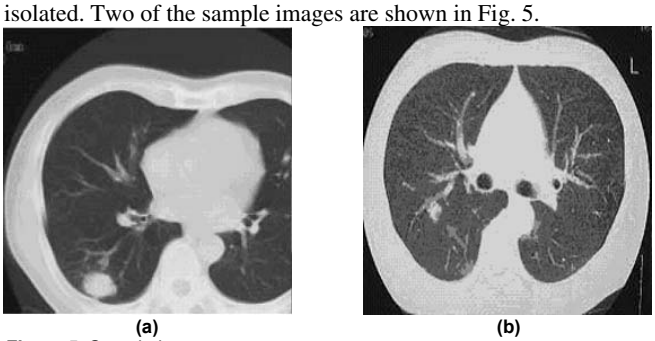
The concept of Q-filter is shown in Fig. 4. In addition, we shall usually put *r1 = r3*.

Two filters are used to cover each area conceptually from the top (Fig. 4 (c) (d)). Pitch difference q occurs between the disk and the ring if a ring filter falls in, in the case of solitary shadow to the bottom. We extract solitary shadow selectively in this way.

Experiment of automatic extraction of the lung cancer region with Q-filter

Sample Images

All the X-rays images which I used are CT images with 256*256 pixels. Every image has a cancer lesion of more than 10 mm in diameter. We can divide them into three groups. In the first four images, {a, b, c, d}, cancer cells stick to the wall surface of lung, in the second two images, {e, f}, cancer cells stick to blood vessels, and in the third four images, {g, h, i, j}, cancer cells are isolated. Two of the sample images are shown in Fig. 5.



(a) (b)

Figure 5. *Sample images*

Experiment

The schematic diagram of our experiment is shown in Fig.6. We show the revision values of GWDT for each image in Table 1 and the radius of each disk filter and ring filter in Table 2.

Table 1. Non-linear revision value

Image No.	a	b	c	d	e	f	g	h	i	j
Revision Value	2	3	1.5	3	3	2	2	2.5	2	3

Image No.	a	b	c	d	e	f	g	h	i	j
R1	1	1	1	1	1	1	1	1	1	1
R2	11	9	5	16	9	3	15	15	10	15
R3	12	10	6	17	10	4	16	16	11	16

Table2. Radius values of the disk filter and the ring filter [mm]

Result

We show the experimental result in Table 3. In addition, we show the binarized images and output images of Fig.5(a) and (b) in Fig.7(a-1) and (b-1) and Fig.7(a-2) and (b-2), respectively. We also show the processed images by GWDT and output images of Fig.5(a) and (b) in Fig.8(a-1) and (b-1) and Fig.8(a-2) and (b-2), respectively. Finally, we show the expanded images and output images of Fig.5(a) and (b) in Fig.9(a-1) and (b-1) and Fig.9(a-2) and (b-2), respectively.

Discussion

We processed 10 sample CT images by using three different preprocess method and a Quoit filter. The following are observed;

1. It turns out that Q-filter processing is not influenced by the line shades, such as a blood vessel shadow and lung tissue, and an isolated cancer part is clearly extracted because of its feature of being spherical in shape.

2. Comparing the binarization method with the expansion method, the expansion method was able to divide a cancer cell from blood vessel shadows more clearly. As for the binarization method, it is difficult to decide the threshold value especially when the density value of these two shadows are close Thus we can say the combination of expansion and Q-filter is effective for extraction.

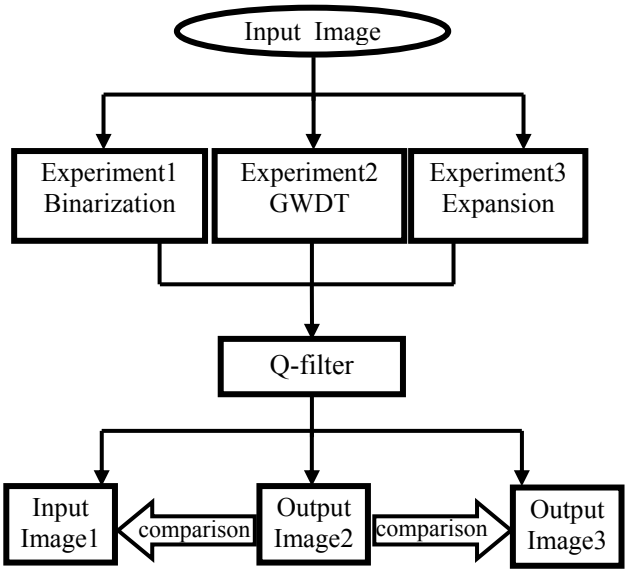
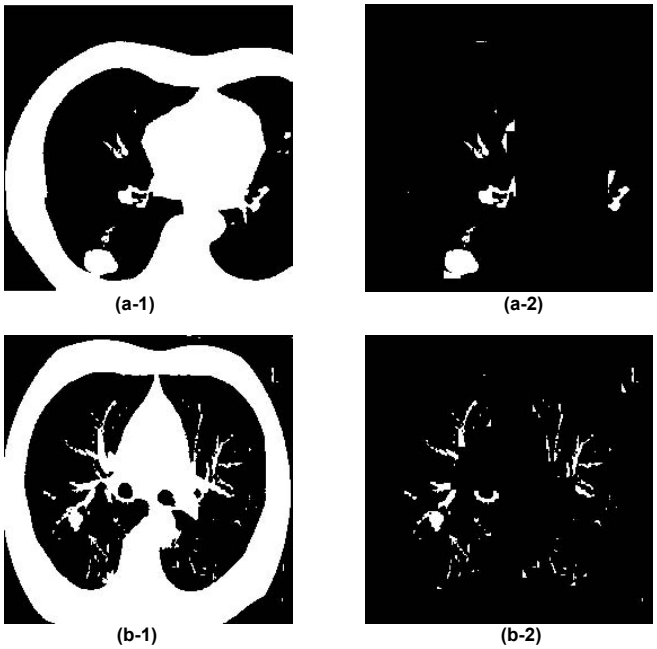


Figure 6. *The algorithm of the Q-filter*



(a-1) (a-2)

(b-1) (b-2)

Figure 7. *Binarized images (*-1) and output images (*-2)*

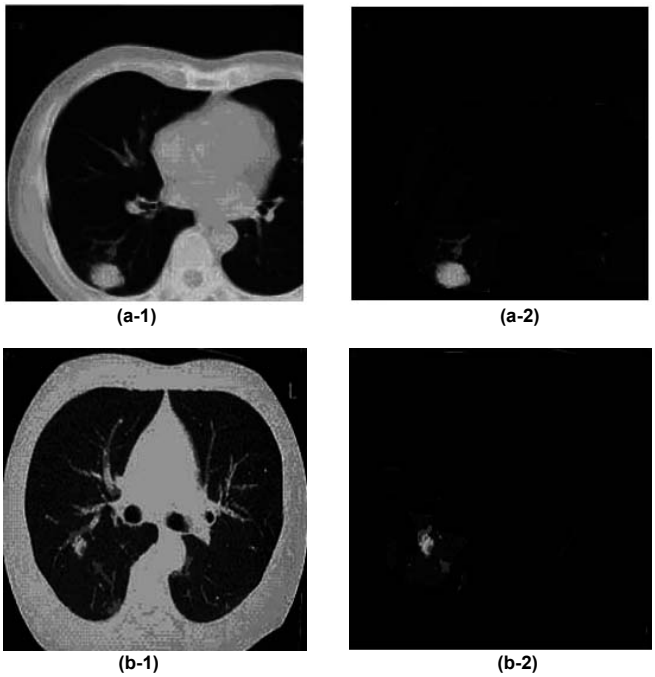


Figure 8. *Processed images by GWDT (*-1) and output images (*-2)*

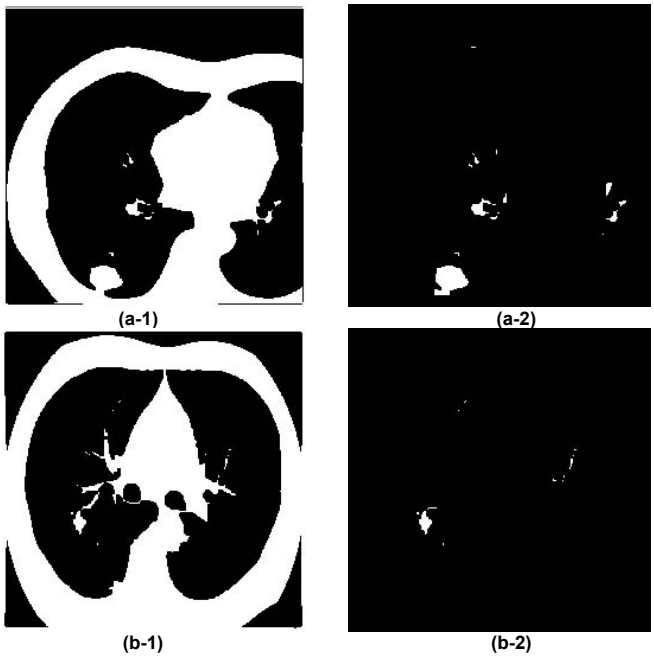


Figure9. *Expanded images (*-1) and output images (*-2)*

3. Comparing the expansion method with the GWDT method, GWDT was observed better. The cancer cell area less than 5 mm almost dissapeared after the expansion processed and was unable to be extracted. When an image is processed by GWDT method, the contrast between bright and dark areas is emphasized, and the lesion region was also emphasized. Thus GWDT reduces the influence of interference by blood vessels.

4. From the discussion 1 through to 3, the combination of GWDT preprocess and Q-filter process is the best of three to extract lung cancer lesion candidate in a CT image..

Table3. Overlook rate

	Success	Failure	Overlook rate
Extraction1	10	0	0%
Extraction2	10	0	0%
Extraction3	10	0	0%

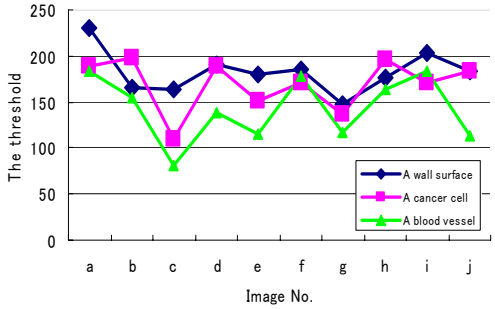


Figure10. *Brightness stairs value*

Conclusion

In this study we proposed some image processing methods using binarization, GWDT, expansion and Q-filter to extract candidate lesions of lung cancer. We examined that GWDT is very effective to make original CT images more easy to handle with Q-filter from our experiment.

As a future work we are planning to examine the effectiveness of other combination of preprocess and process methods such as the combination of GWDT and variable Q-filter.

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Author Biography

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