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Segmentation of Intima Media Complex of Common Carotid Artery

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ABSTRACT: Atherosclerosis is a disease of blood vessels caused by the formation of plaques in artery walls. Its diagnosis is one of the most important medical examinations for the prevention of cardiovascular events, like myocardial infarction and stroke. The segmentation of the intima-media complex (IMC) of the common carotid artery (CCA) wall is important for the evaluation of the intima media thickness (IMT) on B-mode ultrasound (US) images. IMT is considered an important marker in the evaluation of the risk for the development of atherosclerosis. Carotid intima media thickness (IMT), which is the distance between the lumen-intima and the media-adventitia interfaces, is a measure of early atherosclerosis. segmentation algorithm is based on active contours and active contours without edges and provides information to achieve accurate segmentation. The level set formulation by Chan and Vese model provides a segmentation of the CCA US images into different distinct regions, one of which corresponds to the carotid wall region below the lumen and includes the far wall IMC.

KEYWORDS: Carotid Artery, Level Set Segmentation, Active Contour, Intima Media Thickness.

I.INTRODUCTION

The cardio vascular disease (CVD) is one of the most common causes of death in the western world and stroke is the most common cause of disability in women. Therefore, the need to identify the asymptomatic patients at higher risk is great. The main pathophysiological mechanism leading to CVD is the development of atherosclerosis: the degeneration of the arterial walls though lipid and other blood-born material on vascular territories throughout the body. Carotid intima media thickness (IMT), which is the distance between the lumen-intima and the media-adventitia interfaces, is a measure of early atherosclerosis. It can be evaluated quantitatively, noninvasively and with low cost, using high-resolution B-mode ultrasound (US) where it can be seen as the double line pattern on both walls of the longitudinal images of the common carotid artery (CCA). Atherosclerosis is diagnosed when there are large values of the intima-media thickness (IMT), the distance between the innermost boundaries of the intima and the adventitia of the artery, Carotid IMT is correlated with all traditional vascular risk factors and is regarded as a marker of atherosclerosis.

It provides an index of individual atherosclerosis and has been shown to positively correlate with the severity of atherosclerosis and can predict cardiovascular events independent of traditional risk factors. Even though other measures such as carotid wall irregularity can be used for the diagnosis of atherosclerosis, IMT is the measure most commonly used at present . Thus, the IMT may be used for the screening of population as at least half of premature heart attacks and strokes, can, and should, be prevented . IMT can be measured through the segmentation of the intima media complex (IMC), which corresponds to the intima and media layers of the arterial wall. Proper evaluation of the carotid IMT could be used to identify people at higher risk than traditional CVD risk factors alone. The determination of the IMC boundaries is, however, a complicated task, as the IMC is a thin, relatively low contrast structure, that may be affected by US artifacts, may appear differently due to either different imaging angles or differences in anatomy, and deteriorates with age.

Ultrasound imaging has lower cost and smaller risk to the patient than alternative methods like X-ray angiography or intravascular ultrasound . However, Bmode images are a challenge to segmentation due to several degrading factors like speckle echo shadows movement artifacts attenuations. The segmentation of diseased arteries brings additional difficulties since there is no shape prior for plaques and the differences between the texture of the plaque and the

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texture of other nearby tissues are not strong enough for texture-based segmentation. Ultrasound is the most used diagnostic tools to assess CVDs. Ultrasounds offer several advantages in clinical practice such as: (i) they are nonionizing radiations, (ii) they allow a safe and relatively quick examination of the patient, (iii) they have no dangerous biological effects, (iv) equipment is relatively low-cost (if compared to other medical imaging devices) (v) the ultrasound equipment is widely available in many centres, and lastly and (vi) ultrasounds can effectively visualize the arterial wall itself. Unfortunately, ultrasounds are operator-dependent. Also, ultrasound images have a signal-to noise (SNR) ratio that is lower than other imaging modalities (such as, MRI and CT).

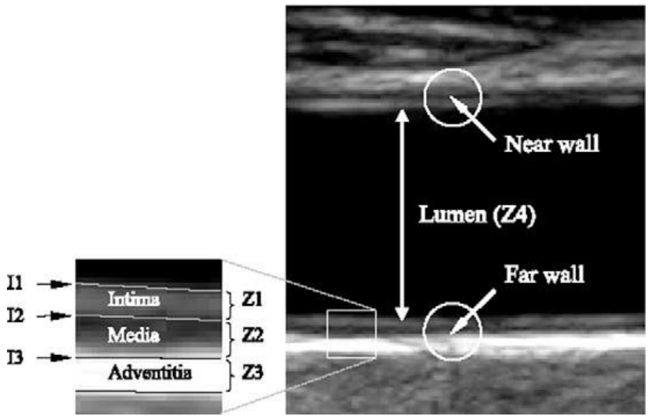

Fig 1: Longitudinal view of lumen

The lumen (zone Z4) is the region where the blood flows. The CCA wall is formed by the intima (zone Z1), the media (zone Z2) and the adventitia (zone Z3) regions. The boundaries between these four regions are represented by the lines I1, I2 and I3. The measurement of the IMT is often limited to the far-end wall, due to its better visibility in B-mode images. The IMT, as risk indicator, possesses many advantages :
(i) It is a validated early marker of atherosclerosis
(ii) The measure is highly repeatable
(iii) It can be measured non-invasively
(iv) It can be used to quantify pathology monitoring

The method for the segmentation of the intima media region in ultrasound images, which combines splines (for the adventitia detection), dynamic programming (DP), smooth intensity thresholding surfaces and a successful geometric active contour model known for its accuracy, flexibility and robustness. Our method presents several attractive features, in particular: it is robust to speckle and irregular contrast; it includes a global smoothness constraint. Initialization of the active contour is automatic; unlike balloon-based snakes, the propagation force of the active contour does not depend on gradients and does not require a predefined direction, several image features are used in the segmentation; no training is required. Human interaction is minimal; it is able to segment both near-end and far-end carotid walls; it supports plaques of different sizes, shapes .

II.METHODOLOGY

The method is based on the use of active contours and active contours without edges to segment different regions in the carotid US images. The level set formulation of the active contours without edges by Chan and Vese represents curves in an implicit manner, and can handle changes and which has been one of the main difficulties that snake based CCA algorithms faced. The active contours without edges algorithm is used to segment the US images into the lumen and the carotid wall, and the segmentation results are combined to evaluate the needed parameters and process the US image for accurate segmentation of the IMC at different stages of the algorithm.

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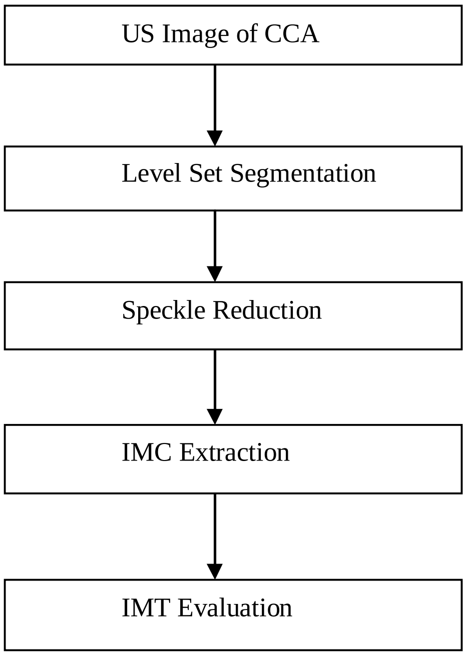

Fig 2: Block Diagram

A.LONGITUDINAL US IMAGE OF CCA

For the evaluation of the IMT, B-mode longitudinal US images of the CCA are used, which display the vascular wall as a regular pattern that correlates with anatomical layers. The images cover longitudinally the carotid artery and show the near wall, the lumen and the far wall. IMT appears as a double-line pattern on both walls of the CCA in the longitudinal US image, and consists of the leading edges of two anatomical boundaries: the lumen-intima and media-adventitia.

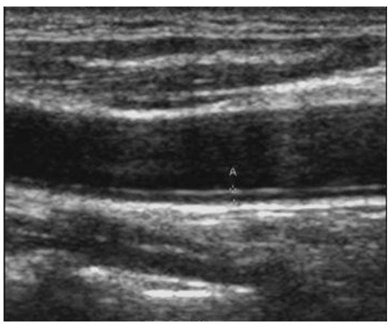

Fig 3: B Mode US Image of CCA

B.LEVEL SET SEGMENTATION

Level set methods offer a highly robust and accurate method for tracking interfaces moving under complex motions: they work in a number of space dimensions but more importantly they can handle topological changes naturally. Using the level set formulation of the active contours without edges by Chan and Vese ,the regions corresponding to the lumen and the carotid wall (including the intima, the media and the adventitia) are automatically segmented. The Chan–Vese model corresponds to a region-based level set method which uses the Mumford–Shah functional in the level set

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framework for a piecewise constant representation of an image. The evolution of the curve is governed by properties of the region of the image $u0\ (x, y)$ enclosed by the curve. The method is robust to speckle as well as irregular contrast, but most importantly it is completely automated, does not require user interaction and is not depended on edges. After the Chan–Vese model is applied the image is segmented into a number of regions some corresponding to the artery wall while others to the background and the lumen.

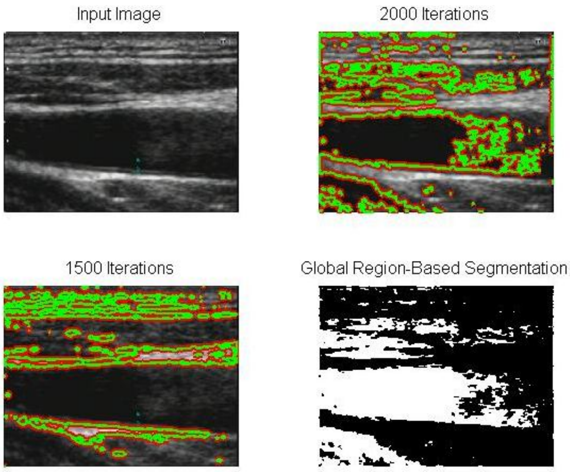

Fig 4: Level Set segmentation Output image

C.SPECKLE REDUCTION

Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar (SAR) images. Speckle noise in conventional radar results from random fluctuations in the return signal from an object that is no bigger than a single image-processing element. It increases the mean grey level of a local area. Speckle noise has a significant impact on the correctness of boundary detection. The edges of the adventitia are also affected by this noise. Median filter is used to de speckle the image.

Fig 5: Speckle reduction Output

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D.CCA EXTRACTION-ACTIVE CONTOUR

A snake is an energy-minimizing spline guided by external constraint forces and influenced by image forces that pull it toward features such as lines and edges. Snakes are active contour models: they lock onto nearby edges, localizing them accurately. The snakes segmentation technique implemented in this study is based on an energy function as defined by Williams and Shah . Snakes provide a unified account of a number of visual problems, including detection of edges, lines, and subjective contours; motion tracking; and stereo matching. We have used snakes successfully for interactive interpretation, in which user-imposed constraint forces guide the snake near features of interest.

The boundary of the far wall adventitia, resulting from the application of the Chan–Vese level set provides an excellent initialization for the segmentation of the IMC using snakes . The extracted boundary, between the lumen and the adventitia approximates very closely the lumen-intima boundary and provides the contour points needed to run the snake. The gradient of the line that best fits the initialization boundary, using least squares error approximation, provides a constraint for the choice of points used to initialize the parametric active contour.

$$E^*_{snake} = \int_0^1 E_{snake}(v(s))ds = \int_0^1 (E_{internal}(v(s)) + E_{image}(v(s)) + E_{constraints}(v(s)))ds \quad (1)$$

where $\mathbf{v}(s) = (x(s), y(s))$ is the vector representation of the contour with the arc length s as the parameter. $E_{internal}$ corresponds to the internal regularization energy that imposes continuity and bending constraints and comprises two components, while E_{image} represents the image energy incorporating local gradient magnitude:

$$E = \int \{\frac{1}{2}\alpha(s)|v'(s)|^2 + \frac{1}{2}\beta(s)|v''(s)|^2 + \gamma(s)\ (-|\nabla I(v)|^2)\}ds \quad (2)$$

where prime denotes differentiation and the parameters α, β, and γ are normalizing factors used to balance the relative influence of the three energy term. The resulting segmentation corresponds to the IMC. The boundary of the far wall adventitia, resulting from the application of the Chan–Vese level set provides an excellent initialization for the segmentation of the IMC using snakes . The extracted boundary, between the lumen and the adventitia approximates very closely the lumen-intima boundary and provides the contour points needed to run the snake.

Fig 6: CCA extracted using snake algorithm

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E.IMT EVALUATION

Segmentation of IMC provides the important aspects to evaluate the intima media thickness. The thickness if the IMC is the result obtained on dividing total number of pixels present in the segmented portion of the US image by the dots per inch present in it. The thickness is evaluated in mm.

III. RESULT & CONCLUSION

The proposed method extracts the intima- media complex from the ultrasound images of common carotid artery. Level-set method segments the input images into the lumen and the carotid wall. The segmentation results combined with anatomical information forms the basis for the IMC segmentation. The image variability is reduced by normalization and speckle removal reduces the noise in the input images. The active contour using snake segments the intima media complex which is used to evaluate the intima media thickness. Mean absolute distance is calculated for the segmented images and it is found that the carotid arteries in normal cardiac conditions have IMT in the range of 0.4mm to 1.5 mm. The arteries with IMT greater than the specified range have signs of atherosclerosis. The presented technique represents a generalized and standard methodology towards completely automated and accurate IMT measurement. It may be used for aiding the clinicians through providing support in their examination, reducing not only evaluation time, but also the variability between readers whilst improving reproducibility.

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