Extraction of Lung Cancer Area in Digital CT Images

Fei Chen and Shigeru Kitakubo; Dept. of Systems Engineering, Nippon Institute of Technology; 4-1 Gakuendai, Miyashiro, Saitama,345-8501, JAPAN

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 examined the technique of new image recognition by changing filter size for lesion shadow flexibly 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 technique 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%). The subjective symptoms such as a cough or the bloody phlegm appear from the early days, and I watch expectoration cytodiagnosis inspection and, as for the squamous cancer, early detection by the boundary diagnosis is possible to occur at the big bronchus which is near to a hilum of a lung. The construction of lung cancer examination system LSCT(Lung cancer Screening system by CT) based on high X-rays CT of the 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 the lungs tumor of the chest measured by LSCT has been overlooked about 30% probability. Therefore CAD (Computer-Aided Diagnosis) which reduces the doctors' burden proves the importance of image processing. The study of the method which largely reduces the number of the indication screens to the doctor is pushed forward by extracted candidate lesion shadow automatically, and showing only the found section of the candidate shadow to the doctor. For the early detection of the lung cancer, a lung cancer examination system by the X-rays CT is used. In this study a technique of new image recognition is established in attention to lung cancer, to discover lung cancer at early stage with higher lung tumor identification rate by the image processing.

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 which is developed for the automatic extraction of the candidate lesion. Lesion shadow is solitary, and the Q-filter specifically reacts for solitary shadow by the filter which developed with the supposition that there is. In this report, we show some experimental results of the extraction with the case that it seems a blood vessel overlaps with a lesion. By using Q-filter together with GWDT we can extract a lesion of every size without being affected by neighboring shadow.

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.

$$q(x,y) = (f \oplus D)(x,y) - (f \oplus R)(x,y) \tag{1}$$

$$(f \oplus D)(x,y) = \max_{(x_1,y_1)\in K_D} \{ f(x-x_1, y-y_1) + D(x_1,y_1) \} \tag{2}$$

$$(f \oplus R)(x,y) = \max_{(x_1,y_1)\in K_R} \{ f(x-x_1, y-y_1) + R(x_1,y_1) \} \tag{3}$$

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.

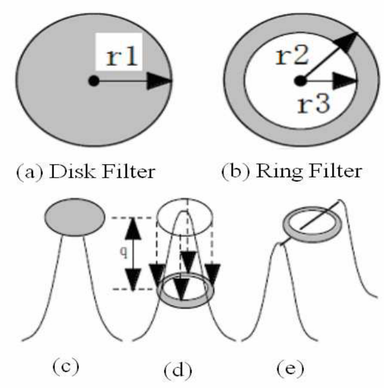


Figure 1. *Concept of Q-filter*

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

$$D(x,y) = \begin{cases} 0, & x^2 + y^2 < r_1^2 \\ -\infty, & others \end{cases} \quad (4)$$

$$R(x,y) = \begin{cases} 0, & r_2^2 \le x^2 + y^2 \le r_3^2 \\ -\infty, & others \end{cases} \quad (5)$$

The concept of Q-filter is shown in Fig.1. In addition, we shall usually put $r1 = r3$.

Two filters are used to cover each area conceptually from the top (Fig.1 (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.

Q-conversion and Q-inverse conversion

The algorithm of Q-filter is shown in Fig. 4. First, according to formula (1) - (3), D filter and R filter are applied to an input picture, and the difference of the result saved. In this process Q-filter is used once, thereby, the isolation shade takes out a sufficiently big output. However, D filter and R filter are applied once again to obtain $q(x, y)$ output, and the difference of each result is saved. The combination of 1st and 2nd Q-filter will be called Q-inverse conversion for convenience.

Emphasis of the lesion shadow by GWDT

When a blood vessel shadow overlaps with lesion shadow 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. 2, 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.

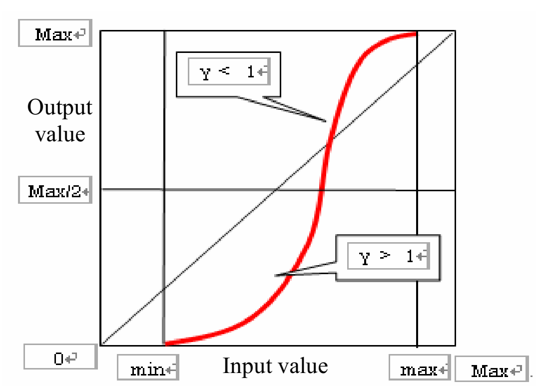


Figure 2. *Gamma correction*

As shown in Fig. 2, 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:

$$y = Max\left(\frac{x}{Max}\right)^{\gamma} \quad (6)$$

where
$\gamma<1$ when making it brighter,
$\gamma>1$ when making it darker.

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

Sample Images

We use 10 sample images with 256*256 pixels in size, 6 of which are real X-ray images of a lung with cancer lesions of more than 10 mm in diameter, and the other 4 are CG images with circles or rectangles which we call false CT images.

We show 3 real CT images in Fig.2 (a)-(c) and 3 false CT images in Fig.2 (d)-(f).

Experiment

The schematic diagram of experiment is shown in Fig.4. We show the revision values of GWDT for each image in Table1.

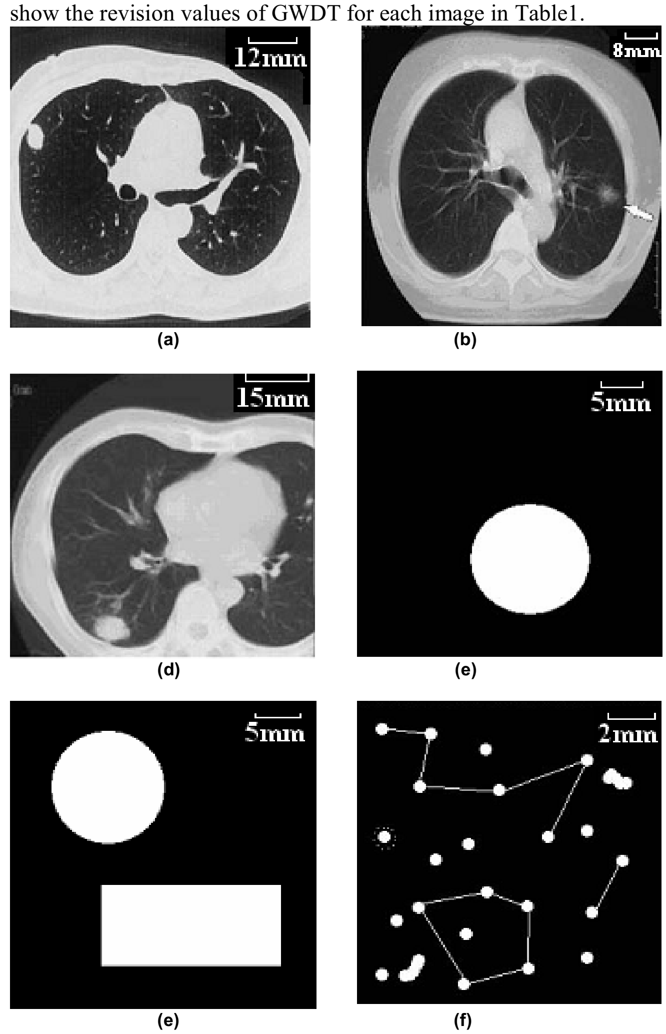


Figure 3. *Sample images: (a)-(c) real CT images(d)-(f) false CT images*

Table 1. Non-linear revision value

Image No.	(a)	(b)	(c)	(d)	(e)	(f)
Revision Value (γ)	4	2	3	1	3	2

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

Image No.	(a)	(b)	(c)	(d)	(e)	(f)
R1; radius of a disk filer	1	1	1	5	5	7
R2; inside radius of a ring filter	16	16	10	6	6	7
R3; outside radius of a ring filter	17	17	11	7	7	12

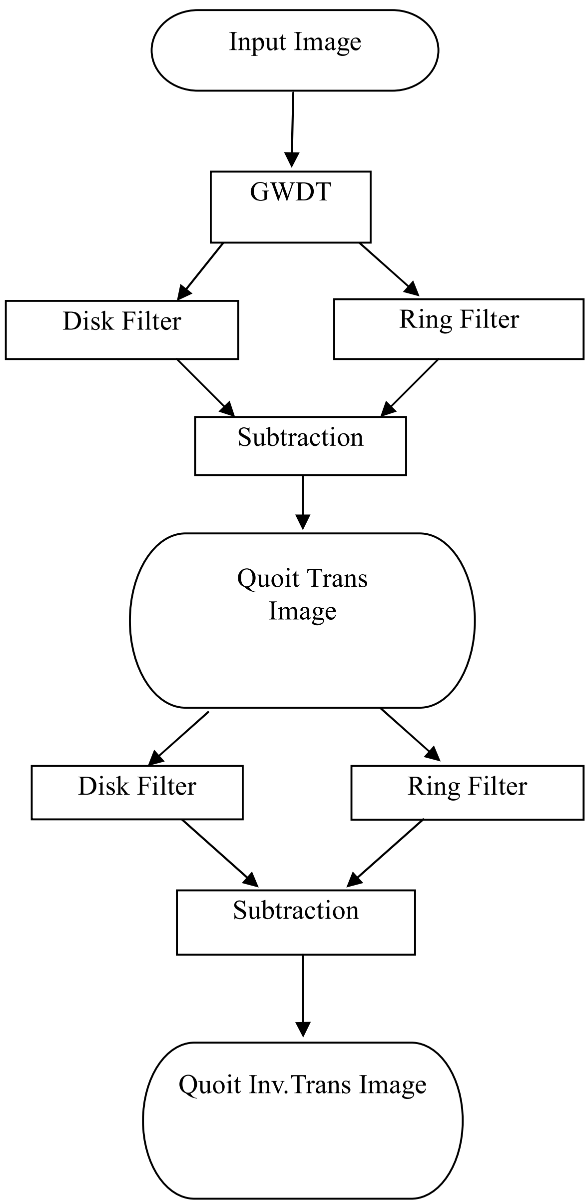


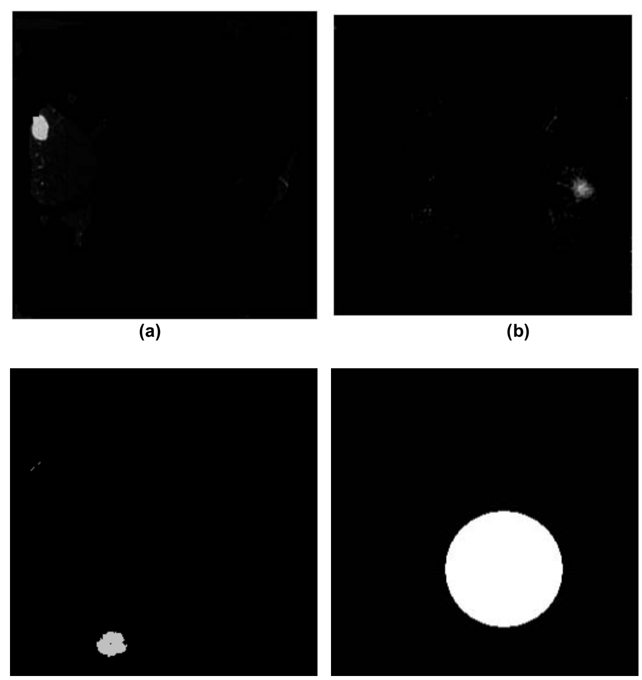
Figure 4. *The algorithm of the Q-filter*

Result

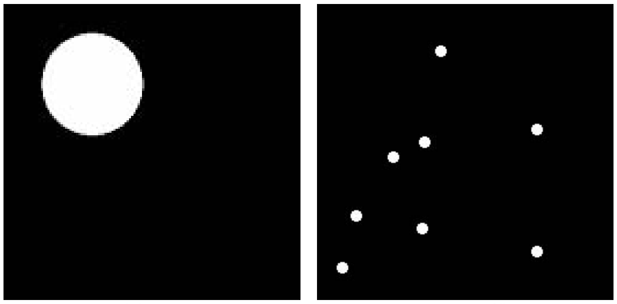
We show the experimental results in Table 4. In addition, we show three processed images after GWDT in Fig.5, and 6 images after Q-filter extraction in Fig.6.

(a) **(b)** **(c)**

Figure 5. *Images after the GWDT*



(a) **(b)** **(c)** **(d)**



(e) (f)

Figure 6. *Images after Q-filter extraction*

Discussion

1. By GWDT the focus part was emphasized, and it became clear that the influence of the filter depression disturbance by a blood vessel part is reduced.

2. 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 isolation cancer focus part is vividly extracted to the feature of being close to the globular form of a lung tumor.

3. From the extraction result is shown in Table 4, although a lung tumor of 5mm or more was extracted, still have a low extraction rate for the lung tumors with smaller diameter.

4. As shown in Table 1, when not using GWDT, the overlooked rate with a bad extraction rate of the cancer cell of lungs was 40%. This is because the organization of the Gang cell and others contacts and cannot recognize as an independent cancer cell.

Table3: Extraction result without GWDT method

	Extraction success	Extraction failure
False CT image	4	0
Real CT image	2	4
Overlookedt rate	40%	

Table4: Extraction result with GWDT method

	Extraction success	Extraction failure
False CT image	4	0
Real CT image	5	1
Overlooked rate	10%	

Conclusion

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

As a future work we are planning to examine the effectiveness of the combination of GWDT and variable Q-filter.

References

[1] Y. Isobe et. al., Characteristics of Quoit Filter, a Digital Filter Developed for the Extraction of Circumscribed Shadows, and Its Applications to Mammograms, Trans.Inst. Electron.Inform. Communi.Engnr. Jpn, Vol.J76-D-2, No.2, pp. 279-287 (1993).

[2] Jun-ichiro Toriwaki et al., Fundamental Properties of the Grey Weighted Distance Transformation, Trans.Inst. Electron.Inform. Communi.Engnr. Jpn, (D)60 - D(12):1101-1108 (1977).

[3] A. Rosenfeld and J. L. Pfaltz: "Sequential operations in digital picture processing", J. Assoc. Comput. Mach,. 13, 4, p.471 (996).

[4] D. Rutovitz: "Data structures for operations on digital images ", in G. C. Cheng et al., Pictorial Pattern Recognition, Thompson Book Co., Washington, D. C. p.105 (1968).

[5] G. Levi and U. Montanari : " A grey-weighted skeleton", Inf. & Control, 17, p.62 (1970).

Author Biography

Chen Fei is a graduate student of Nippon Institute of Technology. She is now studying image processing in Kitakubo Laboratory of Nippon Institute of Technology.