

# Segmentation of Artery Areas on None-enhanced Fresh Blood Imaging Based on Dot Enhancement Filter and 3-D Region Growing Method

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**Abstract:** Peripheral arterial disease (PAD) is characterized by lower extremities arterial obstruction due to atherosclerosis and manifests in lower extremities as intermittent claudicating, limb ischemia, or gangrene. The diagnosis of the PAD using magnetic resonance imaging (MRI) equipment without contrast medium is available as a useful visual screening in clinical practice. In this paper, we propose a new method for segmentation of arterial images, which are obtained from non-contrast enhanced magnetic resonance angiography (MRA) based on dot enhancement filter and 3-D region growing methods, and satisfactory experimental results are obtained.

**Keywords:** PAD, non-enhanced MRA, dot enhancement filter, 3-D region growing methods

## I. INTRODUCTION

Vascular diseases are among the most important public health problems and one of the leading causes of death in the worldwide. Furthermore peripheral arterial disease (PAD), one of the vascular diseases can result from atherosclerosis, inflammatory processes leading to stenosis, an embolism or thrombus formation, which causes either acute or chronic ischemia (lack of blood supply) in lower extremities, and the resulting PAD requires angioplasty or surgical bypass and may require amputation. Recently, because patients having the arteriosclerosis increase along with increasing patients of life-style related diseases, early detection and treatment for the PAD are vitally important [1].

In the diagnosis of the PAD, it is useful for detection of arteries to use computed tomography angiography (CTA) and magnetic resonance angiography (MRA). As for CTA, it can be acquired direct imaging of the arteries as an alternative to digital subtraction angiography (DSA). However, because of necessitating injecting contrast agent for diagnosing the arteries by multi-slice computed tomography (MSCT), it may be not necessarily safe examination. On the other hand, MRA is a very useful imaging technique which is obtained by magnetic resonance imaging (MRI), which has various advantages, for example, the ability to provide images blood flow signals without the need for contrast agent. In addition, a consideration for radiation exposure is not necessary for all patients. Especially, fresh blood imaging (FBI) method developed to image arteries in recent years may be useful to detect a variety of vascular diseases causes of the PAD [2-4]. The FBI is a non-enhanced MRA technique, which employs arterial signal difference between systole and diastole during a cardiac cycle, i.e., subtraction of the diastolic bright-blood arteries from the systolic black-blood arteries allowed visualization of the arteries by cancelling the

veins. However, due to peristaltic movement of organs such as the intestine or the bladder, unnecessary background area may frequently develop on these MR images, and diagnoses of the vascular disease may be affected. Nevertheless, image processing techniques to resolve these issues have not been established.

The medical image processing and analysis technique to segment of vascular structures is one of the important tasks in computer vision and image processing field. Many researchers introduced 3-D and/or 2-D image processing techniques for visual screening not only in the medical field but also in the computer vision. Especially, in the field of handling a high resolution medical image, including CT, ultrasound image, and MRI, the 3-D image reconstruction process make burden to radiologists. Therefore, manual analysis for routine clinical use is impractical. In that point, they require a method for displaying the 3-D image and supporting a computer aided diagnosis (CAD) [5, 6]. Many CAD systems have been developed on the medical field to analyze the internal organs based on CT, and MRI etc [7, 8]. Unfortunately, most clinical routines still rely on manual operations. Automatic image processing techniques to detect the vessels on MR imaging are necessary.

A new development of a CAD system to visualize the results of extracted blood vessel area on non-enhanced fresh blood MR imaging based on a 3D-region growing method of tree structure theory and using feature value by selective enhancement filter will be presented in this paper.

## II. MATERIALS AND METHODS

This section presents our proposed image preprocessing method for detecting the blood vessel region on MR images. These MR images, used in this paper are provided as DICOM (Digital Imaging and

Communication in Medicine) images, are achieved as the images which removed the vein region with use of FBI method. Fig. 1 gives an example of the original MR image obtained by the FBI method. A white area in Fig. 1 shows the blood vessel area. The outline of some image analyzing technique is shown below.

Moreover, the overall scheme of the image processing technique for extracting the region of blood vessels is illustrated in Fig. 2. The method consists of three main steps; extracting the initial enhanced points, acquisition of 3-D coordinate on the blood vessel regions, and displaying the blood vessel.

To segment the artery areas on MR imaging which is obtained non-enhanced FBI technique, some image processing techniques are introduced. In the first step, pre-processing technique such as smoothing and

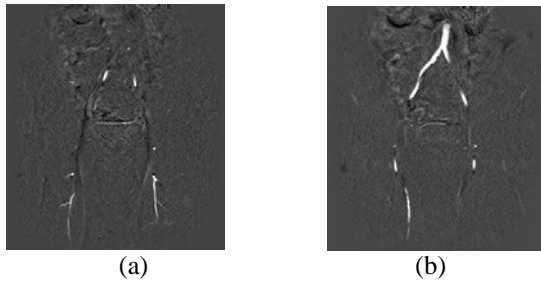


Fig. 1 Examples of a successive MR image which is obtained by the FBI method.

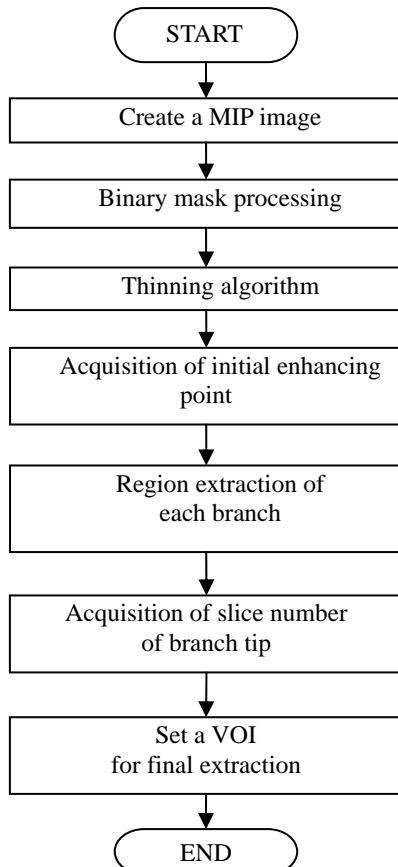


Fig. 2 Flow of procedure

binarization are performed to reduce image noise. In the second step, we make a maximum intensity projection (MIP) image from coronal plane to detect the initial artery areas on the FBI images. In the third step, we perform the thinning algorithms and selective enhancement filter (dot and line enhancement filter) on volume of interest (VOI) before adopting the 3-D region growing technique, finally a MIP image for diagnosis is made from these images extracted.

### 2.1 MIP

MIP is a method of adopting the maximum signal (pixel value) on the projective direction as a projection value. Fig. 3 shows the notion of MIP technique, which is introduced in our technique. In Fig. 3, (a) illustrates a coronal view, and (b) shows an axial view. In this study, first of all, the MR images obtained by using of FBI method are inputted as original image. Next, MIP image is reconstructed from the original image. At this time, three dimensional coordinates value of the area where have maximum pixel value on the viewpoint are saved.

### 2.2 Extracting the initial blood vessel regions

To extract the blood vessels area, binary mask processing (same threshold which has CT value of 3000 in all the cases) is done to all volume data in the first step of extracting a region of interest. Next, to decide starting point of region growing method, thinning algorithm is performed. The thinning algorithm is operation for extracting a central line of one pixel in width by making thinning the line width in a given figure. When a figure is used the thinning algorithm, because it is easy to analyze the shape and the relation of combination, the thinning algorithm is widely used.

The image including the noise obtained by thinning algorithm is also performed the thinning processing. In this study, to obtain only the blood vessel area, eight neighbor pixels are searched from the point of the blood vessels area, and by tracking the point which have these thinning pixel values, all of thinning parts except these points are reduced, we can obtain thinning images which are only the blood vessels parts. At this time, the highest point is made as the starting point, and this point has three dimensional coordinates which comes from the MIP image. As a result, the starting point of region growing method can be decided automatically.

### 2.3 3D-region growing method and tree structure

The region growing method is one of the important methods for segmentation on computer vision, medical imaging, and analyzing a video image field [9, 10]. It is applied to specify an accurate position of the blood vessel area, by performing the area expansion processing. When a good performance could not achieved for detecting the line segment, the successive blood vessel area appears as a discontinuous point of the line element on the MR image. It is because it could not correctly extract the peripheral vessel when it was

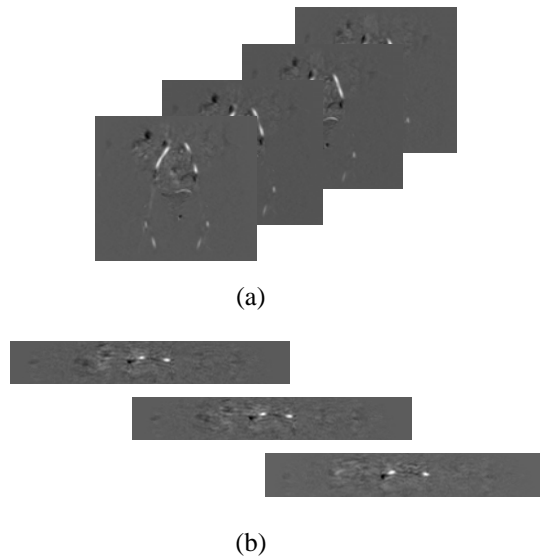


Fig. 3 MIP image which is obtained coronal plane from the MRI image

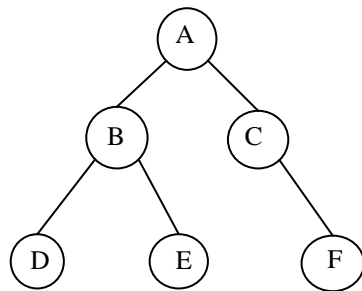


Fig.4 Tree structure

applied to binary imaging threshold processing. The resulting the extraction of the peripheral blood vessel area becomes difficult. To avoid this problem, in the first stage, we introduce a region growing method. Moreover, we assume that these blood vessels are exist some direction on the FBI images which having the tree structure shown in Fig. 4. These blood vessels are extracted in a slice of the images from the starting point on the region growing method. Next, three dimensional enhancement is done by extracting between successive slices. After enhancing process, labeling is done at a slice of the image, and divergence is understood A to B and C in Fig. 4. At this time, the threshold is changed by the labeled area of a blood vessel section. The blood vessel area is extracted by changing the threshold at each divergence B to D in Fig. 4. It returns to the previous divergence and the process is done to the branch that did not do the extraction process (D to B). At this time, the slice of branch tip (section of the peripheral blood vessel) can be obtained. The entire blood vessel area is extracted by repeating this processing (B to E, E to C and C to F).

#### 2.4 Extracting the peripheral vessel

The thick blood vessel area can be extracted by the above mentioned technique. However, it is difficult to

do the extracting process with a parameter when the top and bottom of the blood vessel are extracted. It is because the pixel value is resembled in the peripheral blood vessel area. To overcome this problem, we propose to set VOI in the second stage and to perform the 3D-region growing processing as the feature value which is applied dot and selective enhancement filter with selective enhancement filter to the thick blood vessel area [10]. As a result, when the over extraction is occurred, the influence can be decreased. Moreover, the processing time can be reduced by setting the area of interest, and limiting the range of processing. Thus the slice number of the peripheral blood vessel section is obtained in the first stage, and in the second stage, the range setting of VOI is specified from the slice and the center of gravity of the blood vessel section.

### III. EXPERIMENTAL RESULTS

To detect blood vessel area, we applied automatically proposed method to MR image obtained by FBI method. Image size is 256 x 256 [pixels] and the image set consists of 50 to 100 slices images per case. Automatic extracting of the blood vessel area is performed by the discrimination analysis using the 3D-region growing method and the tree structure. The experimental results on processing for source images for 11 cases were shown with a good performance of extraction of blood vessel area. A result of the extraction processing is shown in Fig. 5. A MIP image from the coronal view is created from the original image as shown in Fig. 5 (a). In this Figure, the image noise of the bladder and the area where a high density value is indicated in other organs appear in the image beside the artery area to be extracted. A MIP image of detection result on initial artery area and final detection result are shown in Fig. 5 (b) and 5(c), respectively.

Overall the performance for these extraction results are evaluated by comparing some center lines on the original MIP image from the coronal and sagittal view which acquired by our proposed method with the correct data of blood vessel area indicated visually by a medical doctor. In particular, we assume that the true positive (TP) is the rate of crossover the extracted blood vessel area automatically to the correct data, and also the false positive (FP) is the rate of the over extraction area to the correct data. Moreover, the average recognition rate is acquired by the results applied to the true non-enhanced MR images of 11 cases with the proposed method. The result of the average recognition rate is shown in Table 1. Next, the result of the correspondence ratio for the assessment of performance is shown Table 2. Each equation of the TP, the FP and the correspondence ratio (CR) are shown in equation (1), (2) and (3), respectively.

$$TP = \frac{n(A \cap B)}{n(A)} * 100 \quad [\%] \quad (1)$$

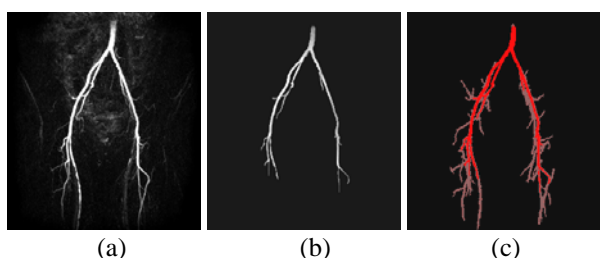


Fig.5 Extraction result

$$FP = \frac{n(C)}{n(B)} * 100[\%] \quad (2)$$

$$CR = \frac{n(A \cap B)}{n(A \cup B)} * 100[\%] \quad (3)$$

$A$ ,  $B$ ,  $C$  and  $n$  in these parameters of each equations are shows the gold stand by radiologist, the extracted result, the over extraction and the number of pixels, respectively. In this study, the TP from the coronal view and the sagittal view are 82.95% and 92.1% in the average recognition rate are achieved, respectively.

Table 1 Result of average recognition rate of 11 cases

	TP (%)	FP (%)
Coronal	82.95	27.44
Sagittal	92.17	49.18

Table 2 Result of correspondence ratio of 11 cases

	Agreement rate (%)
Coronal	61.94
Sagittal	66.59

#### IV. DISCUSSION AND CONCLUSIONS

In this paper, we have developed a CAD system as an automatic extraction of blood vessel region to analyze non-enhanced MR image employing a FBI method in lower limbs area. In the extraction of the blood vessel area, a good performance was obtained by use of a 3-D coordinate value as the starting point from the MIP image with the thinning algorithm, the region growing method based on tree structure. In the assessment result of the precision of detecting in Table 1, a good performance has been obtained both the TP and the FP in the MIP image from the coronal view. On the other hand in the MIP image from the sagittal view, though the FP was slightly higher the value than one from the coronal view, a good performance was obtained with the TP was over 90%.

However, some cases including venous area on the original image may have mis-detections that the venous area as well as the arterial area is extracted, and for this reason, some improvements for extracting algorithm in the blood vessel area are required.

#### REFERENCES

- [1] Conen D, Rexrode KM, Creager MA, Ridker PM, Pradhan AD.: "Metabolic syndrome, inflammation, and risk of symptomatic peripheral artery disease in women: a prospective study", *Circulation*, Vol.120, No.12, pp.1041-1047, 2009.
- [2] Miyazaki M, Lee VS.: Nonenhanced MR Angiography, *Radiology*, 248, pp.20-43, 2008.
- [3] K. Nakamura, A. Yamamoto, M. Miyazaki, S. Kawanami, Y. Shioya, Y. Matsufuji: "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, pp.1356, 2003.
- [4] A. Yamamoto, K. Nakamura, M. Miyazaki, Y. Shioya, S. Kawanami, Y. Matsufuji: "Non-contrast-enhanced MRDSA of peripheral arteries using continuous acquisitions of ECG-Triggered 2D half-Fourier FSE within a cardiac cycle", *Proc. International Society of Magnetic Resonance in Medicine*, Vol.11, pp.1709, 2003.
- [5] MacMahon H, Doi K, Chan HP, Giger ML, Katsuragawa S, Nakamori N: "Computer-aided diagnosis in chest radiology", *J Thorac Imaging*, Vol.5, No.1, pp.67-76, 1990.
- [6] J. M. Fitzpatrick, D. L. G. Hill, Y. Shyr et al.: "Visual Assessment of the Accuracy of Retrospective Registration of MR and CT Images of the Brain", *IEEE Trans. Med. Imaging*, Vol.17, No. 4, pp.517-585, 1998.
- [7] N. Ray, S.T. Acton, T.A. Altes et al.: "Merging parametric active counts within homogeneous image regions for MRI-based lung segmentation", *IEEE Trans. Med. Imaging*, Vol.22, No.2, pp.189-199, 2003.
- [8] S. Busayarat, T. Zrimec: "Detection of bronchopulmonary segments on high-resolution CT preliminary results", *IEEE International Symposium on Computer-Based Medical Systems*, pp.199-204, 2007.
- [9] J. Yi, J.B Ra: "A locally adaptive region growing algorithm for vascular segmentation", *International Journal of Imaging Systems and Technology*, Vol.13, No.4, pp.208-214, 2003.
- [10] Li Q, Sone S, Doi K.: "Selective enhancement filters for nodules, vessels, and airway walls in two- and three-dimensional CT scans", *Medical Physics*, Vol.30, No.8, pp.2040-2051, 2003.