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스네이크모델을 기반으로 한 경동맥 이미지분할

Automatic Carotid Artery Image Segmentation using Snake Based Model

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요 약

최근 의료영상을 이용한 질병 진단법에 대한 관심이 증가하고 있는 추세이다. 관절경화증은 경동맥의 동맥을 좁게 하여 뇌로 들어가는 혈류의 일부 또는 전체를 차단하는 원인이 된다. 뇌로 흘러가는 혈류가 차단되는 경우 심각한 뇌졸중을 야기하기도 한다. 만일 초기에 경동맥 플라크를 발견하고 이를 치료하면 심각한 뇌졸중을 예방할 수 있다. 본 논문에서는 경동맥의 동맥 초음파 영상에서 경동맥 플라크를 쉽게 발견하기 위한 능동적 윤곽선 추출기법에 기반을 둔 자동 분할기법을 제안한다. 실험에서 사용되는 초음파 영상은 자동 분할기법을 적용하기 전에 적절히 정렬되어있다고 가정한다. 경동맥의 동맥 초음파 영상에 대하여 스네이크 모델을 이용하여 자동분할 방법과 수동분할 방법을 질적 비교한 결과 제안된 방법이 성공적으로 적용되었음을 보여준다. 실험결과 제안된 방법은 방사선사들이 플라크를 쉽게 찾는데 도움을 줄 수 있는 자동화 방법이 될 것으로 예상된다.

Abstract

Disease diagnostics based on medical imaging is getting popularity day by day. Presence of the arthrosclerosis is one of the causes of narrowing of carotid arteries which may block partially or fully blood flow into the brain. Serious brain strokes may occur due to such types of blockages in blood flow. Early detection of the plaque and taking precautionary steps in this regard may prevent from such type of serious strokes. In this paper, we present an automatic image segmentation technique for carotid artery ultrasound images based on active contour approach. In our experimental study, we assume that ultrasound images are properly aligned before applying automatic image segmentation. We have successfully applied the automatic segmentation of carotid artery ultrasound images using snake based model. Qualitative comparison of the proposed approach has been made with the manual initialization of snakes for carotid artery image segmentation. Our proposed approach successfully segments the carotid artery images in an automated way to help radiologists to detect plaque easily. Obtained results show the effectiveness of the proposed approach.

Key words : Brain, Plaque detection, Snakes model, Carotid Artery Image, Image segmentation
(뇌, 플라크 검출, 스네이크모델, 경동맥 영상, 영상분)

Ⅰ. Introduction

Carotid arteries are main blood supplies to the brain. Narrowing the carotid artery may block the

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blood flow into the brain and causes a serious brain stroke. Early detection of the plaque in the arteries may prevent from such types of strokes. Non-invasive natures of diagnostic techniques in medical profession are invaluable. Ultrasound imaging is an attractive technique due to its non invasiveness. However, ultrasound images are of the poor quality due to the presence of spackle noise and waves interferences. As a result, carotid artery ultrasound images need considerable efforts from radiologists to detect the plaque. Hence, a computer aided diagnostic (CAD) technique for segmentation of carotid artery ultrasound images is highly desirable. It may help the radiologists extract significant information about the plaque and in determining the stage of disease[1]-[2].

Most of the CAD techniques require user intervention at certain level. Sometimes inexperienced user intervention may lead toward false results. Snake based method [3], dynamic programming [4] and combination of both [5] are used for automatic IMT measurement. In [6] authors have proposed a semi-automatic snakes based method for segmentation of carotid artery images. In their approach, a proper seed point is essentially required from the user to segment lumen of the carotid artery. Since, the basic drawback of snake based method is its initialization. Further, inappropriate snakes' initialization may leads toward misleading results. In this paper, we propose an automatic initialization of snakes to segment the carotid artery ultrasound images. Obtained results show the effectiveness of the proposed methodology.

The remaining paper is organized as follows. Section 2 describes the proposed approach, section 3 presents the experimental results and discussion. Conclusion and future work is described in section 4.

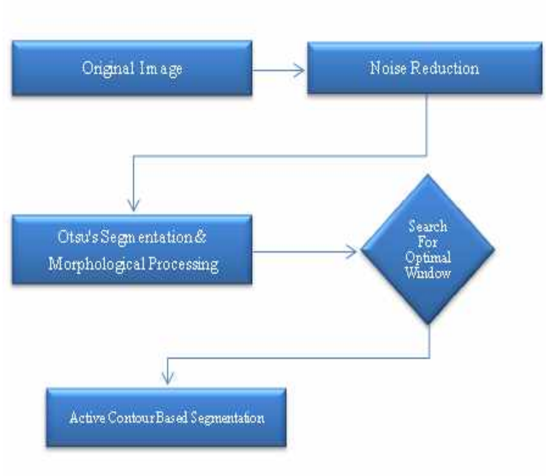

그림 1. 제안된 방법에 대한 흐름도
Fig. 1. Flow chart of the proposed approach

Ⅱ. The Proposed Approach

The proposed scheme of automated carotid artery image segmentation consists of the following steps. Its graphical representation is shown in Fig. 1.

2-1 Image Pre-processing

The major drawback of ultrasound images are its poor quality due to the presence of I. Image Pre-processing

The major drawback of ultrasound images are its poor quality due to the presence of spackle noise and wave interferences. To obtain better segmented image, noise must be removed. For this purpose, we have used median filter for noise removal as image pre-processing step. It is a non linear filter and preserves the image detail in better way. Further, median filter is an easy to apply technique for noise removal.

2-2 Snakes Initialization

The major disadvantage of active contour model is the initialization of snakes[7]. The initial selected window greatly affects on segmentation results. In this paper, snake initialization window is selected in an automatic way to segment the carotid artery ultrasound images. Snakes initialization in an automatic manner is one of the main contributions of this research work. The input to this step is pre-processed image. Automatic window selection methodology is described in detail in the following subsection.

a. Otsu's Method of Segmentation

First of all, we have to find the objects in the carotid artery ultrasound image. For this purpose, we employ Otsu's method [8] to separate the objects from the background. The Otsu's method is an automatic method of histogram based thresholding. Further, it is a non parametric and unsupervised threshold selection method. The main objective is to separate out the objects from image background considering it as a two class problem (background and the objects). The algorithm calculates the optimal threshold to separate the objects from background so that the intra-class variance becomes minimal by using the following equations.

$$\sigma_{\omega}^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) \tag{1}$$

where, σ_i^2 is the class variance, w_i are the probability of the classes separated by threshold t. Expression (2) is used to maximize the intra-class variance.

$$\sigma_b^2(t) = \sigma^2 - \sigma_{\omega}^2(t) = \omega_1(t)\omega_2(t)[\mu_1(t) - \mu_2(t)]^2 \tag{2}$$

The probability of the class $\omega_1(t)$ is computed from the histogram as using expression (3):

$$\omega_1(t) = \sum_0^t p(i) \tag{3}$$

Whereas, the mean of the class is computed by expression (4):

$$\mu_1(t) = \sum_0^t p(i)x(i) \tag{4}$$

The objects and the background are separated from the carotid artery ultrasound images. Some noisy patterns may remain there. These noisy patterns have to be removed by morphological opening operation using expression (5). The opening operation is usually used for smoothing the object contours and for elimination of thin protrusions[9].

$$f \circ b = (f \ominus b) \oplus b \tag{5}$$

After the opening morphological operation, the area inside the artery walls needs to be intelligently identified. For this purpose, negative of the Otsu's segmented image is obtained using the expression (6).

$$s = 1 - r \tag{6}$$

where, 's' is the resultant negative binary image and 'r' is the segmented image by Otsu's approach.

The advantage of image negative is that we are interested to find out the area inside the artery walls. After finding the area inside the artery, the algorithm intelligently decides the location and size of the window for snakes' initialization.

The location of the window varies from image to image depending upon the objects in the carotid artery ultrasound images. Once the window is determined the active contour method may be applied to segment the carotid artery ultrasound images successfully.

2-3 Segmentation of Carotid Artery Ultrasound Images

In our study, we have employed active contour method to segment the carotid artery ultrasound images. Active contour model is proposed by [10] and is widely used in computer vision applications. It is based on the energy minimization function. The advantage of using active contour model for segmentation is that the snakes are autonomous and self adapting in search for a minimal energy state and can easily be manipulated. The active contour model can be used to track objects in both spatial and temporal domains.

The governing equation of the snake is based on the internal and external energy components. The expression (7) is used as the governing equation of the active contour model.

$$E(v) = \underbrace{\int_0^L \alpha(s)\left|\frac{\partial v}{\partial s}\right|^2 + \beta(s)\left|\frac{\partial v^2}{\partial s^2}\right|^2 ds}_{S(v)} + P(v) \quad (7)$$

The parameters α and β are used to control the internal energy S(v) contour stiffness and elasticity. The gradient of image is calculated to find the external energy P(v). The minimum energy is obtained when contour approaches the edge of interests.

To assemble the contours, N piecewise polynomials are used. Each of which is built with as pace-independent shape function like B-Spline [11] weighted by the node parameters. The energy function, expression (7) is minimized corresponding to Euler Lagrange partial differential equations (PDE).

$$M\frac{d^2u(t)}{dt^2} + C\frac{du(t)}{dt} + Ku(t) = q(t) \quad (8)$$

where u(t) is the vector containing N nodes, M represents mass matrix, C shows the damping matrix, stiffness matrix is described by K and external for cesare represented by q[12].

The motion equations (8) are solved by replacing time derivatives with their discrete approximations. By discretizing time variable t results in the following difference matrix equation

.

$$Fu_\zeta = A_1 u_{\zeta-1} + A_2 u_{\zeta-2} + q_{\zeta-1} \quad (9)$$

where,

$$A_1 = 2M/(\triangle t)^2 + C/(\triangle t), \quad (10)$$

$$A_2 = -M/(\triangle t)^2, \quad (11)$$

$$F = A_1 + A_2 + K \quad (12)$$

The computational cost of expression (9) is very high because of F inverse calculation. But an alternative formulation has been proposed by Weruaga et al. [13] for translation of the energy function (7) into frequency domain. Matrix inversion is avoided through this procedure because it becomes a point-wise inversion in frequency domain. Initially it is valid for closed contours; however, with the help of hidden extension it can be applied to open contours as well. The following equations are used for the implementation of open active contours in frequency domain:

$$z_\zeta = a_1 u_{\zeta-1} + a_2 u_{\zeta-2} + \eta^{-1} q_{\zeta-1} \quad (13)$$

$$d_\zeta = \Gamma\{z_\zeta\}, \quad (14)$$

$$[u_\zeta \;\; e] - IDFT\{DFT\{[z_\zeta \;\; d_\zeta]\}.\hat{h}\} \quad (15)$$

where, u_ζ is N snakes vector, $q_{\zeta-1}$ external forces vector, global mass is represented by η, hidden snake rule is implemented using $\Gamma\{.\}$, d_ζ is the N-node snake extension, e is dummy residual vector, $\hat{h}$ is the low pass filter of discrete Fourier transform (DFT).

To get the final solution smoother, B-splines is used as a shape function [12], and at each update of the contour some additional calculations are performed. To get better execution time ratio, we use cubic B-splines in this study [14] and interpolate node parameters u using cubic B-splines to achieve active contour v in the image plane.

Ⅲ. Results and Discussion

The carotid artery ultrasound images used in this study are obtained from Shifa International Hospital, Islamabad, Pakistan. The Color Doppler ultrasound machine is currently being used for this purpose. We have converted the images into grayscales and further processing has been done on grayscale images. A small dataset of 50 images for different patients of different ages has been tested through our proposed approach. All computations have been performed on Intel Core i7 PC with Matlab 7.12.0 (2011a).

Fig. 2 (a) shows one of the original carotid artery ultrasound images. The region of interest (ROI) is selected from the original image. Fig.2 (b) shows the selected ROI. To reduce the spackle noise and wave interferences, median filter is applied on the original image.

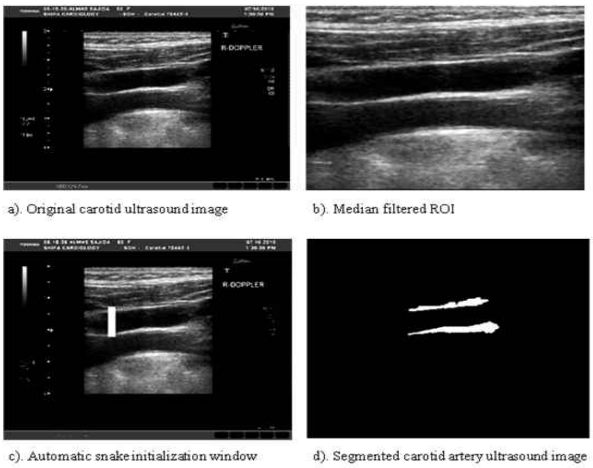

그림2. a) 경동맥 초음파 영상, b) ROI 영상 c) 스네이크 모델 초기화에 의한 자동 선택된 윈도우 d) 분할된 경동맥 초음파 영상

Fig. 2. a) One of the original carotid artery ultrasound image, b) the cropped median filtered ROI, c) the automatically selected window for snake initialization, d) the segmented carotid artery ultrasound image using active contour method.

A suitable and accurate window has been determined using the procedure described in section 2.2. The selected window for snake initialization is shown in Fig. 2 (c). The carotid artery ultrasound image is segmented using active contour approach is shown in Fig. 2 (d). From Fig. 2 (d), it may be observed that the image is segmented accurately using the active contour method which greatly depends upon the snakes' initialization. If initialization is done well, one can get significant results using active contour technique. As described earlier, manual initialization may lead to false segmented results. Hence, there is need of such a mechanism in which minimum interaction form user is required. In our proposed approach, we have developed a technique for automatic initialization of the snakes for carotid artery ultrasound image segmentation. It segment out the carotid artery ultrasound images in an automatic way and does not require user intervention.

A comparison of manual and our proposed approach of automatic snake initialization have been made for segmentation of carotid artery ultrasound images. The proposed approach shows promising segmentation results for carotid artery ultrasound image segmentation. Fig. 3 column (a) shows the carotid artery images of different patients segmented by our proposed approach using automatic initialization of snake window and Fig. 3 column (b) shows results through manual snakes initialization. From Fig. 3, it can be observed that images segmented by the proposed approach of automatic initialization and manual initialization approach do not make any difference, which shows the effectiveness of our proposed approach.

Countries like Pakistan, where there is lack of health facilities to the people living in remote areas. The proposed approach may become helpful to test the possible plaque status in the carotid artery in the absence of a skilled radiologist. Further, the proposed approach can be used as an initial diagnosing tool for the carotid artery diseases and this early detection of plaque in artery may prevent from serious brain strokes.

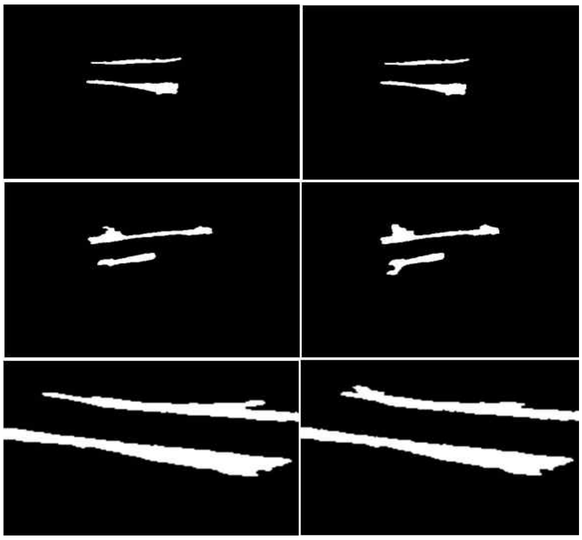

그림 3. a) 제안된 방법의 자동분할 결과 b) 제안된 방법의 수동분할 결과
Fig. 3. a) segmentation results using our proposed approach of automatic snake initialization b) the image segmented by manual initialization of snakes.

Ⅳ. Conclusions

This paper proposes an approach for automated segmentation of carotid artery ultrasound images using active contour model. The basic problem with the snake model is its initialization. To overcome the problem of manual initialization, we have proposed automatic initialization of snakes for carotid artery images. Carotid artery ultrasound images are segmented by our proposed approach in an automatic way. Performance comparison is carried out with the manual initialization of snakes. Using manual initialization, window is set empirically and it may be placed at right location. However, if user has less experience and initializes the window at improper place; he may not get accurate segmented results. While using the proposed approach, the user interaction is minimized and user experience may not affect the results. Segmentation based on minimal user interaction shows the usefulness of the proposed technique. In our future work, we intend to extend the automatic snake initialization at different types of medical images for effective image segmentation and classification.

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