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Extraction of Fine Blood Vessels from Ultrasound Images
超音波画像における細径血管抽出

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1. Introduction

This paper is concerned with image processing for developing noninvasive ultrasound imaging system to display fine blood vessels. Ultrasound, X-rays, and light are mostly used for imaging blood vessels. Ultrasound finds its wide applications from examination to treatment. Here we discuss a method to detect fine blood vessels of several hundred microns to 2 millimeters in size and to display their shapes in a three dimensional way.

It is not difficult to detect a large blood vessel in an ultrasound image, since the brightness or the echo level of the blood vessel can be differentiated easily from that of neighbor tissues. On the other hand, the small blood vessels show little difference in brightness from the neighbors. Besides, their contours are not clear due to speckle noise and thus preprocessing is essential to our purpose.

Ultrasound images are accessed from the developed non-invasive imaging and diagnostic system for ultra fine blood vessels [(1)]. It scans the region of 1[cm] ×1[cm] ×3[cm] using 30MHz transducer and 128 successive cross sectional images are obtained for processing. So far various smoothing and enhance methods have been proposed elsewhere. We examined an adaptive morphological operation in image processing and found that it can smooth and enhance the image at a time. We applied the useful filtering technique to the three dimensional ultrasound data. Speckle noise is reduced and the edges (counters) of blood vessels are enhanced in all cross sectional images. Furthermore, the contours can be enhanced by adding the edges detected in the divided sub-images. The detected edges may often include not only the edges of blood vessels but also edges from very weak echo areas and artifacts. These unnecessary edges are normally excluded by the decision rule that the cross sections of a blood vessel are each connected in space. Finally selected contours in all cross sections are displayed to give a three dimensional shape and any three cross sections can be also displayed.

2. Preprocessing

In this system, a cross sectional image of size 512x512x8[bits] is obtained by linear mechanical scan and the 128 successive cross sectional images are stored moving the scan plane along the direction of blood vessel in the region of interest. Since the quality of an ultrasound image depends not only on ultrasound diagnostic equipment but also on individual body. It is also affected by speckle noise, and thus the image processing technique is preferably independent as much as possible of these factors. Various kinds of smoothing process and morphology operations are used in many applications [(4,5)]. Here we introduced an adaptive morphological filter, which adjusts the value of the structuring element by itself corresponding to the local image. The speckle noise is smoothed out and edges are enhanced at a time by the 3D morphological filter [(6)]. The shape and the size of the structuring element are decided by a statistical survey on speckle in and around the blood vessels. The shape is ellipsoidal and has 11x7pixels in the cross section and three pixels in successive cross scan. The parameters of the structuring element are determined by a statistical index called separability. The morphological opening and closing operations give rise to successive 128 smoothed cross sectional images with enhanced edges.

3. Extraction and display of blood vessels

The contours are extracted as follows.

① Small regions are binarized by moving a window step by step in each cross section and their edges are summed up. Binarization is carried out only when some conditions are met to avoid unnecessary edges. The condition is determined by the interclass variance of the corresponding small region and the multi-threshold levels of the cross section.

② The enhanced cross sections are each binarized again to produce candidate contour components.

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③ False edges due to such artifact as strong shadow of the wall of blood vessel and edges within the blood vessel at the local binarization are removed. We select only the edges located near the common region between the two overlapped cross section. Furthermore, we choose components which touch one of the six faces in the scanned cubic space. Blood vessels pass through the scanned region.

④ Finally the selected contours are displayed in a 3D fashion to complete the post processing.

4. Experimental results

An ultrasound image of cross sectional size of 1 cm^2 and a 3D image of the extracted vessels are shown in Figs. 1 and 2, respectively. Table 1 shows average gradient and separability in the original image along the extracted contours of vessels. Average brightness

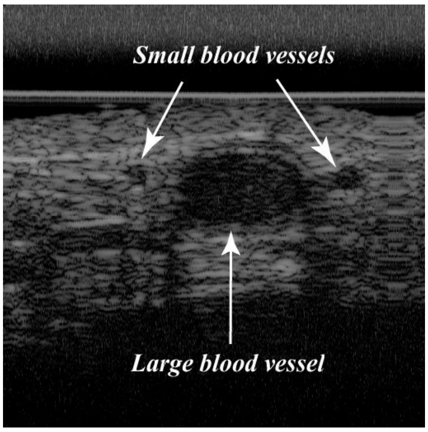

Fig. 1 Ultrasound image of blood vessels.

gradient within the window of 3x7 pixels with its center along the contour points is normalized and separability is defined as the ratio of the inter class variance to the variance within the circle of radius 10 pixels.

5. Conclusion

We found we can extract the contours of fine blood vessels from an ultrasound image even if the brightness is small in difference between the inner and the outer region of the blood vessel of interest. Future work is to improve the system and to develop image processing technique to visualize ultra fine blood vessels.

Acknowledgement

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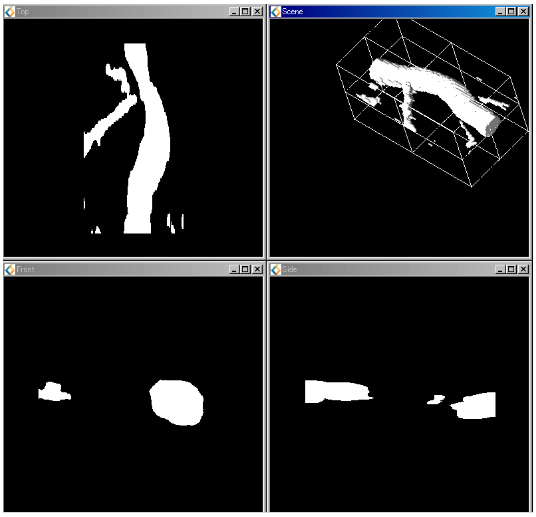

Fig. 2 Three dimensional view of the extracted blood vessels.

	gradient	separability
Large blood vessel	0.5203	0.7467
Small blood vessels	0.0136	0.7642

Table 1 Average gradient and separability of the original image along the border of the extracted blood vessels.

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