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BLOG EDGE DETECTION METHOD FOR

CAROTID ARTERY ULTRASOUND IMAGE

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ABSTRACT

Nowadays, ultrasound image is important and very useful in medical field. It is a technique used for visualizing body structures including tendons, muscles, joints, vessels and internal organs. For the atherosclerosis diagnosis, ultrasound imaging is commonly used because of the noninvasively assessment in monitoring condition inside the carotid artery. In certain conditions, the acquired images may be unclear caused by speckle noise and other factors. Thus, may affect the accuracy of artery wall detection. This study proposes an edge detection method that could detect edges in carotid artery images accurately without including noise or fine details by using the combination of the Bilateral Filter, Otsu Threshold and Gabor Filter. The Bilateral Filter is used to suppress the noise level in the input image. Otsu Threshold used to segment the regions into background and objects. The Gabor Filter is applied to detect edge accurately without including noise or fine details. From our simulation, the proposed method is capable of producing sharp edgemap image with less noise and detect edges accurately in comparison to conventional edge detection methods for different carotid artery ultrasound images.

Key words: Bilateral Filter · BLOG · Carotid Artery · Edge Detection · Gabor Filter · Image Processing · Otsu Threshold · Ultrasound image

INTRODUCTION

One of many important processes in image processing is feature extraction, where the information obtained can futher be used for object recognition and image analysis (Mahamad et al. 2014). Ultrasounds are related with the sound pressure wave and frequency. This imaging technique uses high frequency, which is greater than upper limit of human hearing range. This type of image has been applied in many fields such as human body observation (Mahmud and Supriyanto, 2014), fluid/gas flow monitoring (Rahiman et al., 2012) and others. The ultrasound image display is usually corrupted by speckle noise in its acquisition and transmission (Kaur, J. and Kaur, R., 2013). Speckle noise is a complex phenomenon which degrades image quality with backscattered wave appearance (Kaur, R. and Kaur, R., 2013). This noise causes the observer to have difficulty in discriminating edges and fine details of the images in the diagnostic examinations. Thus, the denoising is an important part of ultrasound image processing and in image processing in general. The Bilateral Filter is one of the methods that can be used for denoising image.

Filtering is the fundamental operation for image processing and computer vision. Bilateral Filter is a non-linear technique for edge preserving smoothing (Tomasi and Manduchi, 1998). The Bilateral Filter has also been designed to remove noise from ultrasound images (Vanithamani and Umamaheswari, 2014). This filter removes background noise based on spatial and intensity domain while preserving the structural aspect of an image. The Bilateral Filter smoothes the values using a weighted average in a local neighbourhood and the weight determined according to both spatial and intensity between the center pixel and the neighbouring pixel.

Denoising is useful in noisy ultrasound images to ensure the noise is not included in the edge detection process.

Edge detection can be defined as a process to identify the sharp discontinuities in an image. These discontinuities are also known as abrupt changes in pixel intensity or the pixels that differentiate the boundaries of objects in an image. There are many methods that can be used for the edge detection of ultrasound image (Chai, Wee and Supriyanto, 2011) (Nordin et al., 2012). The most common method for edge detection is to calculate the derivatives of an image. The earlier Sobel, Robert and Prewitt edge detection methods provide results of clear edgemap images or slightly noisy edgemap images for noise-free images by using their proposed edge detection processes (Vanithamani and Umamaheswari, 2014). In the case of noisy images, they may produce false edges caused by discontinuities in gray level due to noise. Further development of edge detection methods for various applications have been introduced in many publications (Ndajah and Kikuchi, 2011) (Heric and Zazula, 2005) (Tzekis et al., 2007). Another method of edge detection is by using Gabor Filter (Udomhunsakul, 2004) (Negi and Mathur, 2014). Gabor Filter is a linear filter used for edge detection in image processing. This filter utilizes complex exponential function modulated by Gaussian function. Frequency and orientation are particularly appropriate for texture representation and discrimination. J. G. Daugman discovered that simple cells in the visual cortex of mammalian brains can be modelled by Gabor functions (Liu, Cui and Li, 2012). Therefore, the perception in the human visual system and the image analysis by the Gabor functions are similar.

For the atherosclerosis diagnosis, ultrasound imaging is commonly used because of the noninvasively assessment in monitoring condition inside the carotid artery (Rocha et al., 2010) (Graf et al., 1999). Several parameters are studied as

the prediction of early-stage atherosclerosis. Previously the parameter of carotid arterial wall thickness which has the average of 502±61 μm, was accurately estimated using ultrasound images (Nabilah, Hideyuki and Hiroshi, 2013). The result shows the accuracy of measuring again using ultrasound even without the phase consideration (envelope signal) for the same objective (Nabilah, Hideyuki and Hiroshi, 2012). Although these technique could extract the saline features from the sequence of B-mode ultrasound images, the image with the existence of plaque in carotid artery for the older patient is not clear, thus, difficult to segment the saline feature. The unclear image is considered to be corrupted by speckle noise caused by interference between coherent waves that, back scattered by natural surfaces, arrive out of phase at the source (Wanare and Shah, 2012). Therefore, denoising is an essential process to increase the edge detection method performance.

PROPOSED METHOD
In this study, the proposed method is performed as follows. First, the denoising is carried out to remove speckle noise by using the Bilateral Filter. Then, the image is segmented into two classes, which are background and object regions by using the Otsu threshold. Finally, the Gabor Filter is applied to detect the edges in the segmented image. The proposed method is named Bilateral-Otsu-Gabor-based edge detection method, or BLOG method, hereafter. The next sub-sections explain in detail how each method is performed.

Speckle Noise Model
Noise that present in the ultrasound image is speckle noise. It may significantly affect the medical ultrasound image shape interpretation and boundary detection. In an ultrasound image, the presence of speckle noise can be observed during the execution of the visualization process. It is a major source of noise in ultrasound images. Speckle noise is a granular noise that commonly exists in ultrasound images and corrupts the quality of the images. This noise can be expressed as follows:

$$f(x,y) = g\,(x,y)\,.\,\eta_m\,(x,y) + \eta_a\,(x,y) \qquad (1)$$

where

$f\,(x, y)$: noisy image
$g\,(x, y)$: unknown noise-free image
$\eta_m\,(x, y)$: multiplicative noise
$\eta_a\,(x, y)$: additive noise

Bilateral Filter
In ultrasound images corrupted by speckle noise, the quality of the images will reduce. The degradation includes suppression of edges, structural details and blurring boundaries. The presence of the speckle noise may also cause low contrast images and causes tumours cannot be detected in the diagnostic phase. Therefore, it is necessary to denoise the image first to improve the quality of the ultrasound images before applying edge detection.

In this study, the Bilateral Filter is used as the denoising method to reduce the speckle noise presence in the ultrasound images. This filter is a non-linear technique to smooth images

(Tomasi and Manduchi, 1998). The Bilateral Filter is also defined as weighted average of intensity of nearby pixels, which is based on the Gaussian distribution. This Bilateral Filter can be expressed as follows:

$$BF = \frac{1}{W_p}\sum_{q \in \alpha}G_{\sigma_s}(\|p\text{-}q\,\|)G_{\sigma_r}(\|f_p\text{-}f_q\|)f_q$$

$$(2)$$

where

BF	: Bilateral filtered image
f	: noisy image
$\frac{1}{w_p}$	:normalization factor
α	:size of the Gaussian Bilateral Filter window
σ_s	:spatial domain standard deviation
σ_r	:range domain standard deviation
$G_{\sigma s}(\|p-q\|)$	:spatial weight for smoothing differences in coordinates
$G_{\sigma_r}(\|f_p-f_q\|)$	:range weight for smoothing differences in intensities

Otsu Threshold
After the noise has been reduced, the segmentation process is performed. Thresholding image is the simplest method of image segmentation. It can be used to create binary images from a grayscale image. A binary image is a digital image that have been quantised to two possible values which are denoted as 0 and 1 that represented as black and white colour.

In this study, Otsu Threshold is used to segment ultrasound images. Otsu Threshold chooses the threshold to minimize the intraclass variance of the black and white pixels. It automatically performs clustering-based image thresholding (Huang, Lin and Hu, 2011). This method can be expressed as follows:

Assume that an image can be represented in K gray levels (0, 1,..., K-1) . The number of pixels at level i is denoted as $s(i)$. The total number of pixel equals $N = s(0) + s(1) +...+s(K-1)$. For a given gray level image, the occurrence probability of gray level i is given by:

$$p(i) = s(i)/N. \qquad (3)$$

If this image is segmented into 2 classes, C_1 and C_2, then threshold value, t, must be selected. Weighted sum of variances of the two classes, C_1 and C_2 are calculated by:

$$\sigma_w^2 = w_1\,\sigma_1^2 + w_2\,\sigma_2^2$$

$$= w_1 w_2\,[\mu_2 - \mu_1\,]^2 \qquad (4)$$

where the probability of class occurrences are

$$w_1 = Prob(C_1) = \sum_{i=1}^{t} p(i), \qquad (5)$$

$$w_2 = Prob(C_2) \sum_{i=t+1}^{K} p(i), \qquad (6)$$

and the class mean levels are

$$\mu_1 = \sum_{i=1}^{t} \frac{ip(i)}{w_1}, \tag{7}$$

$$\mu_2 = \sum_{i=t+1}^{K} \frac{ip(i)}{w_2}, \tag{8}$$

respectively. The class variances can be computed by

$$\sigma_1{}^2 = \sum_{i=1}^{t} (i-\mu_1)^2 \frac{p(i)}{w_1}, \tag{9}$$

$$\sigma_2{}^2 = \sum_{i=t+1}^{K} (i-\mu_2)^2 \frac{p(i)}{w_2}. \tag{10}$$

Gabor Filter
Based on the segmented regions by using Otsu Threshold, the Gabor Filter is used to detect the edges in the ultrasound images. The Gabor Filter is band pass filter, which is used in image processing for edge detection (Zhang, Tan and Ma, 2011) (Mishra, 2013) (Tamilselvi and Thangaraj, 2010). This filter is a complex exponential function modulated by Gaussian function. It can be expressed as follows:

$$g(x,y) = e^{\left(-\frac{1}{2}\left(\frac{x\_theta^2}{sigma\_x^2} + \frac{\gamma^2 y\_theta^2}{sigma\_y^2}\right)\right)} \cos\left(2\pi \frac{x\_theta}{\lambda} + psi\right) \tag{11}$$

where

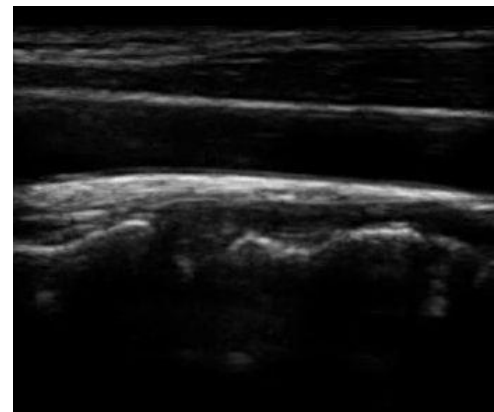|	
x_theta	: $x(cos\theta) + y(sin\theta)$
y_theta	: $-x(sin\theta) + y(cos\theta)$
$sigma$	: size of the Gaussian envelope
psi	: phase offset
λ	: wavelength of sinusoidal factor
γ	: spatial aspect ratio

RESULT AND DISCUSSION
There are different samples of ultrasound images used in this study to validate the effectiveness of the proposed BLOG method for the edge detection of carotid artery ultrasound images. The results are then compared with conventional edge detection methods. In this section, the effect of omitting the threshold process is also discussed.
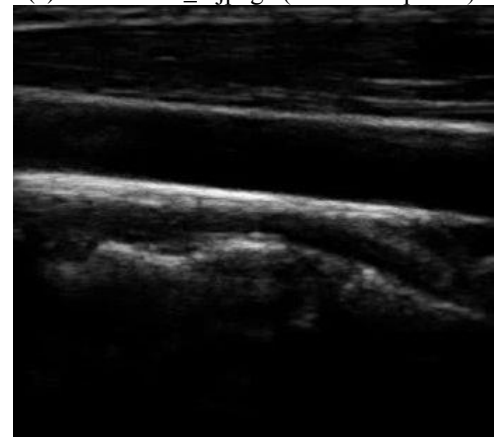
The ultrasound images show the location of reflecting structures or echo sites within the body. This study uses different samples of carotid artery images which are provided in the ultrasound image database (Zukal, Beneš, Číka and Říha, 2015). The database contains ultrasound images of carotid artery of ten volunteers with mean age of 27.5 ± 3.5 years and different weights, whereas mean weight is 76.5 ± 9.7 kg. Two different linear array transducers with different frequencies, which are 10 MHz and 14 MHz, are used. These frequencies were chosen because of their suitability for superficial organs imaging. All images were taken by the specialists with five year experience with scanning of arteries. Images were captured in accordance to the standard protocol with patients lying in the supine position and with the neck rotated to the left side while the right carotid artery was examined (Zukal, Beneš, Číka and Říha, 2015). The samples of the test images are shown in Figure 1 (a) – (e).
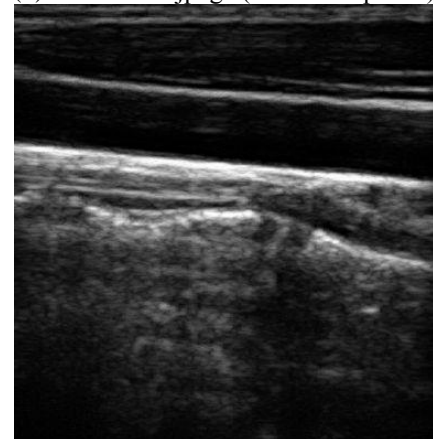
In this study, the simulations are executed by using MATLAB software. The parameter setting for the Bilateral Filter are $\alpha=4$, $\sigma_s =2$, and $\sigma_r = 0.1$, respectively. On the other hand, the parameters selected for the Gabor Filter are $\lambda = 2$, $\theta = 0$, $psi = [0\ \pi/2]$ and $\gamma = 0.5$, respectively. As for the comparison edge detection methods, Sobel Filter and Prewitt Filter, the parameter settings utilize the MATLAB default settings. For convenience in comparing the visual effects, only the results of the two test carotid artery ultrasound images; "17-35-50.jpeg" and "17-36-35.jpeg" are demonstrated for a clearer comparison.

(a) "09-54-44_2.jpeg" (344 x 289 pixels)

(b) "09-55-22.jpeg" (343 x 311 pixels)

(c) "17-35-44.jpeg" (384 x 399 pixels)

(d) "17-35-50.jpeg" (384 x 399 pixels)
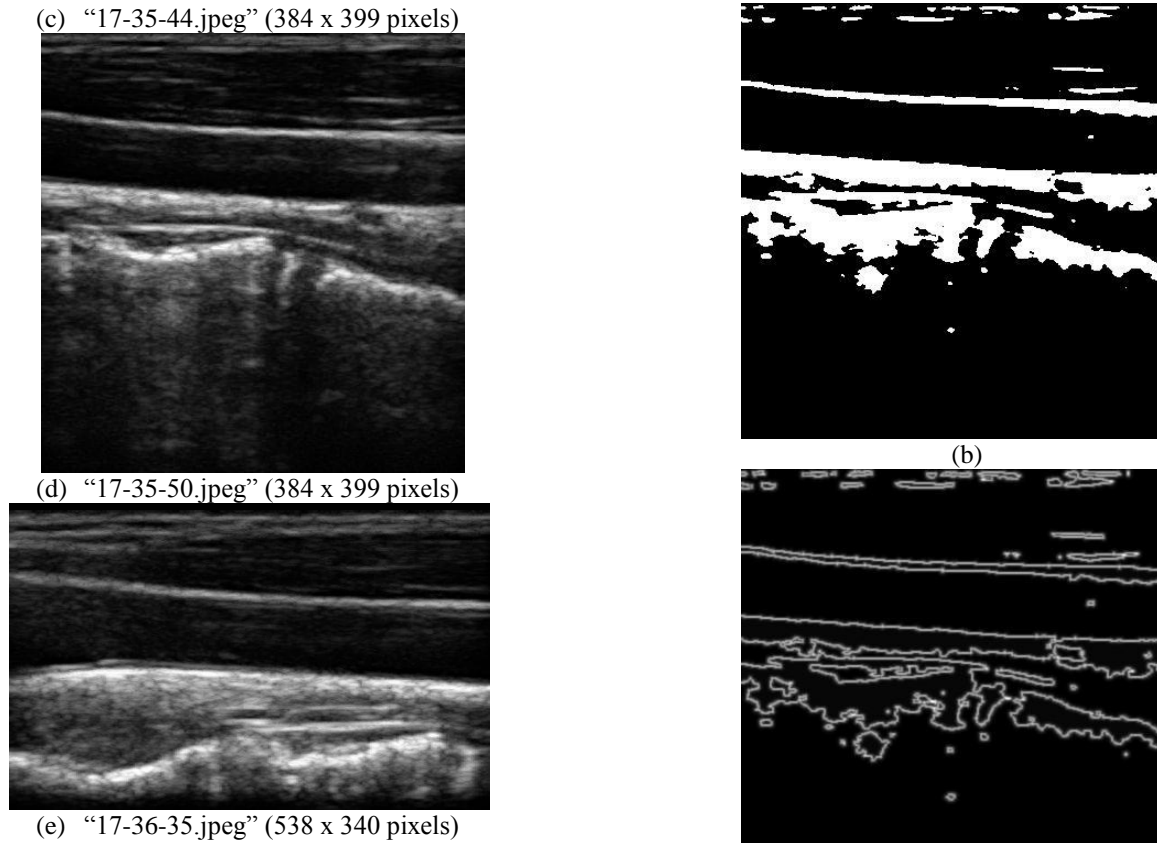

(e) "17-36-35.jpeg" (538 x 340 pixels)

Figure 1 (a) – (e): Examples of test image for carotid artery ultrasound images from (Zukal, Beneš, Číka and Říha, 2015) utilized in this study.

Result of edge detection by using Proposed BLOG Method
Figure 2(a)-(d) and Figure 3(a)-(d) show the result for every process that is performed in the proposed BLOG edge detection method.
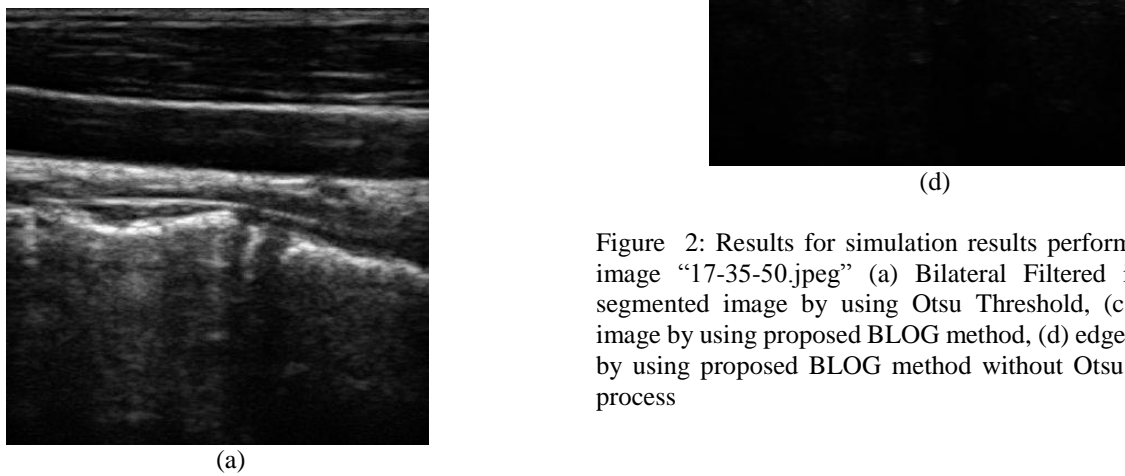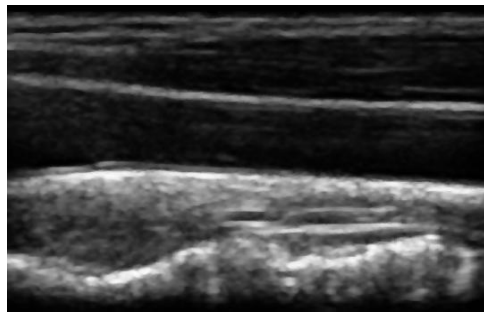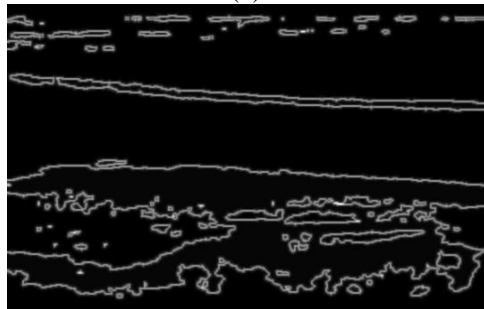

(a)

(b)

(c)

(d)

Figure 2: Results for simulation results performed on test image "17-35-50.jpeg" (a) Bilateral Filtered image, (b) segmented image by using Otsu Threshold, (c) edgemap image by using proposed BLOG method, (d) edgemap image by using proposed BLOG method without Otsu Threshold process
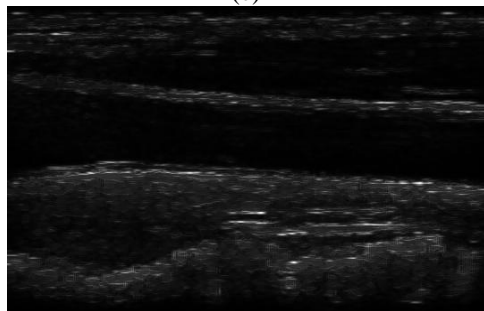
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(a)

(b)

(c)

(d)

Figure 3: Results for simulation results performed on image "17-36-35.jpeg", (a) Bilateral Filtered image, (b) segmented image by using Otsu Threshold, (c) edgemap image by using proposed BLOG method, (d) edgemap image by using proposed BLOG method without Otsu Threshold process.

Figure 2(a) and Figure 3(a) show the results of the test images that have been filtered by using Bilateral Filter. From the result, they show that the noise and fine details of the original image has been smoothed out. This process will assist in detecting process of stronger edges and details. The process of segmentation is implemented by using Otsu Threshold to the image of Figure 2(a) and Figure 3(a), respectively. Strong edges and details are segmented into white region whereas background and fine details are grouped into black region. This process produced the result as shown in the Figure 2(b) and Figure 3(b), respectively. The next process uses Gabor

Filter to identify edges from Figure 2(b) and Figure 3(b), respectively to produce the final output edgemap images. Figure 2(c) and Figure 3(c) show the final edgemap images after applying the whole processes of the BLOG method. Figure 2(d) and Figure 3(d) show the result if the process of segmentation by using Otsu Threshold is skipped. From the result, we can observe the effect occurred when the threshold process is ignored. It can be observed that the strong edges of the images are not detected well. The fine details still remain in the final edgemap images. From the simulation, it shows that the process of threshold provide better result for the edge detection of an image. Therefore, applying the Otsu Threshold before the Gabor Filter is useful to produce a clearer edgemap images for ultrasound images.
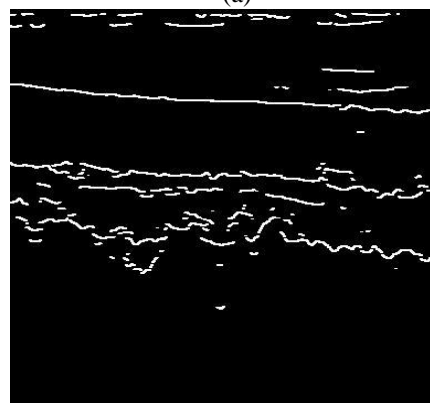
The proposed BLOG method is also compared with conventional edge detection methods: (i) Sobel Filter and (ii) Prewitt Filter. The effects of applying Otsu Threshold before applying these conventional filters are also discussed.
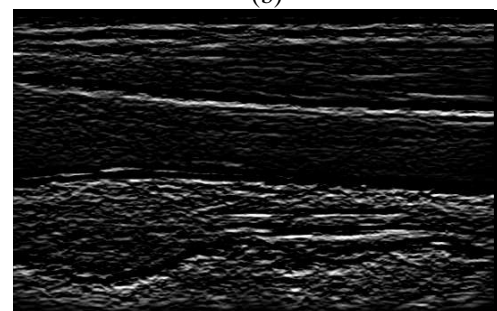
Sobel Filter
Figure 4(a)-(d) shows the simulation results performed by using Sobel Filter.
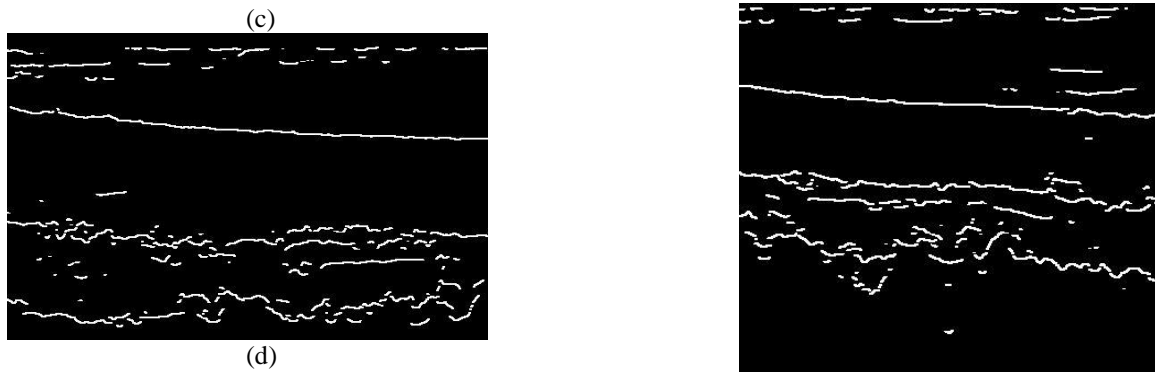

(a)

(b)

(c)

(d)
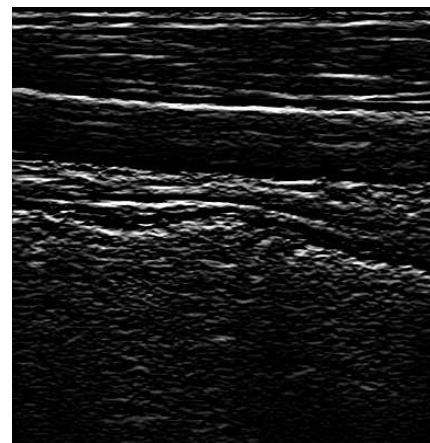
Figure 4: Results for simulation results performed by using Sobel Filter (a) edge detection by applying directly Sobel Filter to test image"17-35-50.jpeg", (b) edge detection by using Sobel Filter to Figure 2(b), (c) edge detection by by applying directly Sobel Filter to test image"17-36-35.jpeg" (d) edge detection by using Sobel Filter to Figure 3(b).

Figure 4(a) and Figure 4(c) show the results of applying Sobel Filter directly to the test images. It can be observed that both strong edges and fine details remain in the edgemap. Therefore, the detection of the arterial wall have not successfully achieved. Figure 4(b) and Figure 4(d) show the results of applying Bilateral Filter and Otsu Threshold before applying Sobel Filter to the test images. From the result, they show that the fine details are not included in the edgemap, but the arterial wall lines are not well obtained and connected.

Prewitt Filter

Figure 5 shows the simulation results performed by using Prewitt Filter. Figure 5(a) and Figure 5(c) show the results of applying Prewitt Filter directly to the test images. Similarly, it can be observed that both strong edges and fine details remain in the edgemap if compared with applying Sobel Filter. Therefore, the detection of the arterial wall have not successfully achieved. Figure 5(b) and Figure 5(d) show the results of applying Bilateral Filter and Otsu Threshold before applying Prewitt Filter to the test images. From the result, they show that the fine details are not included in the edgemap, but the arterial wall lines are not well obtained and connected.
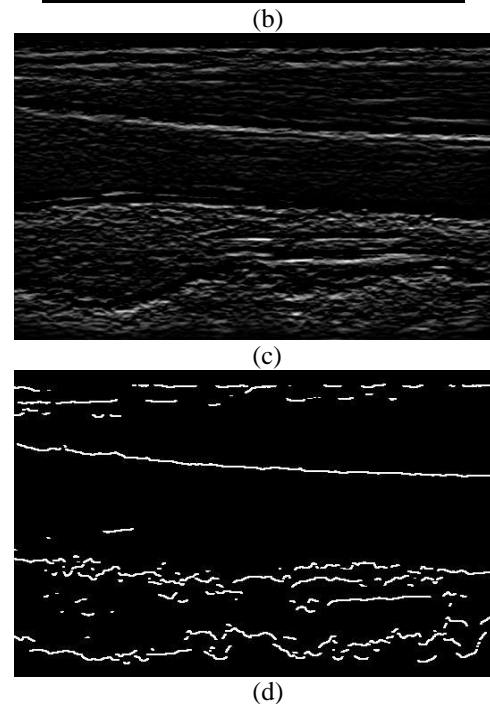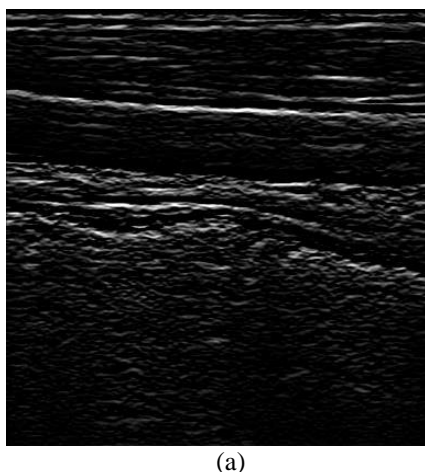

(b)

(c)

(d)

Figure 5: Results for simulation results performed by using Prewitt Filter (a) edge detection by applying directly Prewitt Filter to test image"17-35-50.jpeg", (b) edge detection by using Prewitt Filter to Figure 2(b), (c) edge detection by by applying directly Prewitt Filter to test image"17-36-35.jpeg" (d) edge detection by using Prewitt Filter to Figure 3(b).

Figure 2 to Figure 5 show the results of edge detection of carotid artery ultrasound image by using proposed BLOG method and conventional methods. It can be observed from the visual effects inspections that the proposed method can detect edges without including noise or fine details in the final edgemap of the carotid artery images. The results of this proposed BLOG method are compared with the conventional edge detection methods. They show that the proposed BLOG method have better result in terms of visual effects. Furthermore, the results also are compared in the condition where Otsu Threshold is applied or skipped. The results with implementing Otsu threshold are better than without Otsu threshold in the proposed BLOG method. This is because of the intra-class variance of the black and white pixels are minimized.

(a)

CONCLUSION

In conclusion, the proposed method achieved its objectives in edge detection of artery wall in carotid artery ultrasound images. This method focuses on the combination of Bilateral Filter to smooth speckle noise and fine details in the ultrasound images; where Otsu Threshold is used to classify the image into two regions: background and object. Finally, the Gabor Filter is utilized for final edge detection method.

In this study, it showed that the proposed BLOG edge detection method is better in detecting strong edges in presence of a lot of noise and fine details, especially in the artery compared to conventional edge detection methods.

CONCLUSION

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