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Comparative analysis of noise removal in ultrasound carotid artery image

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ABSTRACT

Cardiovascular diseases are the prominent source of death globally. A recent report of world health organization predicted that 23.3 million people died every year from cardiovascular diseases. Ultrasound imaging finds major application in the diagnosis of diseases in a human vascular system. Complex procedures are required in the analysis of common carotid artery ultrasound images. The aim of this work is to extract intima-media interface of the common carotid artery using segmentation technique in Aphelion Dev software. The histogram equalization method has been used to normalize an input image. The speckle noise has removed from normalized image by comparing various filtering techniques with the statistical parameter of Haralick energy. It depicts Gaussian filtering has the capable of better speckle noise removal from the ultrasound image. The intima-media interface has been extracted

using threshold segmentation method which converts a grayscale image into the binary image. The continuity between pixels of intima-media interface has been incurred by morphological technique. The developed technique will help the physician to identify the irregularities in vessels during diagnosis.

Keywords:
Aphelion Dev, Common carotid artery (CCA), Gaussian Filtering, Threshold segmentation, Ultrasound Image

Abbreviations:
Affine Block Motion Model (ABMM), Block Matching (BM), Computer Aided Detection (CAD), Common Carotid Artery Diseases (CCAD), Cardio Vascular Disease (CVD), Center-Weighted Median Filter (CWMF), Dynamic Programming (DP), Fisher Discriminant Ratio (FDR), Intima-Media Thickness (IMT), Magnetic Resonance Imaging (MRI),Weighted Least-Squares Optical Flow ($OF_{LK(WLS)}$), Positron Emission Tomography (PET),Peak Signal to Noise Ratio (PSNR), Region of Interest (ROI), Synthetic Aperture Ratio (SAR), Single Photon Emission Computed Tomography (SPECT), Support Vector Machine (SVM), Ultrasound (US).

1. INTRODUCTION

In today's scenario, the diagnosis of a medical image becomes more complicated with the existing systems. Cardiovascular diseases (CVD) are the prominent cause of death around the world. It is a class of diseases that involve the heart or blood vessels. A recent report of world health organization anticipated that 23.3 million people died every year from cardiovascular diseases. Cardiovascular disease includes coronary artery diseases (CAD) such as angina and myocardial infarction.

The common carotid arteries are existing on the left and right sides of the body. These divided into the external and internal carotid arteries. The internal and external carotid artery supplies blood to the brain, face and neck. The carotid artery plaque has identified using several medical imaging techniques were developed such as X-ray radiography, Magnetic Resonance Imaging (MRI), ultrasound, elastography, endoscopy, tactile imaging, thermography, medical photography and nuclear medicine efficient imaging techniques as Single-Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET).

The Ultrasound medical imaging is safe and painless it produces pictures inside the body using sound waves. Ultrasound examinations do not use ionizing radiation and there is no radiation exposure to the patient. The medical ultrasound image contains speckle noise. Speckle is a granular noise that degrades the quality of ultrasound images. Thus, several filtering techniques have been used to eliminate speckles from the image. The intention for reducing speckle noise in US image is to increase the human rendition of an image.

Karim Lekadir et al. [1] described a convolutional neural network for automatic characterization of plaque composition in carotid ultrasound. In this, a convolutional neural network (CNN) will automatically extract from the images and the information is optimal to identify the different plaque constituents. The results show that this method has a correlation of about 0.90 with the clinical assessment for the estimation of a lipid core, fibrous cap, and calcified tissue areas.

J. R. Harish Kumar et al. [2] developed an automatic segmentation of common carotid artery in transverse mode ultrasound images. In this, an automated outlining technique based on the active disc formalism is introduced. A matched filter with a template size is chosen based on an estimate of the average size of the carotid artery.The proposed method outcomes in an average detection accuracy of 95.5% and an average Dice similarity measure of 87.36%.

Dhanalakshmi et al.[3]suggested classification of abnormalities in ultrasound carotid artery images using an artificial neural classifier. In this, the multilayer Back Propagation Network (BPN) is used for good generalization capabilities and fast learning capacity. This system increases the classification rate and getting the diagnostic yield of 89.43%. The simulation outcome shows that artificial neural classifier attains good classification accuracies with less implementation complexity.

Christos P. Loizou et al. [4] described a comparison of ultrasound Intima-Media Thickness (IMT) measurements of the left and right Common Carotid Artery (CCA). The snake segmentation algorithm is used for segmenting the Common Carotid Artery. It is shown that the left Common Carotid Artery in Intima-Media Thickness side has slightly higher measurements than the right side for the manual and automated measurements for both the normal and cardiovascular diseases subjects.

David Afonso et al. [5] developed an ultrasonographic risk score for identifying carotid atherosclerotic plaques. In this ultrasonographic activity index (UAI) depend on the plaque active profile and it is a combination of the most discriminate ultrasound parameter. The symptom detection on a transversal dataset of 146 plaques in this ultrasonographic activity index obtained 83.5% accuracy, 84.1% sensitivity and 83.7% specificity.

Emmanouil G. Sifakis et al. [6] suggested a longitudinal B-mode ultrasound image for carotid artery recognition. A user-independent and real-time algorithm issued for carotid artery identification in longitudinal B-mode ultrasound images. By using the optimized values the carotid artery was recognized in all the processed images in both multi-frame and single-frame data.

Dongbo Min et al. [7] presented a novel approach for depth video Enhancement. The quality of the depth video has been improved by increasing its resolution and suppressing noise. The results show that this method has outstanding performance and is very efficient, compared with existing methods.

Filippo Molinari et al. [8] described a Completely Automated Layer Extraction (CALEX) algorithm. In this, a hypothesis holds B-mode longitudinal ultrasound (US) images of the carotid wall. In morphological image processing, a level-set-based algorithm is used for carotid artery lumen identification. The accuracy and development in the IMT segmentation result with CALEX 3.0 system.

Ehsan Nadernejad et al. [9] described a despeckle filtering in medical ultrasound imaging. Many filters can be implemented like wiener filter, an anisotropic diffusion filter, K-distribution based adaptive filter and wavelet filter to de-speckle in medical ultrasound images. The wiener filter can increase the image qualities and simulated power spectrum of speckle.

Loizou C. P. et al. [10] presented a snake segmentation technique for identifying the intima-media layer of the distant wall of the common carotid artery (CCA) in longitudinal ultrasound images, by applying snake segmentation, next normalization, speckle reduction and normalization. The snake segmentation method also develops image normalization and speckle reduction in ultrasound images of the carotid artery.

Dana E. Ilea et al. [11] developed a novel unsupervised Computer Aided Detection (CAD) algorithm that is capable of identifying and measure the Intima-Media Thickness (IMT) in 2D ultrasound carotid images. To identify the two interfaces that forms the intima-media thickness without any user intervention. The result that the computer aided detection system is robust in accurately estimating the Intima-Media Thickness in ultrasound carotid data.

Spyretta Golemati et al. [12] describe the Hough transform to segment ultrasound images of the common carotid artery. The longitudinal and transverse sections of B-mode ultrasound images can be identified using Hough transform (HT). This technique provides a reliable way to segment ultrasound images of the carotid artery. Hough transform method is used in clinical practice to evaluate indices of arterial wall physiology.

Tajinder Kaur et al. [13] described a comparative study of various frequency domain filters for speckle suppression in an ultrasound image. The comparison is based on Wavelet, Ridgelet and Curvelet transform. The performance of image denoising algorithm in terms of Peak Signal to Noise Ratio (PSNR) and the Ridgelet transform gives the best performance for PSNR.

In this paper, the performance of various filters such as Box, Convolution, Median, Mode, Nagao, Rank value and Weymouth filter have been analyzed based on some statistical values like haralick energy, mean, length, maximum pixel count and kurtosis. The segmented intima-media interface using threshold segmentation method has been implemented in aphelion dev software.

2. METHODOLOGY

A. Image Acquisition

The ultrasound scanner with the broadband compacted linear array transducer has been used for the data acquisition of the image. The transducer is worked at a frequency of 12 MHz to attain the arterial movements and the movements are verified using video recorder. The transducer is placed exactly at the starting point of the bifurcation of Common Carotid Artery (CCA). The recorded video is converted into frames and the converted frames are stored as still images for further processing.

B. Image Normalization (Histogram Equalization)

This is the technique that is similar to the histogram stretch. It tries to flatten the histogram to create a better quality image. It treats an image as a probability distribution. Then it finds the cumulative distributive function, after which it normalizes the values and performs the respective mapping. The Histogram Equalization method has been used to improve the appearance of the Common Carotid Artery (CCA) image without affecting the structure.

C. Pre-processing

Pre-processing images commonly involves removing low-frequency background noise, normalizing the intensity of the separate particles images, eliminating reflections, and masking portions of images.

1) Box Filter

A box filter is a form of low-pass blurring filter. The spatial domain of each pixel in the resulting image has a value corresponding to the average value of its adjacent pixels in the input image. It is a form of low-pass blurring filter. The size of box filter window is to set as 5 for filter out the speckles.

2) Convolution (low pass) Filter

A low-pass filter permits a signal frequency lesser than a cut-off frequency and attenuates signals with frequencies greater than the cut-off frequency. The sum of attenuation for each frequency depends on the filter design. In convolution filtering, an image filtering has been performed based on a convolution using a predefined kernel. The kernel value is set to the default as 3x3.

3) Gaussian Filter

Gaussian filters have the properties of having no overshoot to a step function input while reducing the rise and fall time. This performance is closely connected to the fact that the Gaussian filter has the minimum possible group delay. It is considered the ideal time domain filter. Gaussian filtering is used to reduce speckle noise which presents in the ultrasound image without disturbing any important features of the image. The filtering has been performed based on a convolution using a kernel with a Gaussian shape of 5.

4) Median filter

Median filtering is used to eliminate the intensity pixels in isolated portion of the filter mask and it is used to force points with different intensities. This filter is excellent for impulse type of noise. The size of the kernel is set as 3 to remove speckles in carotid artery image.

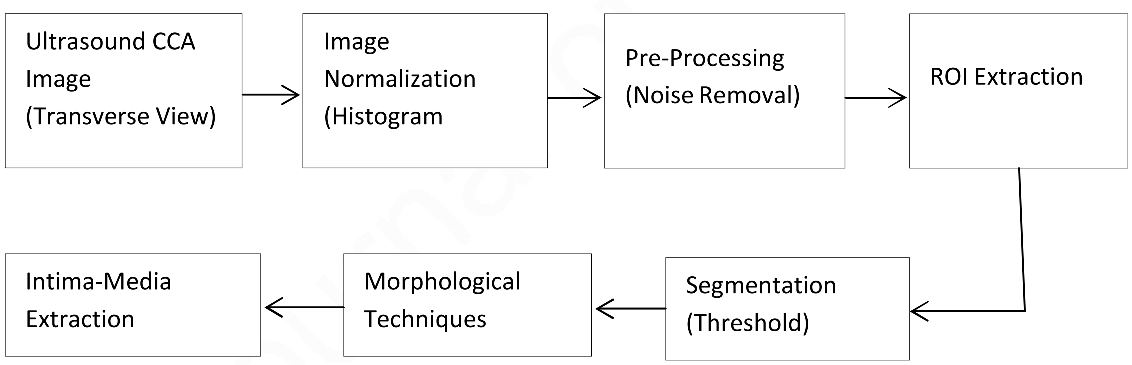

Figure 1

Block diagram for abnormalities detection in cross-sectional view of common carotid artery (CCA)

5) Mode Filter

Mode filtering is used in the removal of speckle presents in the ultrasound carotid artery image. To perform a mode filtering on an image, each pixel value within a window of the image is repeated by the weight value in the corresponding element of the kernel. The window size is set as 7.

6) Nagao Filter

Nagao filter is used to perform the edge-enhancement image smoothing. It tries to find a direction of least variance and then performs mean filtering in that direction. The filter uses nine directions. They are as follows: North (N), Northeast (NE) East (E), Southeast (SE), South (S), Southwest (SW), West (W), Northwest (NW) and Central (Cen). The number of iterations and window size are set as default values of 1 and window size 5 respectively.

7) Rank Value Filter

A Rank filter is used tocompute the filtered value using the local gray-level ordering. Thisensemble of filters shares a common baseof the local gray levelhistogram is computed on the neighborhood of a pixel. If the classical median filter is obtained by taking the middle value of the histogram. The rank value filter has a window size is 3x3 and rank value is set as 10.

8) Weymouth Filter

The Weymouth filtering is an enhancement method tends to eliminate noise, while keeping apparent edges around the image by taking into account the modification of each adjacent pixel value and the central value, along with the spatial distance of the contributing pixel. It also uses the variance within the neighborhood of the pixels. This filter uses a 3x3 neighborhood for each pixel to compute a new value for that pixel.

D. Region of Interest (ROI) extraction

The Region of Interest (ROI) defines the portion of the image where the Intima-media is located. The area situated above and below the interface that separates the blood and the tissue of the vessel has been measured as a region of interest. Factors concern to the lumen and the Intima-media measured to finding ROI correctly. The lumen is characterized by pixels with low intensity and relatively low variance and surrounded by high-intensity pixels fitting to the carotid walls. This feature is used to detect the Common Carotid Artery (CCA) region very precisely.

E. Threshold Technique

Thresholding is the simplest method of image segmentation. Individual pixels in an image are noticeable as 'object' pixels if their value is larger than some threshold value and otherwise as 'background' pixels. This convention is known as the threshold above and pixels include threshold below, which is opposite of threshold above. The threshold value can determine a value automatically, which is known as automatic thresholding. The value 0 represents the blood class and value 255 represents the arterial tissue.

F. Morphological Technique (Dilation)

Dilation of the image is a basic operation of mathematical morphology. It can be applied to binary as well as grayscale images. The basic effect of this morphological operator on a binary image is that it gradually increases the boundaries of the region, though the minor holes present in the image become smaller. The number of iteration has to be set as 4 in order to obtain continuity.

3. RESULTS AND DISCUSSION

The image of the common carotid artery has been obtained from an ultrasound scanner. The cross section of the single frame has been acquired as shown in Fig.1 and used for further analysis. Fig.2 shows the Histogram Equalization of an image and it is used to enhance the contrast of input image. The pre-processing is used to eliminate the speckle noise which is shown below. Fig.3 shows the box filtered image using the window size of 5 used to enhance the contrast of input image. The convolution low pass filtered image is shown in Fig.4 which has the kernel size of 3x3.

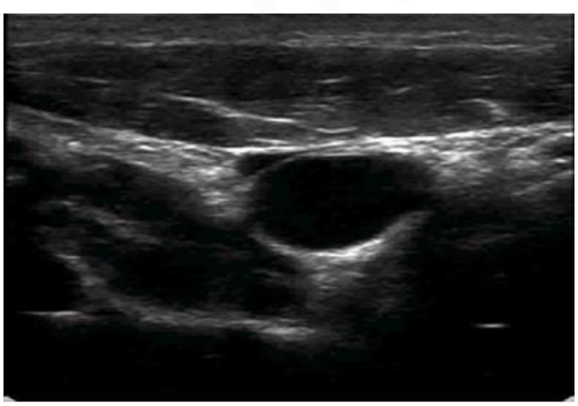

Figure 1 Input Image

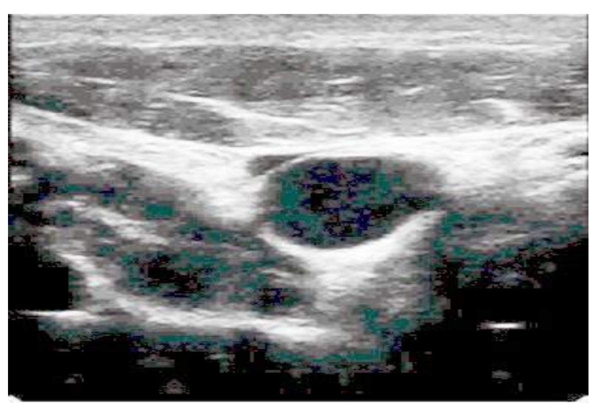

Figure 2 Image Normalisation

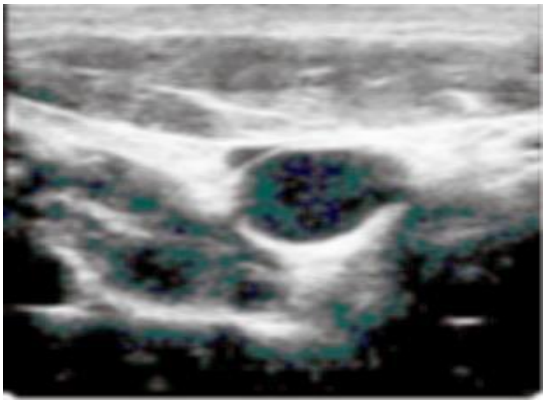

Figure 3 Box Filtering

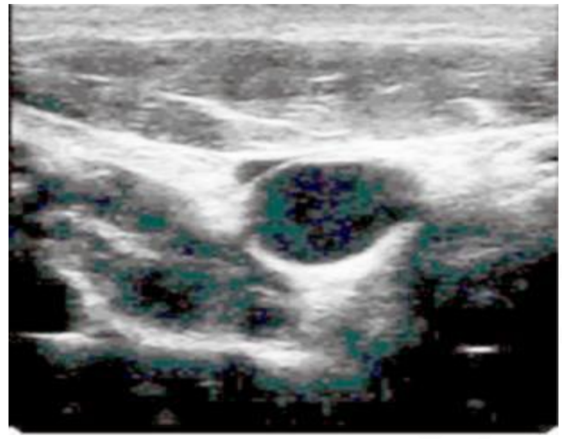

Figure 4 Convolution (Low pass) Filtering

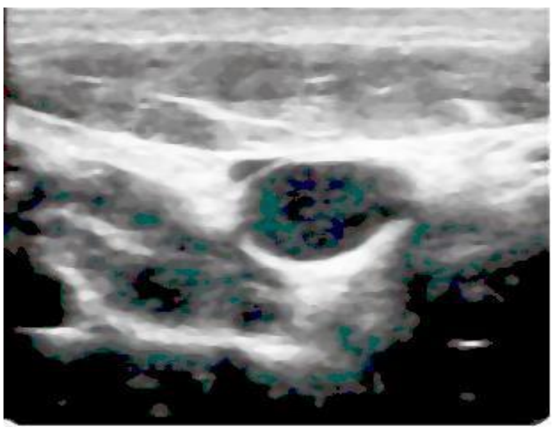

Figure 5 Gaussian Filtering

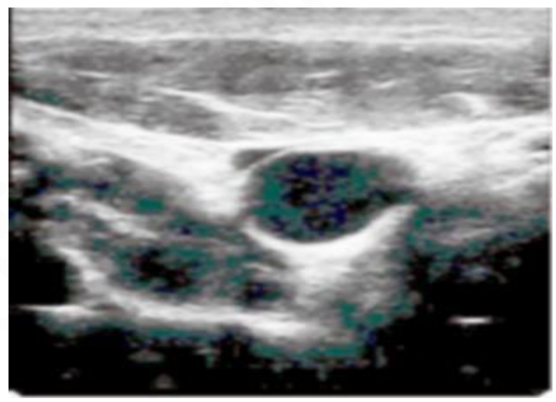

Figure 6 Median Filtering

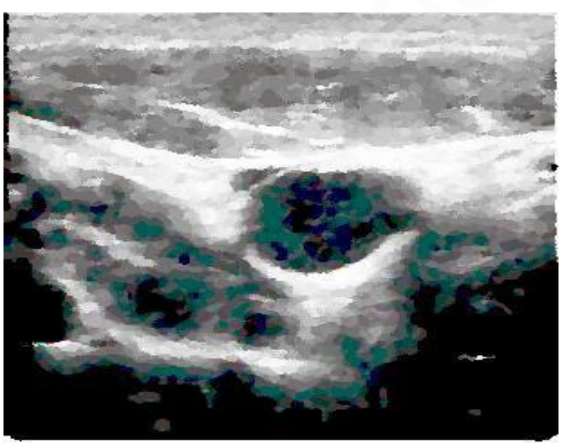

Figure 7 Mode Filtering

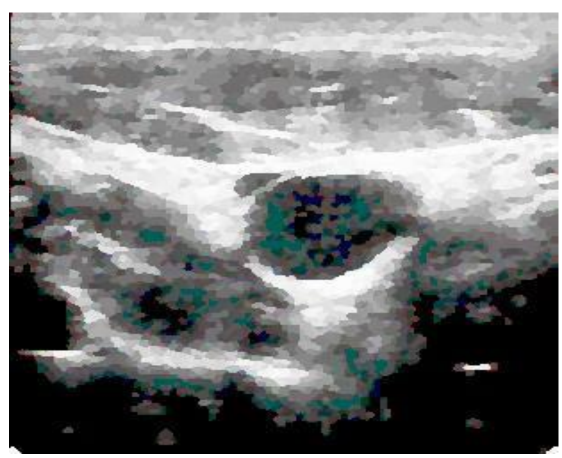

Figure 8 Nagao Filtering

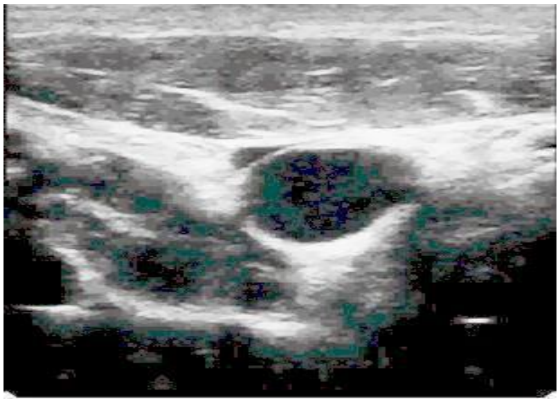

Figure 9 Rank Value Filtering

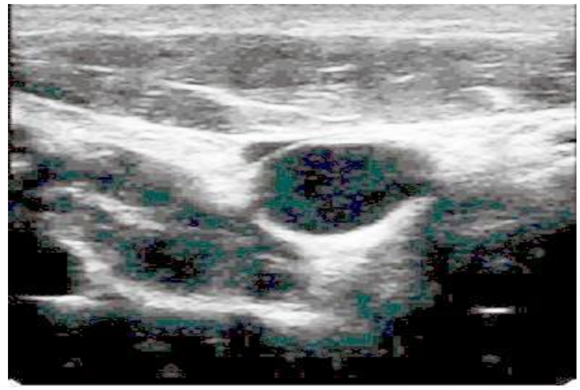

Figure 10 Weymouth Filtering

The output of Gaussian filtering image with the width of Gaussian shape 3 as shown in Fig.5. Fig.6 shows the median filtering image with the kernel value of 3. Fig.7 shows the despeckling image using mode filtering which has the window size of 3x3. Fig.8 shows the resulting image from Nagao filtering with the number of iterations and window size are set as default values of 1 and 5 respectively. The Rank filtering is shown in Fig.9 which has the rank value of 5. The Weymouth filtered image with the neighborhood value of 5x5 as shown in Fig.10. The statistical parameters such as haralick energy, mean, kurtosis, length and maximum pixel count for different filtering techniques are obtained as shown in table.1.

Table 1

Despeckling results on different filtering

Filter type	Haralick Energy	Mean	Kurtosis	Length	Maximum Pixel Count
Box	0	191.937	-1.4689	15.811	230
Convolution	0	171.277	-1.1867	20.518	231
Gaussian	0.5	170.478	-1.1252	20.124	259
Median	0	170.478	-1.3920	19.416	230
Mode	0	189.687	-1.2818	17.691	240
Nagao	0	190.294	-1.2495	17.804	238
Rank value	0	163.791	-1.4959	21.470	237
Wey Mouth	0	181.631	-1.2698	19.416	246

The comparative analysis shows that the haralick energy in Gaussian filtering provides better speckle reduction compared with other filtering techniques.

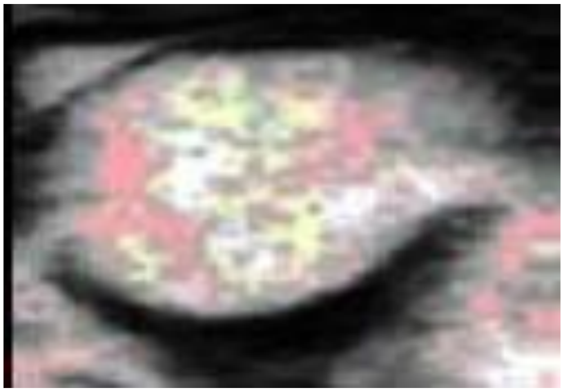

Figure 11 Region of Interest

Figure 12 Threshold segmentation

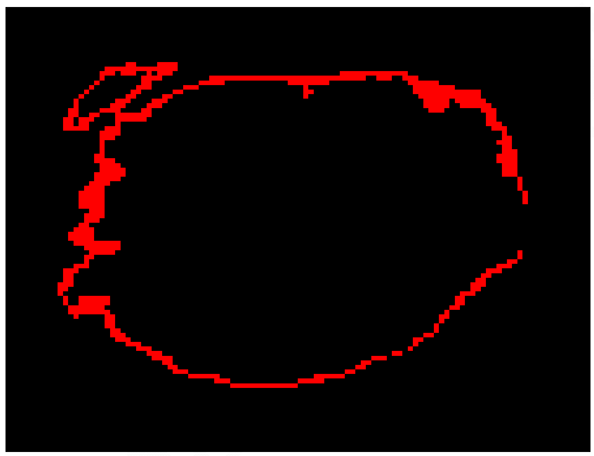

Figure 13 Morphological Technique (dilation)

Fig.11 shows the Region of Interest (ROI) which is extracted from the Gaussian filter image and the portion of the image where the Intima-media located is determined. Threshold segmented image with value T varying from 100 to 230 which impart the lumen-intima interface as shown in Fig.12. The resulting image from the previous step has much discontinuity. In order to reduce this trouble the morphological technique (dilation) is used to extend the disk structure elements of intima-media interface as shown in Fig.13.

4. CONCLUSION

The image segmentation technique has been used to eliminate the implications in the diagnosis of medical images. The speckle noise presence in the Ultra Sound (US) image has been removed to attain the directed object. Images have been filtered using different methods such as Box, Convolution (Low pass), Median, Mode, Nagao, Rank Value and Weymouth and the performances have been analyzed using statistical values like haralick energy, mean, length, kurtosis, maximum pixel count. The results obtained shows that Gaussian filtering is more suitable for higher noise reduction than other filtering techniques. The intima-media interface has been extracted using threshold segmentation method which converts the grayscale image into a binary image. The segmentation of single frame carotid image has been obtained using Aphelion Dev real-time software. The continuity between pixels of intima-media interface has been incurred by morphological technique. The developed technique will help the physician to make a decision for ultrasound carotid images.

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