COMPUTER AIDED DIAGNOSIS FOR ABDOMINAL SURGICAL PLANNING

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ABSTRACT

This paper presents method for extracting blood vessels and lymph node for 3D abdominal CT images. Laparoscopic surgery now becomes very popular as one of minimal invasive surgical procedures. Since the field of view of a laparoscope is very limited, surgical assistance, such as reference image generation or surgical navigation, is quite important to make laparoscopic surgery safe. In realization of such systems, segmentation of blood vessels and detection of lymph nodes are quite important task. We try to segment blood vessels from 3-D CT images by utilizing a line shadow enhancement filter and to detect lymph node by using a minimum directional difference filter. The experimental results showed that the present methods are quite useful for segmenting very thin blood vessels and detecting small lymph nodes from CT images.

1. INTRODUCTION

Recently, the laparoscopic surgery becomes very popular as one of minimal invasive surgical procedures for decreasing loads of the patients. In the laparoscopic surgery, a laparoscope and forceps are inserted through tiny incisions opened on a patient's belly. A surgeon operates forceps while observing pictures on a video monitor which are taken from the laparoscope. However, the movable region of it is quite small and the field of view of the laparoscope is very limited. Thus, although the laparoscopic surgery is less invasive operation, the load on a surgeon increases. For reduction of his or her load, surgical assistance, such as the reference image generation or surgical navigation, would be useful to make the laparoscopic surgery safe and efficient. To realize such system, recognition of anatomical structures, for example, segmentation of blood vessels is a fundamental task.

In the laparoscopic surgery for excision of a tumor, understanding the positions of the lymph nodes related to the tumor is important because such lymph nodes should be completely excised for preventing recurrence on metastasis. It is very effective to present the blood vessel regions which concern with the tumor and the position of the lymph nodes as reference images for the surgical planning or the intra-operative assistance.

So far as extracting blood vessel regions and lymph nodes, there are problems that very thin blood vessels that are not target are extracted and that other tissues or organs having similar CT values are also extracted. For blood vessel extraction, it is preferable that various sizes of blood vessels can be extracted selectively. Thus we employ filters that can enhance line and blob structures and then extract blood vessel and lymph nodes regions from the enhanced images. The multi scaled line enhancement filter is used for segmenting blood vessels, and the minimum directional difference (Min-DD) filter for detecting lymph nodes.

2. METHOD

2.1. Blood vessel segmentation

First, we use a line enhancement filter based on the Hessian matrix in order to segment blood vessel region [1]. The Hessian matrix H is given by

$$H = \begin{pmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{pmatrix}, \quad (1)$$

where I is an intensity value of a pixel. The second derivatives of I are represented as $I_{xx} = \frac{\partial^2 I}{\partial x^2}$, $I_{xy} = \frac{\partial^2 I}{\partial x \partial y}$, and so on. In this paper, the second derivatives are calculated by using a hyper surface fitting technique to improve robustness for image noise, instead of using the difference of CT values. Then, the eigen values of H (λ_1, λ_2 and λ_3 ($\lambda_1 > \lambda_2 > \lambda_3$)) are calculated. We can estimate the structure of each pixel by the combination of magnitudes of the eigenvalues. Line-like structures satisfying the following conditions are enhanced.

$$\lambda_3 \approx \lambda_2 << \lambda_1 \approx 0 \ . \quad (2)$$

Finally, we segment regions that have high intensity from the enhanced image as the blood vessel regions. Although this filter can extract thin or small blood vessel regions, it is difficult to extract thick or large blood vessel regions at the same time. Therefore, large blood vessel regions are extracted using a threshoding process. This result and the result by the 3-D line filter are then combined for the final result.

2.2. Lymph node detection

In order to detect lymph nodes, we use the minimum directional difference (Min-DD) filter that is a kind of differentiation filter [2]. The concept of the Min-DD filter is shown in Fig.1. The Min-DD filter is able to enhance isolated shadows in CT images. The formula of the Min-DD filter is shown below.

$$O(\mathbf{x}_0) = \min_k (I(\mathbf{x}_0 + \mathbf{r}_k) + I(\mathbf{x}_0 - \mathbf{r}_k) - 2I(\mathbf{x}_0)) \ , (k = 1,2,\cdots,L) \ , \quad (3)$$

where O(**X**o) is the output value of a voxel **X**o whose CT value is I(**X**o) . **r** is a condition of the size of the target lymph nodes. In this paper, the target size is 5mm in diameter. And k is a condition parameter which is the angle θ of the neighborhood voxels, and L is the number of direction. We extract voxels whose ouput values

of the Min-DD filter are higher than certain threshold as voxels of lymph node regions.

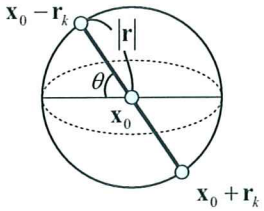


Fig.1 The concept of the Min-DD filter

3. RESULT

We applied the proposed methods to three cases of 3-D abdominal CT images. Acquisition parameters of the CT images are shown in Table 1. In this paper, we apply the interpolation by a sinc function along the axial direction in order to make resolution of the CT images isotropic. It is difficult to obtain ground truth regions of the blood vessel regions and the lymph nodes. Thus, we have evaluated about these results by visual inspection.

The segmentation results using a simple thresholding and the 3-D line filter are shown in Fig. 2. Figures 2 (a) and (b) are examples of segmentation results by the thresholding and the 3-D line filter. We could segment thin blood vessel regions by the 3-D line filter more than the simple threshold processing. However, there are regions of over-extraction at the colonic wall regions and bone regions.

The detection results of the target lymph nodes whose diameter is about 5mm are shown in Fig. 3. Figure 3(a) is a result by the Min-DD filter. We could detect the lymph nodes of the target size. However, a few big lymph nodes as shown in Fig. 3 (b) could not be detected. If we set detection parameters to detect both big and small lymph nodes at the same time, a lot of over-detection will occur. Thus, we have to develop the elimination method of over-detections. As the results, the proposed method was able to segment blood vessel regions and lymph nodes. Thus, we think that these can be very effective to generate reference images for laparoscopic surgery assistance in the future.

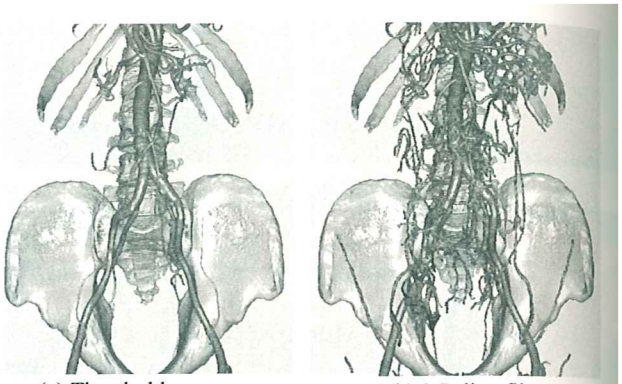
Table 1 Acquisition parameters of CT images.

Case	Image size	Size of pixel	Number of slice
1	512 x 512	0.568 x 0.568 x 0.568	867 (406)
2	512 x 512	0.568 x 0.568 x 0.568	856 (401)
3	512 x 512	0.568 x 0.568 x 0.568	867 (406)

(The numbers in parentheses are number of slice before interpolation.)

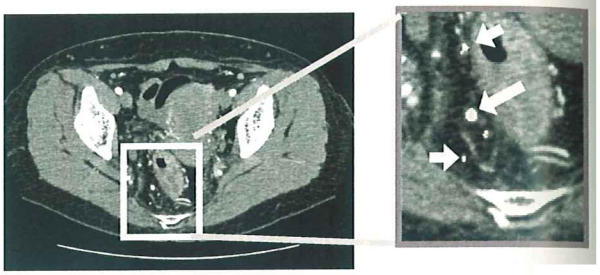
4. CONCULUSION

We proposed a segmentation method of blood vessel region and a detection method of lymph nodes from abdominal CT images. Experimental results using 3D abdominal CT images showed that the proposed methods were promising. Future work includes improvement on blood vessel enhancement by refining enhancement parameters, application to many cases, and development of the procedures for quantitative evaluation.

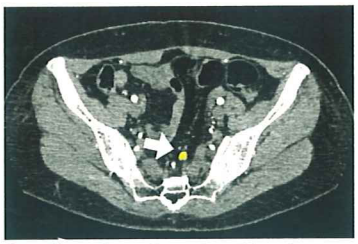


(a) Threshold process (b) 3-D line filter

Fig.2 Segmentation results obtained by a simple threshold process and 3-D line filter (Case #1)



(a) An example of detection results
(Correct extraction areas are indicated by arrow)



(b) An example of lymph nodes missed by the proposed method
(Missed areas are indicated by arrow)

Fig.3 Detection results by the Min-DD filter

5. ACKNOWLEDGEMENT

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6. REFERENCES

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