Carotid Artery Identification in Ultrasound Images

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Abstract—**The carotid arteries are arteries that supply the head and neck with oxygenated blood. Carotid artery recognition is a fully automated, fast, and reliable way to facilitate the low-level task of arterial delineation. Automatic segmentation of the carotid artery from ultrasound images is a critical test in clinical diagnosis. A real-time, user-independent algorithm is introduced for carotid artery localization in 2D (B-Mode) ultrasound images. The proposed algorithm was systematically compared with another algorithm for common carotid artery (CCA) recognition in 2D scans. The data used included 500 images from 50 subjects taken from 5 different institutions and covering a wide range of possible lumen tissue representation. Using the resulting values, the carotid artery was recognized in all the processed images. Thus, the proposed technique will further reinforce automatic segmentation in longitudinal 2D ultrasound images.**

Keywords—Carotid Artery; Common Carotid Artery (CCA); Ultrasound; Segmentation.

I. INTRODUCTION

Automatic measurement and understanding of the geometry of the carotid artery (CA) is crucial in the assessment and management of carotid atherosclerosis. Non-invasive ultrasound imaging of the CA is widely used in the diagnosis of thermo because it allows the characterization of the severity of stenos is and plaque morphology in the clinical routine. However, exact measurement and analysis of the vascular geometry, morphology and elasticity require reliable definition of the carotid wall borders, which at present is not standardized in the diagnosis of the disease. Moreover, although experienced observers perform the outlining of the carotid wall-lumen interface, the procedure is tedious and prone to variability. Therefore, automatic segmentation of the arterial lumen is necessary in the assessment of the disease. Segmentation consists of two tightly coupled tasks: (i) recognition and (ii) delineation. Computer algorithms are very effective in object delineation; however, the absence of relevant global object-related knowledge results in their failure in object recognition. The algorithm concerns CA recognition through lumen medial axis detection. So far, the majority of methods introduced for CA segmentation require manual user assistance in arterial lumen recognition, whereas few others offer full automation. Completely automated CA recognition prior to contour delineation limits user-induced artifacts, thus providing (i) better accuracy in recognizing the random-shaped arterial lumen and (ii) repeatability, whereas it provides (iii) increased productivity compared to the manual one. Moreover, focusing on recognition alone, which remains the most challenging task in image segmentation, may also (iv) improve overall segmentation accuracy by facilitating the measurement procedure, (v) reduce overall computational cost, (vi) provide better flexibility, and (vii) offer better error control, because it is evaluated independently.

Previous work focused solely on automatic arterial recognition in longitudinal B-mode images is relatively limited compared to the work on CA delineation. A flow-mediated vasodilatation measurement procedure is used which is the automatic localization of the brachial artery using a variable window method. However, the described method may fail if the arterial lumen is not horizontally oriented.

An automatic region of interest (ROI) identification approach is used as initialization for a user-independent segmentation algorithm. However, the proposed algorithm may be misled by wall calcium plaque presence, and it is not well-suited for real-time applications. A real-time algorithm is used for the automatic recognition of the common CA (CCA) that acts directly on the envelopes of received radio frequency echo signals. However, their method can be exploited to its full extent when applied to multi-frame data. The two different methods are used for CCA recognition; a single-frame, and a multi-frame approach. However, both their methods are also prone to low Signal-to-Noise Ratio (SNR) in the lumen and to jugular vein presence.

An automatic CA localization approach is used based on a support vector machine (SVM) classifier and a novel random sample consensus (RANSAC) method to suppress misclassified points. However, their approach is not appropriate for real-time applications. The wall segmentation and intima-media thickness measurement techniques are used successfully applied automatic CA localization based on a combination of scale-space and statistical classification in a multi-resolution framework. However, because their CA recognition process was modeled by assuming that the CA's far wall adventitia is the brightest in the image; it may fail in cases where this assumption does not hold. A similar approach for lumen region identification was in the context of a novel automatic algorithm for segmenting the lumen and bifurcation boundaries of CCA, which can be further applied to automatically extract hemodynamic characteristics.

The aim of this work is to develop a robust, efficient, fully automated and real-time technique for CA recognition in longitudinal B-mode ultrasound images. A novel multistep algorithm is presented based on a combination of simple anatomical knowledge and statistics. The method operates efficiently on a single ultrasound image without the need of utilizing any subsequent frame information. But the disadvantage in this method is due to the high speckle content and/or artifacts residing within the arterial lumen, the backbone appeared slightly affected. So, in the proposed system the image to be segmented is processed with the application of an anisotropic diffusion filter for speckle removal and morphologic operators are employed in the detection of the artery.

The Problem statement is the accurate measurement and understanding of the geometry of the carotid artery (CA) is crucial in the assessment and management of carotid atherosclerosis. Existing system uses a real-time algorithm for carotid artery localization in longitudinal B-mode ultrasound images. But in cases of non-uniform luminal intensity, caused e.g. by high speckle content and/or artifacts residing within the arterial lumen, the backbone appeared slightly affected. Also, the algorithm may not be able to distinguish between lumen and hypoechoic tissue, e.g. when increased speckle content and/or a highly stenotic hypoechoic plaque are present, which is generally believed to be associated with soft and unstable tissue.

The main intent of this work is to achieve high robustness and reliability in the carotid artery recognition system. The main work is to remove the speckle noise by using the Gaussian low-pass filter so that the smoothed image with the two 2D histograms allows the identification of the lumen region of the carotid artery based on its hipoechogenic characteristics.

II. Proposed System

A. Proposed Work

In the proposed system, a new algorithm is proposed for the segmentation of the lumen and bifurcation boundaries of the carotid artery in B-mode ultrasound images. Because in the existing method in cases of non-uniform luminal intensity, caused e.g. by high speckle content and/or artifacts residing within the arterial lumen, the backbone appeared slightly affected. Also, the algorithm may not be able to distinguish between lumen and hypoechoic tissue.

So, in the proposed system a new algorithm is proposed for the segmentation of the lumen and bifurcation boundaries of the carotid artery in B-mode ultrasound images. The algorithm may not be able to distinguish between lumen and hypoechoic tissue. The image to be segmented is processed with the application of an anisotropic diffusion filter for speckle removal and morphologic operators are employed in the detection of the artery. However, the image data must be previously processed for speckle noise removal and attenuating the high intensity noisy points in the intensity distribution; in this task, a Gaussian low-pass filter is used.

With the application of a Gaussian low-pass filter, for speckle noise reduction, the combining of the smoothed image with the two 2D histograms allows the identification of the lumen region of the carotid artery based on its hipoechogenic characteristics. The image data must be previously processed for speckle noise removal and attenuating the high intensity noisy points in the intensity distribution; in this task, a Gaussian low-pass filter is used. The method is robust to speckle noise, does not require human interaction and can adjust well the segmentation contours to the lumen boundaries represented in the input images. The algorithm may not be able to distinguish between lumen and hypoechoic tissue. The image to be segmented is processed with the application of an anisotropic diffusion filter for speckle removal and morphologic operators are employed in the detection of the artery. However, the image data must be previously processed for speckle noise removal and attenuating the high intensity noisy points in the intensity distribution; in this task, a Gaussian low-pass filter is used.

B. Proposed Algorithm

The algorithm mainly consists of four steps.

(1) Image area selection: The data sets are taken from institutions and covering a wide range of possible lumen and surrounding tissue representations. Usually, images are noisy and low contrast. So that pre- processing steps are considered for this kind of noisy image. The carotid artery (CA) structure often appears in the center of the image the lateral 10% of the image width was ignored, as in, whereas preserving the entire image height (Fig 1(a)).

(2) VIP signal selection: VIP means Vertical Intensity Profile. In the area selected image, the concept of lateral interspacing adapted for vertical signal selection was followed. A finite number (N) of VIP signals was considered every s_{step} mm thus reducing its 2D information content to a series of 1D signals. The lateral interspacing of $s_{step} = 0.5mm$ was selected, because it provides a rather adequate sample size for robust and accurate CA recognition, and has a relatively low computational cost. After testing, any value of s_{step} in the interval (0 0.5) mm yielded the same success rate, while smaller values were only at the expense of increased computational cost (Fig 1(b)).

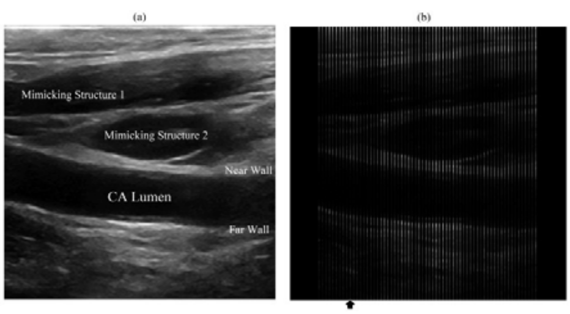

Fig. 1.(a) A longitudinal B-mode ultrasound image of the CA (b) The N vertical intensity profile (VIP) signals

(3) *Single Lumen Center Point Detection:* For each selected VIP signal a statistics-based, multistep procedure was used for the estimation of a single lumen center point. This procedure is based on the ultrasonographically depicted CA anatomical characteristics. In particular, starting from the bottom of the ultrasound image and moving upwards, first one ordinarily encounters the (usually brightest) far wall region, then the (usually darkest) lumen, and then the (usually second brightest) near wall. By using these attributes defined by the attribute authorities, the access police will be generated inorder to limit the data accessing of multiple users. The user who matches with the access policy only can decrypt the data’s. This step consists of 4 another sub categories. Its include, VIP local mean and variance computation, Potential lumen and wall segments identification, Segment filtering, Potential lumen centre point identification.

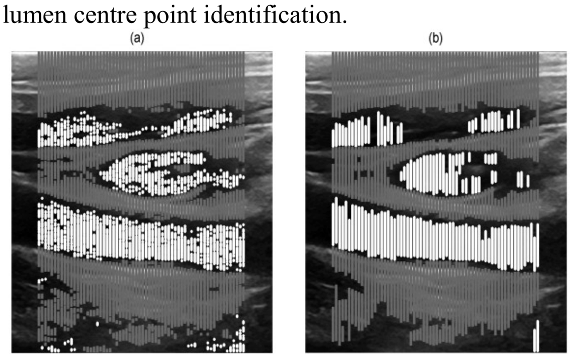

Fig.2. Potential Lumen and Wall Segments (a) before filtering (b) after filtering

(4) Backbone Processing: At the end of the application of the lumen center point detection algorithm to all VIP signals, a number of Group U and/or Group D points that equals or is smaller than N is generated. However, due either to artifacts in some VIP signals, or to the impossibility to find segments points meeting the imposed constraints, the resulting set of points needs to be further processed to substantially increase the success rate. Therefore, another multi-step procedure is followed, the input of which consists of a subset of these points. This subset of points, designated as the ‘backbone’, is suitably initialized, filtered, extended and smoothed, so as to extract a robust and accurate arterial lumen center representation. Backbone Initialization, Backbone Filtering, Backbone Extension, Backbone Smoothening are the 4 major steps.

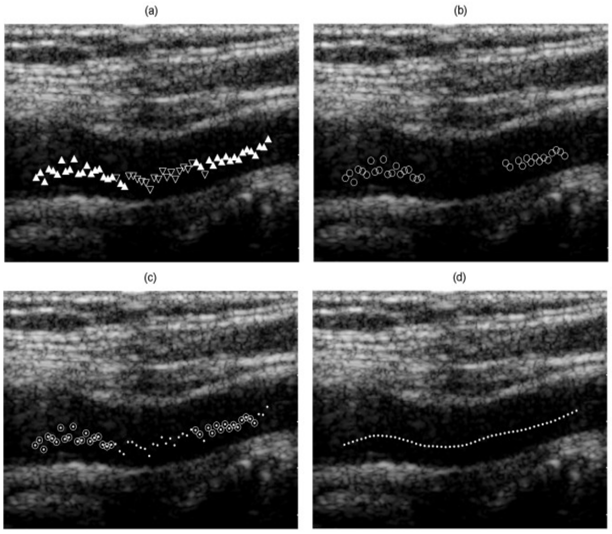

Fig. 3. Intermediate step of Proposed CA recognition algorithm. (a) Lumen center point detection output (b) Backbone filtering output. (c) Backbone extension output (d) Backbone smoothing

C. System Architecture

The overview of the system architecture design is shown in Fig. 4. Briefly, a finite number of equally spaced, vertical intensity profiles (VIP) are considered in a single image. The CA recognition algorithm was developed and evaluated within Matlab® 7.9 R2009b (The Math Works Inc., Natick, MA, USA). A finite number of equally spaced, vertical intensity profiles (VIP) are considered in a single image. For every VIP signal, a statistics-based procedure is used for single lumen center point identification.

A subset of the resulting lumen center points, designated as the 'backbone', is further processed to accurately estimate the CA lumen position. In image area selection, because the CA structure often appears in the center of the image, the lateral 10% of the image width was ignored, whereas preserving the entire image height. In the VIP signal selection, the concept of lateral interspacing adapted by Rossi *et al.* for vertical signal selection was followed. Specifically, a finite number (*N)* of VIP signals was considered every *step* mm, thus reducing its 2D information content to a series of 1D signal. The lateral interspacing of *sstep* = 0.5 mm was selected, because it provides a rather adequate sample size for robust and accurate CA recognition, and has a relatively low computational cost. After testing, any value of step in the interval (0 0.5) mm yielded the same success rate, while smaller values were only at the expense of increased computational cost. In single lumen center point detection, For each selected VIP signal, a statistics-based, multistep procedure was used for the estimation of a single lumen center point. This procedure is based on the ultrasonographically depicted CA anatomical characteristics. In particular, starting from the bottom of the ultrasound image.

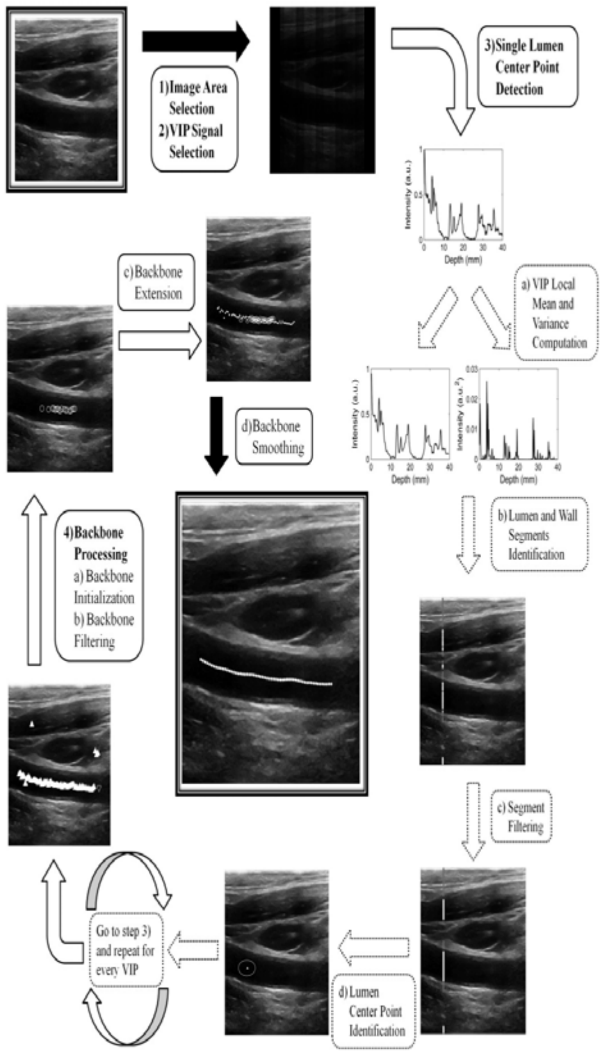

Fig.4. Overall structure of the robust CA recognition algorithm.

III. Conclusion and Discussion

The algorithm provides a simple, fast, robust and highly efficient way to locate the CA in longitudinal B-mode ultrasound images. Applied directly to the raw image, it managed to recognize the CA with high robustness and reliability. The success rate was achieved after systematically evaluating the proposed algorithm on images from different image acquisition systems and transducers, sonographers, settings, subject's profiles and clinical conditions, and was proven parameterization tolerant. Moreover, the method's particularly low computational cost, its single-frame sufficiency, along with its extendibility, facilitates both a wider range of on-line and off-line applications. All these render the introduced technique a suitable and reliable tool for lumen recognition that will further reinforce the completely user independent segmentation of the CA in longitudinal B-mode ultrasound images.

The future work will be focused on evaluating this method on patients who are suffered from advanced cardiovascular conditions, such as those with atherosclerosis plaque. A suitable and reliable tool for lumen recognition that will further reinforce the completely user independent segmentation of the CA in longitudinal B-mode ultrasound images. Moreover, the method's particularly low computational costs, its single-frame sufficiency, along with its extendibility, facilitate both a wider range of on-line and off-line applications.

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