Detection and Measurement of Intima Media Thickness of the Common Carotid Artery

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Abstract— Atherosclerosis is a condition where the arteries become narrowed and hardened because of excessive build up of fatty substances called plaques around the artery wall. The disease disrupts the flow of blood around the body resulting in serious cardiovascular complications. The Intima Media thickness (IMT) is used as a validated measure for the evaluation of atherosclerosis. Manual assessment of the IMT results in inaccurate measurements. So there is a need for automatic identification of Intima Media with proper segmentation algorithms and measurement of IMT. To fulfill this need, an effective segmentation method, Otsu thresholding is proposed for the identification of the intima media of the common carotid artery and measurement of the intima media thickness to indicate the presence or absence of atherosclerosis. To reduce the speckle noise in the ultrasound image of the common carotid artery, Speckle Reduction Anisotropic Filter is used. This improves the detection efficiency.

Index Terms— Ultrasound Image, Atheroschlerosis, Carotid Artery, Intima Media Thickness, Otsu Thresholding, Speckle Reducing Anisotropic Filter, Watershed Segmentation.

1 Introduction

Cardiovascular disease is one of the leading causes of deaths in the metropolitan cities. Cardiovascular ailments are relative to atherosclerosis. Atherosclerosis is responsible for the thickening of the arterial wall.The atherosclerotic process refers to the degeneration of the arterial wall and the deposition of lipids and other blood borne material within the arterial wall of almost all vascular territories [8]. The first indication of atherosclerotic vascular disease is a thickening of the intimal and medial layers of the arterial wall. It is commonly known as intima media thickness (IMT).This results from inflammatory-fibroproliferative responses to various forms of insult. It involves lipid accumulation, and the migration and proliferation of many cells in the sub-intimal and medial layers, so that plaques are formed. It is the rupture of such plaques that causes myocardial infarcts (heart attacks), cerebrovascular events (strokes), peripheral vascular disease (gangrene) and kidney infarcts respectively.IMT higher than 0.9 to 1.0 mm indicates a potential atherosclerotic disease [7]. Hence, the robust segmentation and measurement of the IMT has a considerable impact in the early diagnosis of atherosclerosis. Early atherosclerosis is readily visualized in large superficial arterial vessels such asthe common carotid using ultrasound and is a well established independent predictor of cardiovascular events [18].

Although manual assessment of the IMT results in accurate measurements, the process of annotating ultrasound data is not only labor intensive, but is also highly dependent on the experience of the medical practitioner. Manual tracing procedures are not reproducible and they are generally characterized by high intra and inter user variability. This affects the correct evaluation of the cardiovascular risk. So there is a need for automatic identification of Intima Media with proper segmentation algorithms and measurement of IMT. This greatly supports the clinical practitioners in their evaluation.

Several methods have been proposed for automatic identification of the Intima Media and measurement of IMT.They include techniques based on edge detection, dynamic programming, active contours (snakes) and probabilistic approaches.

Cheng et al. [3] detected the intima-media complex of the common carotid artery using snake technique. Francesco Faita et al. [4] described an automatic real time system which uses edge detector for the evaluation of intima media thickness of the carotid artery. Liang et al. [17] used multiscale dynamic programming for the detection of boundaries in carotid arteries with optional modification by a human operator.Molinari et al. [8] evaluated the different segmentation techniques for intima media detection and evaluated their performance. Dana et al. [18] developed a Computer Aided Detection system embedding a statistical model to identify the intima media complex.Loizou et al. [6] evaluated an integrated system for the segmentation of atherosclerotic carotid plaque in ultrasound video of the common carotid artery using parametric active contours.

The proposed technique aims to identify the IMT to detect early abnormalities in the carotid arteries using segmentation technique, Otsu Thresholding.Before thresholding, the image is converted into grayscale and speckle noise is removed using Speckle Reducing Anisotropic Diffusion filter. After Intima Media is detected the thickness is measured to indicate the presence of atherosclerosis.

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2 Materials and Methods

2.1 Input Image

The experimental data consists of N=10 ultrasound images of the common carotid artery that were captured using Voluson GE e8 equipment. The image is a true colour image. The data comprises of both normal and abnormal with plaque images.

2.2 Block Diagram

The block diagram of the proposed algorithm is shown in Figure 1.

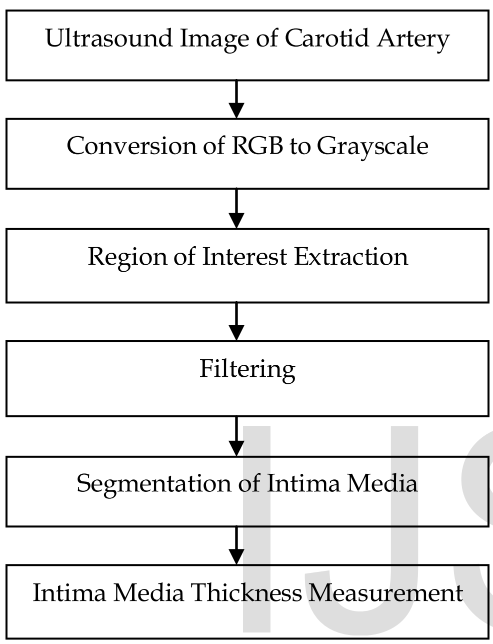

Fig. 1. Block diagram of Intima Media Thickness measurement

2.3 Region of Interest Extraction

The input image is a true color image. It is converted to a grayscale image for easy processing. Then the required portion, either the upper or lower portion of the right or left carotid artery is cropped.

2.4 Filtering

The cropped carotid artery region consists of multiple noises. Among them speckle noise content is high. Speckle has a negative impact on ultrasound imaging. The speckle noise degrades the fine details and edge definition, limits the contrast resolution and hence it should be filtered out.The process of removing the specle noise content in the image is called De-speckling. Speckle Reducing Anisotropic Filter (SRAD) is used for Despeckling.SRAD filter [14], [15] removes the noise from the image via solving a partial differential equation (PDE).

2.5 Segmentation

Two different segmentation techniques namely Watershed segmentation and Otsu thresholding are analysed for intima media detection.

A. Watershed Segmentation

The watershed segmentation is a morphological based method of image segmentation. The gradient magnitude of an image is considered as a topographic surface for the watershed transformation. The complete division of the image through watershed transformation relies mostly on a good estimation of image gradients.

The procedure for watershed segmentation is described as follows [11], [12]:

1. The gradient magnitude is used as the segmentation function and is computed by applying the Sobel edge mask.
2. The foreground objects are marked to avoid problems of oversegmentation. Morphological techniques called "opening-by-reconstruction" and "closing-by-reconstruction" are done to clean up the image.
3. The background markers are computed.
4. The segmentation function is modified.
5. The Watershed Transform of the segmentation function is computed.
6. The result is visualized by superimposition of the foreground markers, background markers, and segmented object boundaries on the original image.

B. Otsu Thresholding

Thresholding is the simplest method of image segmentation. Thresholding is used to create binary images from a grayscale image.Individual pixels in an image are "object" pixels if their value is greater than the threshold value and "background" pixels otherwise. An object pixel is assigned the value of "1" while a background pixel is given the value of "0". Otsu's thresholding method [10] is used to determine the threshold. The measure of spread for the pixel levels on each side of the threshold is calculated by iterating through all the possible threshold levels.

The procedure for Otsu thresholding is described as follows:

1. Histogram and probabilities of each intensity level is computed.
2. Initial probability and mean value is set up.
3. Step through all possible thresholds t=1… maximum intensity.
4. Probability and mean values are updated.
5. The between class variance is computed.
6. The desired threshold corresponds to the maximum between class variance
7. Two maxima are computed.
8. The desired threshold is computed to obtain the binary image.
   Desired threshold = (Threshold1 + Threshold 2)/2.

The image of the carotid artery when thresholded results in a

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binary image where the white portion indicates the intima media region.After the image is converted into a binarized image, morphological operations such as removal of all the smaller pixels and the removal of the the holes occurred between two lines are done.

2.4 Measurement of Intima Media Thickness

After the segmentation of the intima media region, the thickness of the intima media is measured. Thickness above 0.9 mm indicates the presence of atherosclerosis.

3 Results and Discussion

Simulation of intima media segmentation using watershed segmentation and Otsu thresholding was performed using MATLAB and the results are shown below.

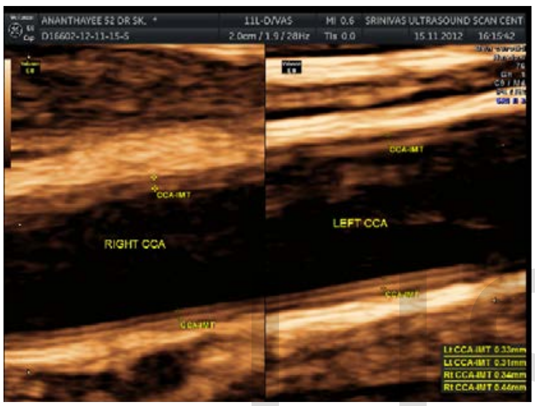

Fig. 2. True colour ultrasound image of the common carotid artery (both right and left) manually annotated by the medical practitioner.

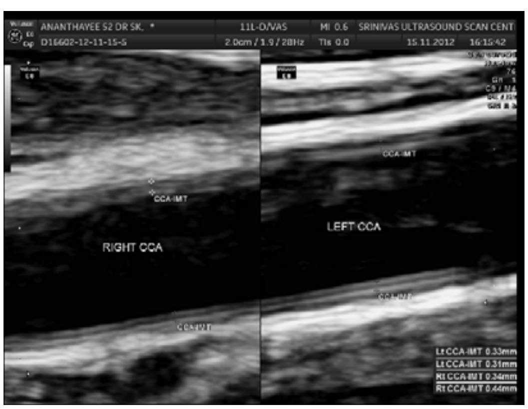

Fig. 3. Ultrasound image of the common carotid artery after conversion to grayscale

The required portion ie the upper or the lower portion of the right or left common carotid artery is cropped to segment the intima media region and measure its thickness.Fig. 4 shows the cropped portion of the lower left common carotid artery and Fig. 5 shows the image after the removal of the speckle noise using SRAD filter.

Fig. 4. Cropped portion of the lower left common carotid artery.

Fig. 5. Image after the removal of speckle noise

The watershed segmentation is applied to the filtered image to segment the intima media region.Fig. 6(a) shows the watershed lines and Fig. 6(b) shows the markers and object boundaries superimposed on the cropped image.

Fig. 6. (a) Watershed lines (b) Superimposition on cropped image

Then Otsu thresholding is applied to the filtered image to compare its performance with watershed segmentation.A binary image is obtained as a result of thresholding. The white portion indicates the intima media region.Fig. 7(a) shows the binarized image.Then morphological operations such as removal of smaller pixels and removal of holes is done to exactly obtain the intima media region.Fig. 7(b) shows the binarized image after the removal of smaller pixels and Fig. 7(c) shows the image after the removal of smaller pixels.

Fig. 7. (a) Binary image (b) Removal of smaller pixels (c) Removal of holes

Watershed segmentation does not properly segment the intima media region in plaque images. Hence Otsu thresholding is used for segmentation and from the segmented portion the intima media thickness is measured.

Table I shows the IMT measurement of upper and lower intima media of the right and left common carotid artery in comparison to the annotation made by the doctor.

TABLE 1
INTIMA MEDIA THICKNESS MEASUREMENT

Image	Left Carotid Artery				Right Carotid Artery			
	Upper IMT		Lower IMT		Upper IMT		Lower IMT	
	Doc mm	IMT mm	Doc mm	IMT mm	Doc Mm	IMT Mm	Doc mm	IMT mm
1	0.45	0.43	0.51	0.49	0.50	0.52	0.55	0.45
2	0.42	0.41	0.38	0.40	0.47	0.47	0.40	0.38
3	0.55	0.47	0.52	0.50	0.55	0.54	0.48	0.47
4	0.33	0.33	0.31	0.25	0.34	0.30	0.44	0.44
5	0.58	0.55	0.66	0.65	0.40	0.40	0.57	0.50
6	0.72	0.73	0.50	0.44	0.75	0.66	0.41	0.41
7	0.56	0.50	0.79	0.70	0.71	0.69	0.89	0.89
8	1.05	0.99	0.85	0.87	1.08	1.00	0.99	1.05
9	0.67	0.67	1.98	1.93	0.98	0.95	0.86	0.84

4 CONCLUSION

Otsu Thresholding Segmentation method is found to perform better for both normal and abnormal image and the intima media thickness is found to be closer to that of the manual annotation of the medical practitioner. Watershed segmentation performs better only for normal images.

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