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Research Article

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Solitary pulmonary nodules detection based on dot-filter and region growing

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ABSTRACT

The methods we proposed is the Dot-Filter and Region growing for the detection of solitary pulmonary nodules. Firstly, Two-dimensional dot-filter is constructed by using Two-dimensional Hessian matrix, and is used to detect the solitary pulmonary nodules. For the CT values of the vessels and airway do not conform to Gauss distribution, lots of normality treated as nodules will emerge after the way used above. Finally, we use Region growing and Tree-dimensional Hessian matrix to eliminate the false-positive. It is a method with high speed and high accuracy.

Key words*:* Detection of solitary pulmonary nodules; Hessian matrix; Dot-Filter; Region growing

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INTRODUCTION

Lung cancer is one of the most common cancers in our life and the rate of incidence and mortality of lung cancer increases rapidly. Among all kinds of cancers lung cancer is the leading cause of deaths all over the word, and someone forecast that there will be 5.5 million people with lung cancer, among which there will be 4 million people died by 2020[1].If the lung cancer can be discovered earlier and treated in time, the patients are able to survive more likely[2]. Lung cancer is lung nodule in the early time, so, it is especially important for the patients to receive detection and diagnose early. When a radiologist screen the CT images, he will have to read a large number of images, and unfortunately he will overlook some lung nodules. Thus, using a computer-aided diagnostic(CAD) scheme to detect lung nodules is important because of it can provides radiologists with the information of the lung nodules in the CT images, helping the radiologists save much time.

The computer-aided diagnostic (CAD) scheme can detect the solitary nodules automatically in the lung pulmonary, decreasing the miss rate. But for solitary nodules detection, the current methods are not satisfying enough. A simplified model based on level set method(referred to as the C2V model),proposed by Chan and Vase ,combined the maturity theory of level set method ,resolve the revolution of the curve, still remaining the advantage of the diversification of adaptive topology of level set method, is suitable for gradient and no gradient contour detection at the same time and is easy to visualize and fast convergence[3].After the C2V method has been put forward, a lot of research and application are achieved, and many scholars have studied the object’s segmentation and tracking based on C2V model of constrained shape. But most studies can only extract the trained-shape and can only extract one target from an image [4].Some other methods such as the method named Dot Filter, extract solitary nodules. However, the solitary nodules extracted include many false positives such as parts of vessels and the cross section of two vessels or even more. The reason causes that is that the nodules and vessels in the lung image does not conform to Gauss distribution, but be supposed to conform to Gauss distribution. Documents [5-7] use Tree-dimensional Hessian matrix to extract objects, leading to the appearance of disconnection of the vessels.

In this paper, we propose the method of detection of Solitary pulmonary nodules in a two-dimensional CT image Based on Dot-Filter and Region growing. The method to detect solitary pulmonary nodules consists of four steps .Step 1, because the dot-filter does not work well when the original image has noise. We use Gaussian function to convolute with f(x, y) which represents an original image. Step 2, with dot-filter constructed by two-dimensional hessian matrix constructed by every pixel f (i, j) in the image we obtained in Step 1 we extract suspected nodules. Step 3, we use the suspected nodules as seed for region growing based on the gray scale defined 130.Step 4, we will use all the images obtained in Step 3 as three-dimensional data for detecting solitary nodules with three-dimensional hessian matrix which is similar to two-dimensional hessian matrix in Step 2.The flow chart of the method is shown in Figure 1.

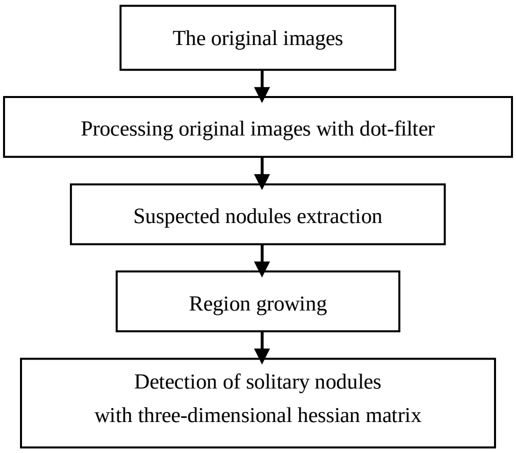


Fig.1: the specific flow chart of the method detecting solitary pulmonary nodules

DOT-FILTER CONSTRUCTED BY HESSIAN MATRIX

Qiang Li [8] proposed that using hessian matrix to construct dot-filter can effectively extract dot-like objects. To the medical CT images, it is more effective enhancement of local structure based on the shape of organization. On two-dimensional images, use the dot model conformed to Gauss distribution to represent a nodule as well as line model, the equation is:

$$d(x, y) = \exp\left\{-\frac{x^2+y^2}{2\sigma^2}\right\} \qquad (1)$$

$$l(x, y) = \exp\left\{-\frac{x^2}{2\sigma^2}\right\} \qquad (2)$$

Here, d(x, y) is a dot expression consisted of a 2D Gaussian function represents dimension of the dot in a Gaussian function. According to the variety value of σ which represents the scale of dot and line in Gaussian function, we simulate the image of Gaussian function d(x, y) and l(x, y) as Figure 2:

Fig.2: Simulated model of Gaussian dot

For an original two-dimensional image, we use its second derivatives to design our enhancement filters. Suppose a 2D image f(x, y) has four second derivatives represented by f_{xx}, f_{xy}, f_{yx} ,and f_{yy} ,where $f_{xy} = f_{yx}$ its two-dimensional hessian matrix H of the pixel in the image is shown as follows

$$H = \begin{bmatrix} f_{xx} & f_{xy} \\ f_{yx} & f_{yy} \end{bmatrix} \qquad (3)$$

Supposeλ_1, λ_2 are the eigenvalues of H, and satisfied that abs (λ_1) is bigger than abs(λ_2). if $|\lambda_1|<|\lambda_2|$,exchange them. The two expressions below mean that the dot and line relative to $|\lambda_1|$, $|\lambda_2|$ must satisfy.

$$\text{dot}: \lambda_1 = \lambda_2 = -\frac{1}{\sigma^2} < 0 \quad (4)$$

$$\text{line}: \lambda_1 = -\frac{1}{\sigma^2} < 0,\ \lambda_2 = 0 \quad (5)$$

Qiang Li [9] proposed an effective enhancing -filter which has two criterion:
(1) Sensitive. For example a dot-filter must have a acute output when a dot area with a good sensitive is input. We use g $(\lambda_1, \lambda_2) = |\lambda_2|$ denotes the Magnitude Function, which is relative with the sensitive. Then we can find that to a dot g $(\lambda_1, \lambda_2)>0$ and to a line g $(\lambda_1, \lambda_2)=0$.

(2) Specific It must have a transparent good result to enhance the specific area such dot-filter should enhance dot area and meanwhile restrain the line area. We use k $(\lambda_1, \lambda_2) = |\lambda_2|/|\lambda_1|$ denotes the Likelihood Function, which is relative with the specific. Then we find to a dot k$(\lambda_1, \lambda_2)=0$ and to a line k$(\lambda_1, \lambda_2)>0$.

Thereby, we construct dot-filter w_d=g (λ_1, λ_2) k (λ_1, λ_2) according to expression (4) to enhance dot area in the lung image When $\lambda_1 = \lambda_2 < 0$, the pixel (x, y) is in the nodule. We define that the final enhancement filter for dot is expressed as [10]

$$w_d = \frac{|\lambda_2|^2}{\lambda_1} \qquad \lambda_1 < 0,\quad \lambda_2 < 0, \quad (6)$$

$$w_d = 0 \qquad \text{others}; \quad (7)$$

As the scale of the lung nodules is different between each other, we change the value of σ in Gaussian function. The detail of extracting dot with multitude scales of dot –filter is:

(1)Conform the range of scale of the nodules in the image and compute the value of σ.
(2)To every σ, repeat (3) ~ (8).
(3)Gaussian function convolve with 2D f(x, y) above
(4)To every pixel, repeat (5)~(7)
(5)Compute H and its two eigenvalues
(6)Compute w_d
(7)Stop computing
(8)Select the maximum of w_d

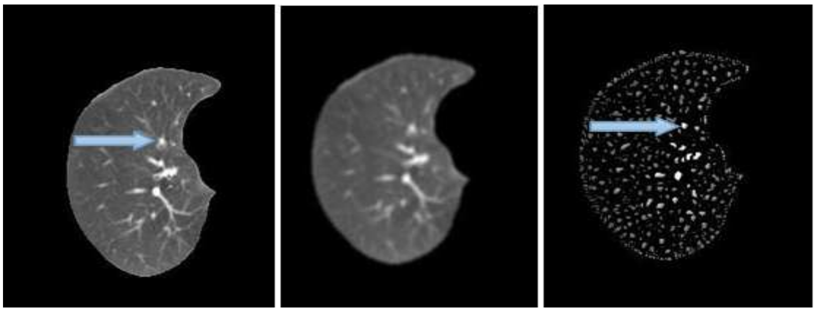
Now we first try it with Figure 2, and the output is shown as Figure 3 A and Figure B

A B
Fig.3: A) enhanced with one scale B) enhanced with multitude scales

Figure 3 A: enhanced with one scale. Figure 3 B: enhanced with multitude scales .According to Figure 3,we can easily obtain that dot-filter with variety value of σ not only extracts all dot model, but also eliminates the lines.

APPLICATION OF DOT-FILTER CONSTRUCTED IN 2D IMAGES
From now we will apply the Dot-Filter constructed above based on Hessian matrix to lung CT images, the efficient

of that is shown as Figure 3.Lung CT images are afforded by one big hospital for experiment of lung nodules detection based on Dot-Filter and Reign growing. Figure 3 A) Original lung image B) image convolved with Gaussian C) enhanced with Dot-Filter. The arrows in the image A denotes the nodule diagnosed by radiologist.



A B C

Fig.4: Detection of the solitary nodules in a 2D CT image enhanced. By Dot-Filter
A) Original lung image B) image convolved with Gaussian C) Enhanced with Dot-Filter

DOT-FILTER CONSTRUCTED BY THREE-DIMENSIONAL HESSIAN MATRIX

For an original three-dimensional image, we use its second derivatives to design our enhancement filters. Suppose a 3D image f(x, y, z) has nine second derivatives its two-dimensional hessian matrix H of the pixel in the image is shown as follows

$$H = \begin{bmatrix} f_{xx} & f_{xy} & f_{xz} \\ f_{yx} & f_{yy} & f_{yz} \\ f_{zx} & f_{zy} & f_{zz} \end{bmatrix} \quad (8)$$

Similar to two-dimensional hessian matrix, we suppose λ_1, λ_2 λ_3 are the eigenvalues of H, and satisfied $|\lambda_1| >= |\lambda_2| >= |\lambda_3|$The three expressions below mean that the sphere line and plane relative to $|\lambda_1|$, $|\lambda_2|$ and $|\lambda_3|$must satisfy.

$$\text{sphere}: \lambda_1 = \lambda_2 = \lambda_3 < 0 \quad (9)$$

$$\text{line}: \lambda_1 = \lambda_2 < 0,\ \lambda_3 = 0 \quad (10)$$

$$\text{plane}: \lambda_1 < 0,\ \lambda_2 = \lambda_2 = 0 \quad (11)$$

To enhance sphere area in 3D CT image, such as nodules, we also construct a dot-filter z_s that is similar to w_d described above

$$z_s(\lambda_1, \lambda_2, \lambda_3) = \frac{|\lambda_3|^2}{\lambda_1} \quad \text{if } \lambda_1 < 0, \lambda_2 < 0, \lambda_3 < 0;\ 0 \ \text{others} \quad (12)$$

The flow is also similar to that for dot-filter constructed by two-dimensional hessian matrix above (1)~(8).The application on 3D CT images is shown in Figure 6.

PRINCIPLE OF REGION GROWING

The purpose of segmentation is to divide the image for several areas. We use R to denote the total area of the image. We then suppose R consist of sub-domains such asR_1, R_2,$\cdots$ R_n, which satisfy [11]:

(a) $\cup_{i=1}^{n} R_i = R$

(b) R_i is a secutive area, of which i is $1, 2, \cdots, n$

(c) $\cap_{R_i} R_j = \emptyset$, among all i and j, $i \neq j$

(d) $P(R_i) = \text{TRUE}, i = 1, 2, \cdots, n$

(e) $p\left(\cup_{R_i} R_j\right) = \text{FALSE}$, to any attached area R_i and R_j

Of which $P(R_i)$ is defined to be a logical word, and $\emptyset$ is empty.

ANALYSIS AND ACTUALIZATION

Method of Reign growing firstly needs the original seed, then combine the pixels around of which their threshold is similar to them with them.

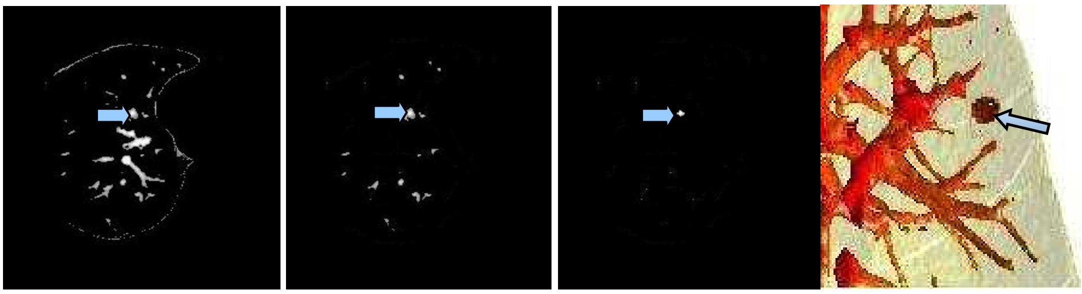
There are three factors affecting the result of Region growing: selection of seed, rule of region growing and condition to stop region growing. We define that if abs (F(i, j)-K)>=0,the region growing will be stopped..F(i, j) is the value of the other attached pixels around the center pixel of the nodules extracted above. K is the threshold that is defined 130.Figure 5 shows the effect of region growing.

A B

Fig.5: A) the image showing the welding defects B) connectivity analysis results on seed point 8

APPLICATION OF REGION GROWING AND DOT-FILTER

With Region growing using the suspected nodules as seeds we obtain the image Figure 4 (A). Then we extract the solitary lung nodules according to the scale of the nodule shown in image Figure 4 (B). The diameter of the lung nodule changes from 3mm to 30mm.At last we use dot-filter constructed by three-dimensional hessian matrix to extract nodules shown as Figure 4 (C), which can improve the efficiency and accuracy of the detection of pulmonary nodules. By using Region growing we can save much time when we use Dot-filter constructed by three-dimensional hessian matrix and reduce much work.



A B C D

Fig.6: A)image after using region growing B)image after eliminating the line-like shape C)image after the dot-filter based on three-dimension hessian matrix D) solitary pulmonary nodules displayed in the three dimensional image

CONCLUSION

In this paper we first use Dot-Filter constructed by Two-dimensional Hessian Matrix to extract dot-like region, then Region growing and Dot-Filter constructed by Three-dimensional Hessian Matrix reduce false positives. Through large numbers of experiments it prove that Region growing saves much time when we use Dot-filter constructed by three-dimensional hessian matrix and reduce much work while extract solitary lung nodules well. In the future, we will be concentrated on extracting the lung nodules contacted vessels and GGO lung nodules.

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