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Automatic Detection of Blood Vessels from CTA Images Employing Morphological Operation

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Abstract: Recently, the disease by arteriosclerosis increases rapidly. Especially, the one that originates in hands and feet's peripheral arterial is called arteriosclerosis obliterans (ASO). ASO is one of the typical diseases that cause a chronic ischemia of limbs and it leads to blood flow obstruction. In the diagnosis of ASO, lower contrast enhanced computed tomography (CT) is useful to observe artery. However it is huge task for radiologists to segment accurately only arteries, which they pay attention, from lower computed tomography angiography (CTA) by manual or semi-automatic with proprietary software. In this paper, we have developed a new technique for detection of the arteries from CTA images by use of a morphological operation. In this technique, N-Quoit filter, that is a useful filter for detection lung nodules, is applied to identify the arteries in CTA images. Some experimental results were shown with a good performance of segmentation of arteries.

Keywords: contrast enhanced CT image, artery detection, segmentation, morphological filter.

I. INTRODUCTION

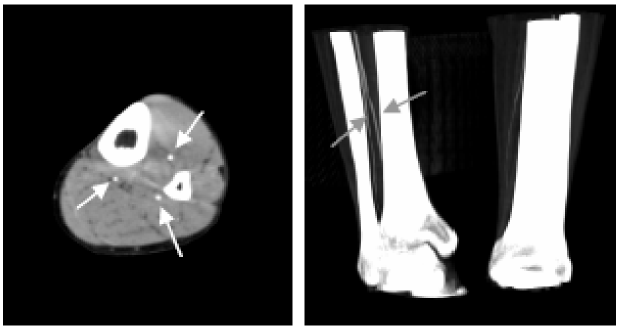
Arteriosclerosis obliterans (ASO; it is also called "PAD (peripheral arterial disease)" or "PVD (peripheral vascular disease)" in USA) is one of the typical diseases that cause a chronic ischemia of limbs and it leads to blood flow obstruction. It is defined as an arteriosclerosis in which proliferation of the intima leads to occlusion of the lumen of the arteries. The ASO commonly shows its effects first in the legs and feet. The narrowing of the arteries may progress to total closure of the vessel. This disease is caused by diabetes, hyperlipemia, hypertension and smoking. Intermittent claudication is the most symptoms of ASO [1] and large experiment in the USA showed that the incidence of male and female with the age of 50 to 70 is 5 to 8 per 1,000 populations for the year.

In the diagnosis of ASO, it is useful for detection of arteries to use computed tomography angiography (CTA) and magnetic resonance angiography (MRA). In Addition, fresh blood imaging (FBI) is a very useful imaging diagnosis method which is obtained by magnetic resonance (MR) imaging. It is also can be analyzed arteries on the anatomical structure in which are enhanced on the images [2]. Especially, three dimensional (3-D) images constructed by some rendering methods from two dimensional (2-D) medical images are needed for observation and intervention of the arteries. On the other hand, detection/segmentation of the arteries from CTA, MRA and MR image from FBI is important task for these scenes. It is, however, there is a considerable issue that radiologists require much time for reconstruction as a 3D image or display it. Hence, it burdens to segment the arteries from medical images manually or semi-automatically using some proprietary software.

To overcome this problem, many researchers have studied about automatic detection/segmentation techniques of blood vessels from medical images and some result showed relatively good performance [3]. However the studies about detection of arteries in lower CTA images have almost not reported. In this paper, we have developed a new technique for detection of the arteries from contrast-enhanced lower CT images by use of a morphological operation. In this technique, N-Quoit filter, which is widely introduced as a useful filter for detection lung nodules [4], is applied to identify the arteries in CT images. In this paper, the technique has been evaluated by applying for actual three CTA images sets of one patient. Some experimental results were shown with a good performance of detection of arteries.

II. MATERIALS AND METHODS

Figure 1 shows the CTA images which is employed in this study. In Fig.1 (a) and (b), some artery areas are indicated with arrows. The aim in this study is to detect the region of arteries such as anterior tibial artery,



(a) (b)

Fig.1. An example of CTA: (a) shows a 2-D CTA and (b) shows a MIP image of CTA images. The arrow areas show the artery regions

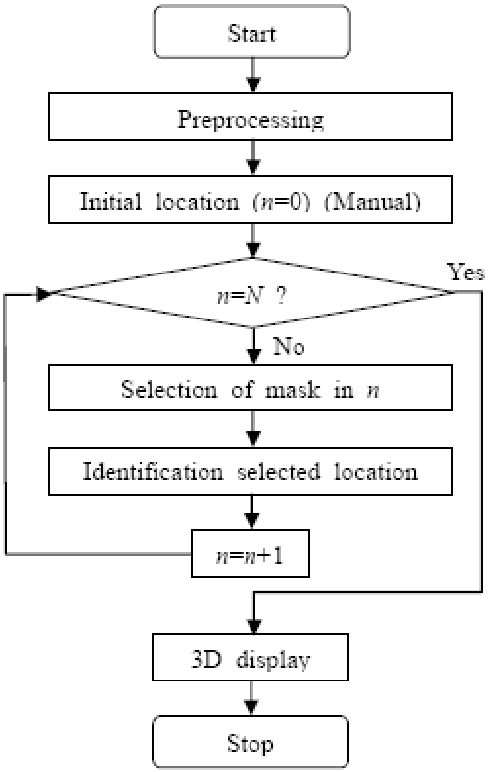


Fig.2. The procedure in this study: n shows the number of slices and N shows maximum slice number.

posterior tibial artery and fibular artery in CTA images automatically. The computerized scheme of this study is shown in Fig. 2. At first, preprocessing is performed to segment the bone regions. In the next step, we select initial point on the image by using mouse point manually in the first slice for tracing/detecting the artery areas in the next slices, automatically. The trace of arteries are performed by search of maximum output value of the N-Quoit filter. This trace is continued from the second number of slice to the end of slice. Finally

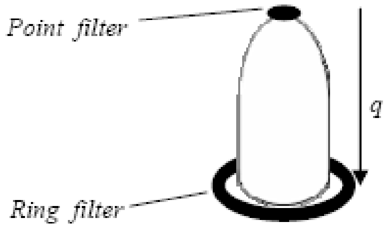
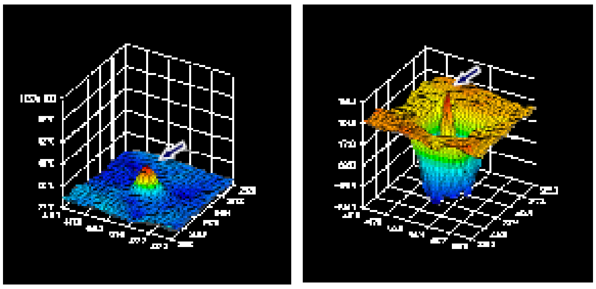


Fig.3. The basic concept of the N-Quoit filter



(a) (b)

Fig.4. Distribution of pixel value (a) and output value of N-Quoit filter (b).

the detected arteries areas are displayed in 2-D or 3-D image.

1. N-Quoit filter

N-Quoit filter have been proposed as a filter which enhances lung nodules in multi-detector row CT [4]. The filter, that is a kind of morphological filters, is sensitive for the distribution of pixels like a circle in the 2-D image. Figure 3 shows the basic concept of the N-Quoit filter. Shown in Fig.3, the N-Quoit filter consists of two kinds of filter, a point filter and a disk filter. If these filters overlay an object like a circle, then only the ring filter falls and vertical interval has large value. On the other hand, in the case of some objects not like a circle, the ring filter does not fall as well the point filter and vertical interval has small value. The output value of the N-Quoit filter is subtracted value of dilation operation with these filters. Following expressions show the output of the N-Quoit filter.

$$q(x,y) = f(x,y) \oplus P(x_1,y_1) - f(x,y) \oplus R(x_1,y_1) = f(x,y) - f(x,y) \oplus R(x_1,y_1) \quad (1)$$

$$f(x,y) \oplus R(x_1,y_1) = \max_{(x_1,y_1)\in K_r} \{f(x-x_1, y-y_1) + R(x_1,y_1)\} \quad (2)$$

Where $q(x,y)$ and $f(x,y)$ show an output and input image, respectively. $P(x_1,y_1)$ and $R(x_1,y_1)$ show a point and ring filter function, respectively. Furthermore K_r shows the

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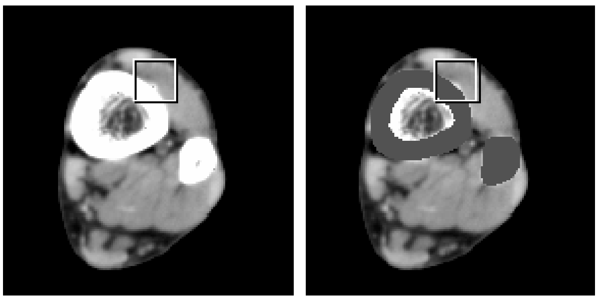
domain of these filters. "⊕" shows dilation operation in morphology. Ring filter function $R(x_1,y_1)$ is expressed as following.

$$R(x_1,y_1) = \begin{cases} 0 & if\ r_1^2 < x_1^2 + y_1^2 \leq r_2^2 \\ -\infty & otherwise \end{cases} \quad (3)$$

Where, r_1 and r_2 show the internal and external diameter of the ring filter. In the CTA images, artery areas are appeared in the form of a circle. Appling the N-Quoit filter for CTA images, the location of the arteries should have higher value of the output image (Fig.4).

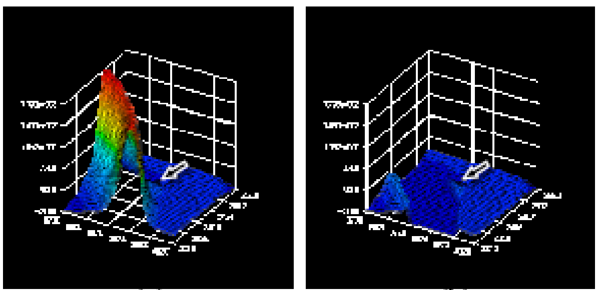
2. Detection of arteries employing N-Quoit filter

It is possible to identify arteries by search of the maximum value of output of the N-Quoit filter. In this paper, some arteries are detected from CTA images by following computerized scheme; first, initial location of an artery is identified in first slices, manually. In the next step, a mask is located on the selected location. In the mask, a location having the maximum output value of the N-Quoit filter is identified as center of the artery. The identified location is determined as the center of mask in the next slice. These processes are continued to the end of slices or the subtracted value of output over the successive slices is less than threshold.



(a) (b)

Fig.5. (a) A CTA image and (b) A segmented bone image



(a) (b)

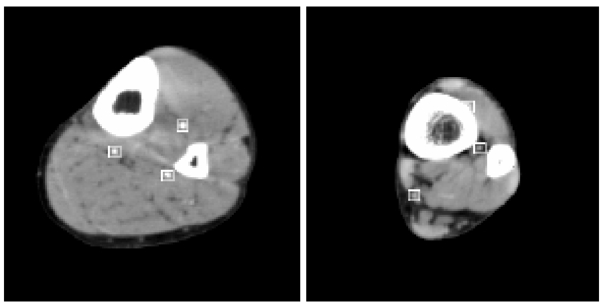
Fig.6. Distribution of pixel value in rectangle region in Fig.5.

However, it might be difficult to identify a location as an artery adjacent to bone. It is because that there are no differences of voxel value between the edge of bone and arteries. In this paper, bone regions are segmented from the CTA images based on following steps previously to avoid mis-detection of the arteries. At first, binarization is applied on original CTA image with threshold determined empirically. At this point, the threshold is relatively higher value for segmentation of internal bone region from CTA images. In the next step, dilation is performed to binarization image to extend the bone region. Finally, segmented bone regions are removed from original CTA images, therefore, pixel value in bone regions set to 0. Figure 5 shows the original CTA image and segmented bone image. Figure 6 shows the distribution of pixel value in a rectangle region which is located in original CTA image and segmented bone image shown in Fig.5.

III. EXPERIMENT

In this paper, the technique has been evaluated by applying for actual three CTA image sets of one patient. Image size is 512 x 512[pixels] and the image set consists of 181 slices images. The slice thickness is 2.0[mm] and pixel spacing is 0.528[mm] x 0.528[mm]. Three versions of CTA images are different in the sharpness, and last one is sharpest in the cases. The mask size is 11 x 11[pixel] and the size of r_1 and r_2 are 3 and 4, respectively. Threshold for binarization is 1000 [H.U.]. Threshold of termination condition for trace of arteries is determined -300 empirically.

Figure 7 shows experimental results of detection of arteries. In Fig. 7, (a) and (b) that are the first and 123rd slices, each rectangle regions on the image are shown



(a) (b)

Fig.7 Experimental result of CTA image. (a) shows slice number 0, (b) shows slice number 123 (b). Each rectangle areas on the image show the extracted artery regions.

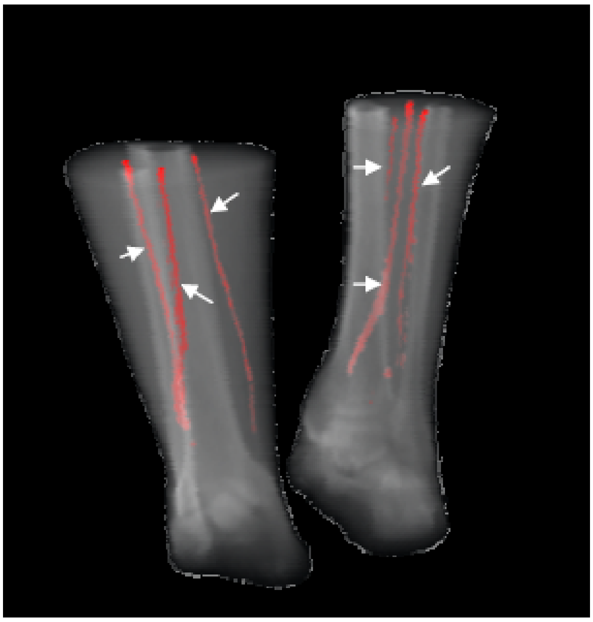


Fig.8.Detected some arteries in 3D image

the selected locations by manually and automatically. In Fig.7 (b), it is apparent that identified regions indicate two isolated arteries and an artery adjusted by bone regions accurately. Figure 8 shows the 3-D image of detected arteries enhanced by red color. In Fig.8, some arteries are displayed accurately apart from other structures. True positive rate of extracted arteries is shown in Table 1. True positive shows that artery in the 2-D image is exactly identified. In Table1, true positive rate is degraded in identification of right artery fibular and right posterior artery. This false identification can be caused by mis-segmentation of bone and for branch of arteries. On the other hand, the accuracy of detection of arteries in case 3 is highest comparing other cases, shown in Table1. In case 3, sharpness is high and the border between bone and arteries are clearer.

IV. Conclusion

In this paper, we have developed a new technique for detection of the arteries from contrast enhanced lower CT image by use of morphological operation. Some experimental results were shown with a good performance of segmentation of arteries. However, some cases include mis-detections of the arteries from CTA images. In general, there is no difference of voxel value between the border of bones and arteries, and, therefore, we need to some models of bones or artery to segment accurately from CTA. It still remains as one of future works.

Table 1 Result of extraction of arteries. A, B and C shows the anterior tibial artery, posterior tibial artery and fibular artery, respectively.

		A	B	C
Case 1	Left	100.0	100.0	100.0
	Right	100.0	83.8	95.4
Case 2	Left	100.0	100.0	100.0
	Right	100.0	86.2	96.2
Case 3	Left	100.0	100.0	100.0
	Right	100.0	100.0	100.0

In this paper, a morphological filter is applied to detect arteries on consideration for shape of arteries like as a circle. It will be possible to apply for other parts of body, however, more accurate for detection algorithms are needed for the branch of arteries. Solving some technical issues for detection arteries, it will be possible to reduce of burden of radiologist and to develop a system for detection of constriction of arteries.

REFERENCES

[1] Meijer WT, Hoes AW, Rutgers DM, et al.: Peripheral Arterial Disease in the Elderly: *The Rotterdam study, Arteriosclerosis, Thormbosis, and Vascular Biology*, Vol.18, pp.185-192, 1998.
[2] K. Nakamura, A. Yamamoto, M. Miyazaki, et al.: Clinical usefulness of non-contrast-enhanced MRDSA to evaluate hemodynamics of arterial diseases –initial experience-, *Proc. International Society of Magnetic Resonance in Medicine*, Vol.11, p.1356, 2003.
[3] S. Busayarat, T. Zrimec: Detection of bronchopulmonary segments on high-resolution CT preliminary results, *Proc. of the Twentieth IEEE International Symposium on Computer-Based Medical Systems*, pp.199-204, 2007.
[4] T. Miwa, J. Kako, S. Yamamoto, et al.: Automatic detection of lung cancers in chest CT images by the variable N-Quoit filter, *Institute of Electronics, Information, and Communication Engineers*, Vol.33, No.1, pp.53-63, 2002. (in Japanese)