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Filtering and Detection of Intima-media Thickness (IMT) for the risk of Carotid Artery Atherosclerosis

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Abstract: ***Ultrasound images of carotid artery in brightness mode (B-mode) are used to detect the probabilities of atherosclerosis and cardiovascular diseases. They are used to measure the intima-media thickness (IMT). Ultrasound images suffer from peculiar phenomena which creates speckle (a type of noise) on the image. The speckles present in the medical images detoriates the quality of the image. This paper presents a work which is used to remove the speckles by utilizing the local characteristics of the image in the filter named as local statistics mean variance (lsmv) filter. It is a preprocessing step of medical image processing. Conventional IMT was done by locating the far walls of the carotid artery. This can be changed by applying segmentation algorithm which could automatically detect the far walls and could measure the IMT. This paper approaches towards automatic edge detection method using Prewitt operator. The objective behind automatically calculating IMT of carotid artery is to reduce the human effort and at the same time would benefit the patient by diagnosing the patient condition. The work that is proposed is analyzed by calculating various parameters in case of despeckling (filtering) as well as segmentation method. The performance parameters show that the proposed method performs better and at the same time reduces the manual effort.***

Index Terms: ***carotid artery, intima-media thickness, lsmv filter, medical image, segmentation***

I. INTRODUCTION

Medical images are commonly used by the doctors to diagnose the diseases. Coronary heart disease (CHD) is the most disastrous disease in the developing countries like India. Day by day the increases in death are switching towards cardiovascular diseases [1] as shown in Fig. 1. This increased rate of death is a serious problem and it should be diagnosed faster. The conventional method of detecting intima-media thickness is first identifying the far wall of carotid artery and then calculating the thickness of the wall. Thus suitable segmentation method which would determine the edges and calculate the thickness automatically would definitely solve the problem of calculating the thickness manually by the doctors.

Fig. 1 Top 10 Causes of Mortality Non-communicable diseases

2008	2030
Cardiovascular diseases	Cardiovascular diseases
Cancers	Cancers
Chronic Respiratory diseases	Chronic Respiratory diseases
Respiratory infections	Respiratory infections
Prenatal Conditions	Diabetes Mellitus
Diarrheal diseases	Digestive diseases
Digestive diseases	Perinatal Conditions
HIV/AIDS	Neuropsychiatric disorders
Tuberculosis	Genitourinary diseases
Neuropsychiatric conditions	HIV/AIDS

The atherosclerosis disease present in carotid artery is a disease in which the internal walls of the carotid artery become thick. The thickening of the walls results into low supply of nutrients and oxygen to the brain. This result into stroke, brain hemorrhage, paralysis or even death. The work is done on B-mode ultrasound image. The image of common carotid artery (CCA) is taken. The ultrasound image suffer from peculiar phenomenon which arise due to interference of the returning signals with different frequencies after striking different tissue layers having different impedances. It appears as black and white spots as noise which is known as speckle. The speckle in the ultrasound image follows Rayleigh distribution. The ultrasound image model after logarithmic compression is converted into additive noise as:

$$x(i,j) = z(i,j) + vl(i,j) \quad (1)$$

where x(i,j) is noisy pixel, z(i, j) is noise free pixel and $vl(i,j)$ is multiplicative noise converted into additive noise. The carotid artery is made of three tissue layers [2] as shown in Fig. 2:

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- Inner most layer where blood flows is smooth and is known as Intima.
- Middle layer is muscular and is known as Media.
- Outer most layer is known as Adventia.

Layers Z1, Z2 and Z3 are the near walls while Z5, Z6 and Z7 are the far walls of CCA. While measuring the intima-media thickness, the first step is to identify the far wall and then to identify the Z5 (intima) and Z7 (adventia) layer.

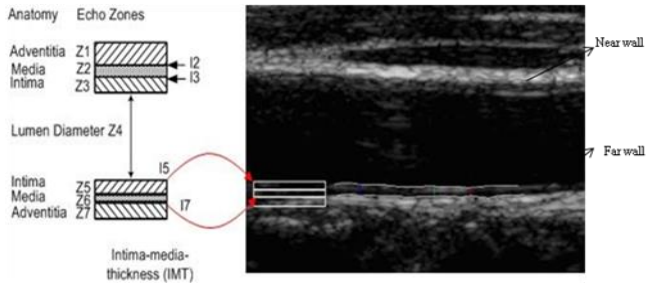


Fig. 2 Anatomy of CCA

The second step is to identify the thickness or the distance between the Z5 and Z7 layer. There are various causes that results into cardiovascular disease like [3]:

- Rise in blood pressure
- Radiation therapy
- Less sleep
- Smoking
- High cholesterol in blood
- Sugar patient
- Fatty diets
- Heavy weight and no physical exercise
- Alcoholic
- Tension
- Air pollution
- Old age

Since the ultrasound image suffers from speckle, therefore first step would be to reduce these unwanted signals which make the visualization and quality of the image poor. Second step would be to estimate the IMT of carotid artery automatically.

II. LITERATURE SURVEY

Various filters [4] in frequency domain and time domain have been proposed. Frequency domain filters requires prior knowledge of the signal and needs cut off frequency to design. In real time application prior knowledge of the signal is difficult and therefore they are not suitable for it. Filters in spatial domain are easy to implement and can be used in real time applications. Spatial filters like Lee [5], Wiener [4], [6], Kuan [7], [8] work effectively but suffer from certain drawbacks like blurring of the edges, high computation time or higher complexity. Local statistics mean variance (LSMV) filter works on local average and variance with controlling parameter acting as weighting factor. The design of weighting factor controls the filter by reducing the noise to minimum or maximum.

After despeckling edge detection of intima and adventia is done in order to calculate intima-media thickness. Various techniques were used to detect the edge like thresholding technique [2], marker controlled watershed [9], gradient based [10], active contour [11], first order absolute moment edge operator [12]. Jalbout et al. [13] has found that main reason behind atherosclerosis disease in childhood is obesity. The author has given the comparison of three RF techniques to measure the IMT of carotid artery. The proposed work uses modified LSMV filter [14] for removing the speckles and then the edges of intima and adventia are detected using gradient based operator. The succeeded section gives the overview of proposed work, followed by results and conclusion.

III. PROPOSED WORK

The ultrasound image is despeckled by proposed LSMV filter given as:

$$z(i,j) = \bar{x} + w(i,j)[x(i,j) - \bar{x}] \quad (2)$$

where, $z(i, j)$ is the pel or pixel which has no noise, $\overline{x}$ is the average value of the neighborhood pixels, $w(i, j)$ is the weighted factor, pixel $x(i, j)$ is having noise and i, j are the position of the pixel in the image. Factor w (i, j) is given by:

$$w(i,j) = {(\sigma_x^2)}/{(\bar{x}^2 + \sigma_x^2)} \quad (3)$$

The steps of the suggested method are shown in the diagram in Fig. 3.

After the speckles are removed from the image, the edges are detected using Prewitt operator. Prewitt operator [15] is given by as shown in Fig. 4.

The gradient vector of Prewitt operator in horizontal and vertical direction is given as:

$$G_x = (A7 + A8 + A9) - (A1 + A2 + A3) \quad (4)$$

$$G_y = (A3 + A6 + A9) - (A1 + A4 + A7) \quad (5)$$

Magnitude of the vector is given by as in (6):

$$\nabla f = \mathrm{mag}(\nabla f) = \left[G_x^2 + G_y^2\right]^{1/2} \quad (6)$$

The direction of the vector is given by as in (7):

$$\theta_{\nabla f(x,y)} = tan^{-1}\left(\frac{G_y}{G_x}\right) \quad (7)$$

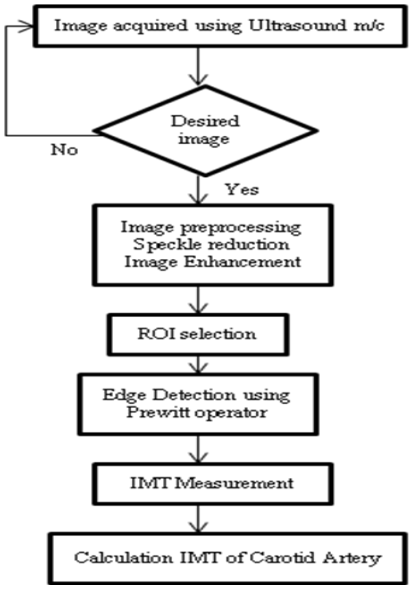


Fig. 3 Flow Diagram of the Proposed Method

After applying Prewitt operator edges are detected and then IMT thickness is calculated by taking the image resolution as 0.0762 mm/pixel.

A1	*A4*	*A7*
A2	*A5*	*A8*
A3	*A6*	*A9*

-1	*0*	*1*
-1	*0*	*1*
-1	*0*	*1*

-1	*-1*	*1*
0	*0*	*0*
1	*1*	*1*

Fig. 4 A 3x3 Prewitt Operator

IV. RESULTS

Aloka Prosound Ultra-6 machine was used to acquire the images of carotid artery. Machine operating frequency is 7.5MHz. The performance of the filter is evaluated on about 20 different images. The original and filtered images were used to calculate the average and standard deviation (SD) for three layers of carotid artery namely as intima, media and adventia which is shown in Table I.

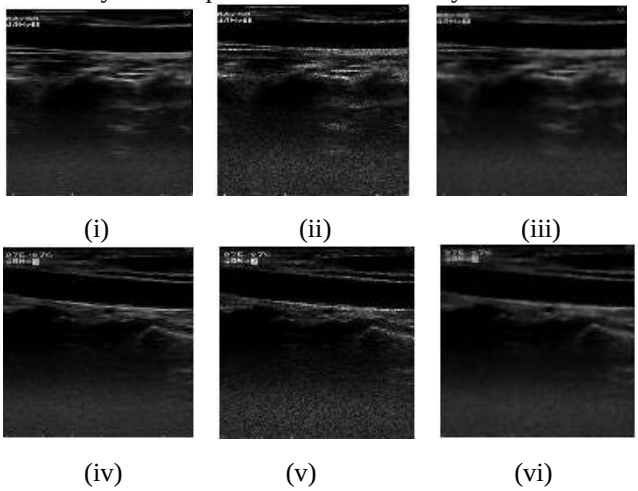
Table I Average and SD of the carotid artery images

Image Type	Average			SD		
	Inner Lumen	Soft Tissue	Outer Wall	Inner Lumen	Soft Tissue	OuterWall
Original	2.0834	34.9136	124.5346	3.2279	17.0930	31.8900
Proposed LSMV	2.7200	34.3680	106.7290	2.6940	15.8100	12.1290

Table II Performance parameters for proposed LSMV filter

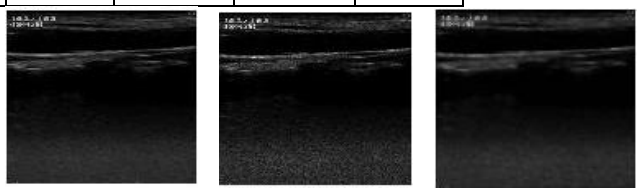
Range of Noise Variance	Parameters which evaluate the method						
	MSE	GAE	PSNR	Q	CC	SSIM	EPI
0.06	49.8040	0	31.1582	0.9590	0.9630	0.8980	0.8740

Table I show that the average value is increased and standard deviation is decreased resulting into brighter values with suppressed noise. The proposed method has been implemented on MATLAB 7.9.0(R2009b) software background. The speckle is introduced synthetically through Matlab. The analysis of the method is done on Intel(R) Core (™) 2 Duo CPU @2.00GHz with 3GB RAM computer. Various performances parameters like Mean square error (MSE),Geometric average error (GAE), Peak signal to noise ratio (PSNR), Structural similarity index measure (SSIM), Quality index (Q), Coefficient of correlation (CC) and Edge preservation index (EPI) are calculated which are shown in Table II. All the parameters in the table are at level of 0.06 noise variance. Parameters show that the LSMV filter works properly and efficiently. Table III shows the IMT thickness that is calculated with the Prewitt operator. It is seen that the Prewitt operator works efficiently and the errors are less when they are compared with the manually calculated IMT.



(i) (ii) (iii)

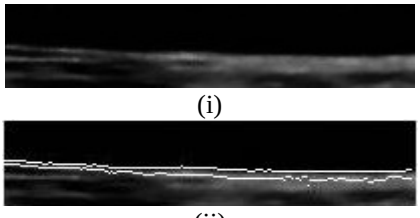
(iv) (v) (vi)



(vii) (viii) (ix)

Fig. 5 Images after despeckled (i), (iv), (vii) Original Images; (ii), (v), (viii) Speckled Images and (iii), (vi), (ix) Despeckled Images 1, 3, 5 respectively.

Fig. 5 shows the original, speckled and despeckled images by LSMV filter. By visualization it can be said that LSMV filter effectively suppress the speckle. Fig. 6 shows the edges detected after selecting the ROI and then applying Prewitt operator on the images. Three images are shown in Fig. 5 whereas the algorithm was applied on 20 data sets. After the detection of edges, intima-media thickness is calculated which is seen in Table III. The table indicates that the automatic detection of IMT is approximately equal to that calculated manually. The results show that the proposed algorithm has efficiently—calculated the intima-media thickness.



(i)

(ii)

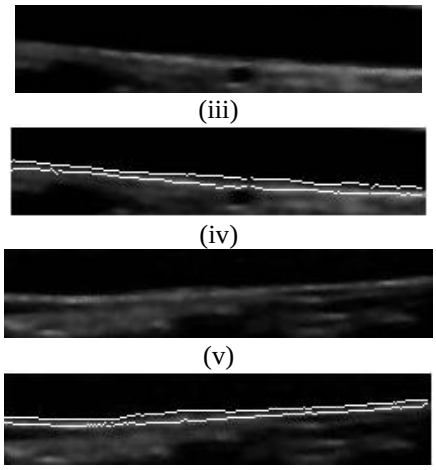


Fig. 6 ROI and Edges detected after applying Prewitt operator on the images 1, 3 and 5 respectively.

Table III Intima –media Thickness calculated for five different images

Image Type	IMT (Manual) (in mm)	Mean IMT Calculated (mm)	Error (mm)
Image1	0.45	0.4572	0.0072
Image2	0.45	0.4630	0.013
Image3	0.33	0.3334	0.0034
Image4	0.56	0.6858	0.1258
Image5	0.57	0.5334	0.0366
Image6	0.45	0.4572	0.0072
Image7	0.67	0.5048	0.0952
Image8	0.79	0.8132	0.0232

V. CONCLUSION

The ultrasound images are most versatile images that are used by the doctors in India because of their several benefits. Ultrasound machines are portable, mobile, noninvasive and non-ionization. Ultrasound images are cheaper but have certain limitations that they suffer from speckles which deteriorate the picture quality. Thus by removing or reducing the speckles would definitely solve the problem of doctors. LSMV filter used in this paper has reduced the speckles effectively. The IMT measurement is manually done by the doctors and therefore automatic measurement would definitely solve the problems of the doctors. The Prewitt operator used in this work has effectively detected the edges of the carotid artery automatically. The calculated IMT by the algorithm is very close to that calculated manually by the doctors. Less error indicates that the proposed method can be efficiently used for automatic IMT measurement in real time applications. Thus it would definitely help the patient by giving prior risk of stroke which causes fatal to the patient life.

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