VOL. X, NO. X, XXXXXXXX ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

COMPARATIVE STUDY OF EDGE DETECTION ALGORITHM: VESSEL WALL ELASTICITY MEASUREMENT FOR DEEP VEIN THROMBOSIS DIAGNOSIS

Noor Hafizzatul 'Izzah bt Mat Harun, Nabilah bt Ibrahim, Nur Shazilah bt Aziz
Microelectronics and Nanotechnology – Shamsuddin Research Centre (MiNT-SRC), Electrical and Electronic Engineering Faculty, Universiti Tun Hussein Onn Malaysia, 86400, Batu Pahat, Malaysia
E-Mail: hafizzatul215@gmail.com, nabilah@uthm.edu.my, nurshazilah96@gmail.com.

ABSTRACT
In this paper, a comparative study of different edge detection methods had been done to determine the vessel wall elasticity for early diagnosis of the Deep Vein Thrombosis condition. Currently, in most research found that the measurement of the vessel detection conducted solely on the raw image obtains from the ultrasound. Thus, the precision of the measurement could be controvertible from time to time. As a matter of fact, the image consists of its individual characteristics or properties that cannot be verified distinctly. Therefore, various methods of edge detection techniques had been applied to the B-mode ultrasound image. There are several edge detection techniques available for pre-processing in computer vision. Though, Canny, Sobel and Roberts are some of the most applied methods. This paper compares each of the methods by the evaluation of the Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR) of the output image. The evaluations are using Matlab software, the algorithms applied on the B-mode image of 10 subjects that had been volunteering for the purpose of the study. Both the MSE and the PSNR were in numeric values, that includes the vessel wall elasticity measurement of the popliteal vein, therefore, the performance of the algorithm is determined.

Keywords: Edge detection, DVT, MSE, PSNR, vessel wall elasticity.

INTRODUCTION

Ultrasound imaging had been an important role in diagnosing various kinds of health condition. This has included for the diagnosing of the Deep Vein Thrombosis condition (DVT). Various in signs and also symptoms of DVT cause the diagnosis of DVT is challenging. In addition, the thrombus that develop may be asymptomatic. That increasingly causes the difficulty in determining the DVT. Therefore, appropriate conduct to deal with properties of DVT is necessary. Among these methods applied, ultrasonography is as accurate as any, with more advantages than CT, MRI, plethysmography and D-dimer test, including low cost, portability, non-invasive, and simplicity. Thus, ultrasound technology is employed, which shows a number of successful DVT diagnosis (Stephanie Sippel). Since Deep Vein Thrombosis (DVT) can give serious threat to the health condition, it is essential to diagnose the DVT condition at the earliest stage. The diagnosis at this level could help in treating or improving the condition of patients with the DVT. The most common diagnoses done by the physicians are using the clinical assessment. However, the result shown that the condition of the patient still cannot be confirmed (Juan N. Useche, 2008).

Therefore, analysis of the ultrasound image plays a crucial role in the medical field. Sanjay et al. in his study reported analysis of Doppler ultrasound finding for DVT (Sanjay M. Khaladkar, 2014). In their study, the criteria that had been considered include the visualization of thrombus, vein compressibility, vein size and also respiratory changes in the subjects. Based on the analysis, the predominant distribution of thrombus developed to be in the above knee region that is the superficial femoral vein with 88.5%, while for the popliteal vein region involved with 69.2%. In the study, they concluded that colour Doppler is useful in diagnosing DVT at risk patient and provide a noninvasive method of investigation. In addition, it is also contributes in evaluating the site, extent and stage of thrombus. As proven, ultrasound imaging had been widely implemented as it is noninvasive method and its low cost that has allowed the use of this technique for more clinical studies. The B-mode image obtain had been analysed to determine the condition of the patient. In this study, the purpose in analysing the image using the edge detection is to measure the vessel wall elasticity of the popliteal vein. Moreover, several methods of edge detection had been applied to compare the vessel wall elasticity measurement of the popliteal vein. Generally, edge is the plot of high intensity pixel and its immediate neighbourhood in the images. Therefore, the shape of the image object decided by its edges. The edges are used in the image analysis to discover its region boundaries. Edge detection is a significant process in computer vision and image processing, thus, it is essential to consider the edge detection operators (Jie Yanga, 2008, P. P. Acharjya, 2012). Rapid change in the pixel intensity of the image is the common meaning of edge. It includes the important features and critical characteristics of an image. Those rapid changes in the pixel intensity, detected by using the first and second order derivatives. The edge is the boundary between the object and its background. The edge detector aimed to avoid the false edges and correctly detecting the true edges (Pushpajit A. Khaire, 2012).

The edge detection technique had been applied to the B-mode image obtained as to analyse the characteristics of the popliteal vein. In edge detection, there are several methods that had been widely used for analysis, such as Sobel, Prewitt, Canny, Roberts, LOG and etc.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Therefore, in this study, several edge detection methods had been combined as to compare the output result obtained from the analysis. Each algorithm of the edge detection method had its own specified approach, thus, the result may vary for each method. Since then, these edge detection operators are differ in term of their localization, derivatives and magnitude (D. Poobathy, 2014). The result obtained will be measured based on the noise level measurement. Noise level, there were two metric standards that universally followed, Means Squared Error (MSE), and Peak Signal to Noise Ratio (PSNR). Commonly, the MSE and PSNR are used in Image Compression. Then, here both measurements were used to compare the edge detected image quality. The MSE represents the cumulative squared error between the edge detected and the original image, whilst the PSNR represent the measure of the peak error. Moreover, in comparison of both original image and the edge detection operators, if the image obtains from the operator give more PSNR and low MSE, it concludes that the operator had good image quality (D. Poobathy, 2014).

METHOD

A. Experimental Procedure

To study the vessel condition of the subject for early diagnosis of DVT, experiment on 10 volunteered subjects had been done. The equipment used for the experiment is TOSHIBA SSA-580A of the ultrasound machine. For the scanning of the leg used the linear transducer with frequency range of 6 MHz to 12 MHz. Besides, narrower transducers may make it harder to localize the veins and to apply uniform compression. Therefore, for larger patients, a lower frequency or even an abdominal probe will facilitate greater tissue penetration. The patient can be placed in either a prone position, or seated on the edge of the bed with the knee flexed and the foot supported. In the prone positions the leg being examined should be down.Video of the scanning is recorded directly from the ultrasound machine in the range of 30 seconds to 60 seconds, using external frame grabber DVI2USB 3.0. This video is recorded for the measurement of the vein wall displacement (N. Harun, 2014).

B. Region Of Interest (ROI)

In the study, the region of interest (ROI) is focused on the area of valve in the popliteal vein. The ROI chosen due to the necessity of doing the measurement of the displacement between the popliteal vein wall. The patent of valve movement shows the opening and closing of valve during the blood flow. Therefore, by having the valve scanning area, it will allow to measure the significant changes of the displacement in between the wall of the popliteal vein. The measurement taken for the wall displacement is at the location near the valve area (N. Harun, 2014). Figure 1 shows the B-mode image of the popliteal vein.

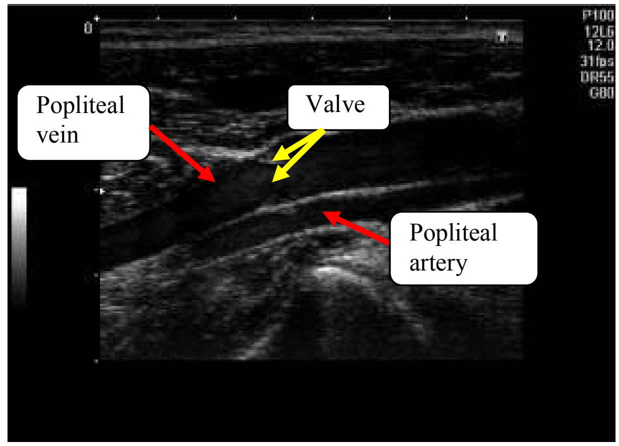


Figure 1: The B-mode image of the valve in the popliteal vein, the popliteal vein positioned side by side to the popliteal artery (N. Harun, 2014).

C. Mean squared error (MSE)

The MSE had been included as of the degradation function and statistical characteristics of noise on the edge detected image. It is the purpose of measuring the average squared difference between the estimator and the parameter. Besides, MSE specifies the average differences of the pixel throughout the original ground truth image with the edge detected image. The higher in value of MSE indicates that a greater difference between the original and processed image (P. Vidya). Equation 1 shows the relationship between the original image and the edge detected image for the MSE.

$$\mathrm{MSE} = \frac{\Sigma_{M,N}[I_1(x,y)-I_2(x,y)]^2}{M,N} \qquad (1)$$

where

M,N : size of image
x : height of image
y : width of image
$I_1(x,y)$: original image
$I_2(x,y)$: edge detected image

The MSE should be less when deal with image restoration, reconstruction and compression. Thus, in terms of edge detection, the MSE could be lower to ensure more edge points are found in the image and able to detect the weak edge points (D. Poobathy, 2014).

D. Peak signal to noise ratio (PSNR)

PSNR is the ratio between the possible maximum power of a signal and the power of the corrupting noise that affect the fidelity of its representation (D. Poobathy). PSNR is the estimation to human perception of reconstruction image quality (P. Kellman). Generally, the higher PSNR normally indicates the reconstruction of higher quality image compression, The PSNR usually expresses in decibel (dB) scale. Equation 2 shows the PSNR calculation based on the MSE.

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{R^2}{\mathrm{MSE}}\right) \qquad (2)$$

VOL. X, NO. X, XXXXXXXX ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

R is the maximal variation in the input image data.

E. Image Processing

Edges are detected by using the Sobel, Canny, Roberts, combination of Canny and Sobel, and also combination method of Canny and Roberts. For Sobel and Roberts operators, the method applied by thresholding the gradient function (Mamta Juneja,2009). While for the Canny method, a threshold is applied to the gradient using the derivatives of Gaussian filter. Figure 2 shows an example of the original image used for the edge detection method.

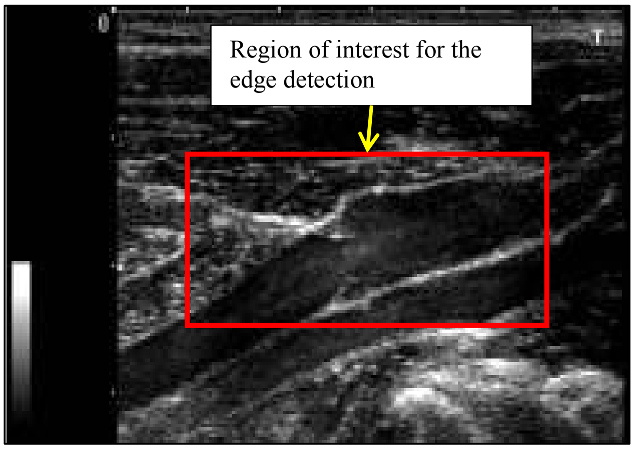


Figure 2: The original image of the popliteal vein (B-mode ultrasound image).

i. Detection using the Sobel operator.

Sobel filter has a simple approximation concept of gradient with smoothing. The 3x3 convolution mask is usually realized to detect gradients in X and Y directions. Equation (3) and (4) show the operator that consists of a pair of 3x3 convolution masks (kernels) (O. Marques, 2011). Figure 3 shows the example of an image using the Sobel operator.

$$h_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (3)$$

$$h_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (4)$$

Figure 3: Sobel edge map of Figure 2.

ii. Detection using Roberts operator.

Roberts cross calculates an efficient, simple, 2-D spatial gradient measurement on an image that highlighting the regions corresponding to the edges. The Roberts operator is applied using two convolution mask/kernel (O. Marques, 2011). In most common usage, Roberts operator use input of grayscale image as well as the output produce. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. Equation (5) and (6) show the 2x2 convolution kernels of the operator.

$$g_x = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \quad (5)$$

$$g_y = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \quad (6)$$

Figure 4: Roberts edge map of Figure 2.

Figure 4 shows the example of image using the Roberts operator.

iii. Detection using Canny.

The Canny edge detector is one of the most popular and effective edge detection operators that available (O. Marques, 2011). The Canny method finds edges by looking for local maxima of the gradient of the image. The method uses two thresholds to detect strong and weak edges (Mamta Juneja, 2009).

VOL. X, NO. X, XXXXXXXX ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Figure 5 shows the example image of the Canny edge method.

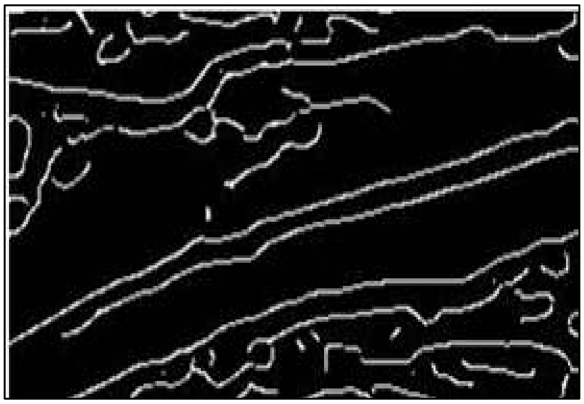


Figure 5: Canny edge map of Figure 2.

iv. Combination of Canny with Sobel and Canny with Roberts.

In the combination of Canny with Sobel and Canny with Roberts operators, the performance evaluation indicated by the measurement of MSE and PSNR. Thus, the quality of the output image from both combinations can be compared and determine the acceptable method for edge detection in vessel wall elasticity measurement. Figure 6 and Figure 7 shows the example of image process by both combinations Canny with Sobel and Canny with Roberts operators.

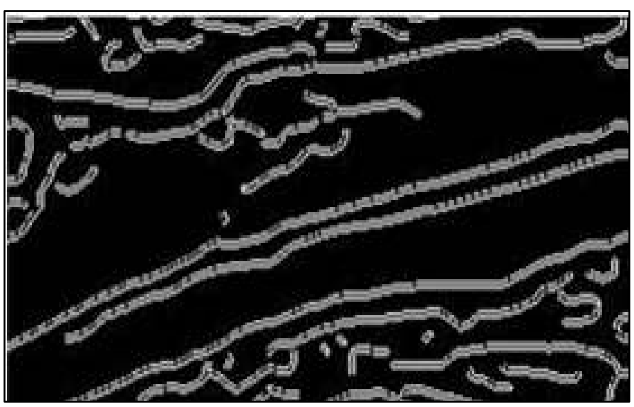


Figure 6: Combination of Canny and Sobel edge map of Figure 2.

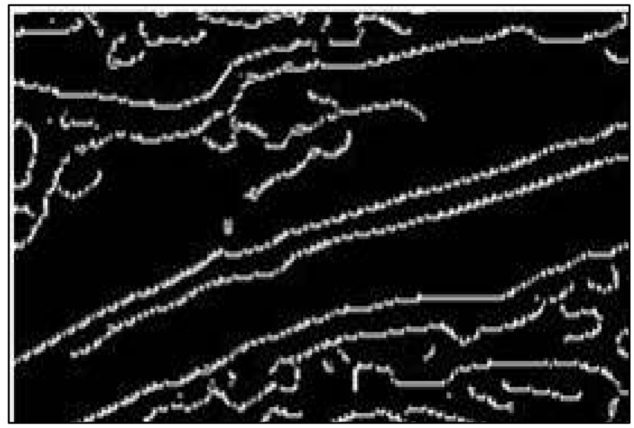


Figure 7: Combination of Canny and Roberts edge map of Figure 2.

PERFORMANCE EVALUATION

A. MSE and PSNR measurement

As mentioned earlier, the edge detection methods were assessed by objective quality measure to find reliable statistical evidence in distinguishing among the output images obtained. The numerical results shown in Table 1 and Table 2 were the outcomes from the Matlab program which is developed to process the B-mode images and to compute the MSE and PSNR value of the output images. The MSE values measured in the range of 1.60 to 16.73. The PSNR value measured at range start from 5.9 dB to 15.98 dB. Based on the measurement obtained, there were an absolute difference in the measurement of MSE and PSNR for different edge detection operators.Figure 8 and Figure 9 show the comparison of average value between the applied algorithm in the measurement of MSE and PSNR calculation. It shows the pattern of the value for the mean MSE and the mean PSNR for each edge detection method applied.

Significantly, from figure 8 and figure 9, the combination of Canny and Sobel operator had the lowest value of PSNR which is 9.62 dB and with the highest average value of MSE that is 7.68. While for the Roberts operator, it has the highest average value of PSNR that is 12.82 dB and lowest average range of MSE which is 4.49. Moreover, based on the output image observed for the Sobel and Roberts operators, the operators were not acceptable for the analysis of edge detection for the vessel wall measurement, eventhough that both operators having the higher value of PSNR indicate that the image is good in image quality. The resultant images of the Sobel and Roberts did not allow for the wall measurement because the vessel wall of the vein cannot be seen clearly and the measurement cannot be done based on that images. Therefore, for the image analysis of the B-mode ultrasound image edge detection using the combination of the canny and Robert is the best option since the PSNR value is high and the MSE is low indicates the good quality of image produced.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table 1: Mean MSE of different edge detection in the B-mode image popliteal vein (for 10 frames) for each subjects[a].

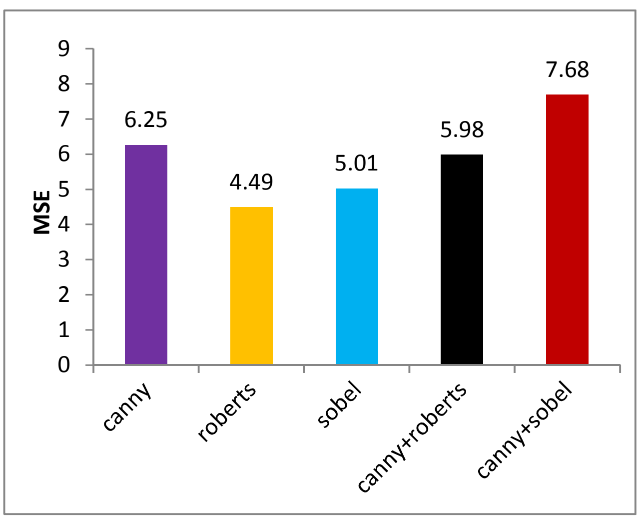
SUBJECT	Canny	Roberts	Sobel	Canny+Roberts	Canny+Sobel
1	3.909	2.120	3.057	3.572	5.545
2	7.351	5.888	7.165	7.043	7.101
3	3.864	2.008	2.589	3.807	5.844
4	7.054	5.684	6.215	6.976	8.335
5	4.501	2.120	2.789	4.029	6.481
6	5.962	2.856	3.415	5.550	8.114
7	2.359	1.640	1.870	2.389	3.579
8	16.433	15.981	15.743	16.004	16.731
9	4.422	2.095	2.700	4.207	6.393
10	6.650	4.493	4.566	6.235	8.638

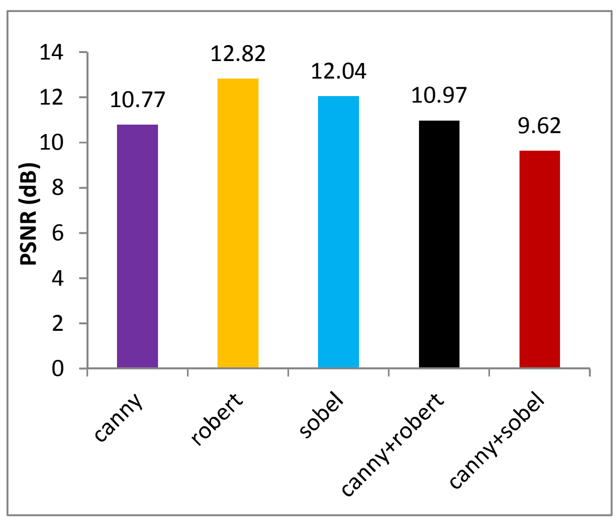
[a]Data are presented as mean value for each measurement of subject.

Table 2: Mean PSNR (dB) of different edge detection in the B-mode image popliteal vein (for 10 frames) for each subjects[a] .

SUBJECT	Canny	Roberts	Sobel	Canny+Roberts	Canny+Sobel
1	12.29	14.87	13.29	12.60	10.70
2	9.46	10.43	9.59	9.65	9.62
3	12.30	15.23	14.01	12.39	10.48
4	9.65	10.60	10.20	9.70	8.93
5	11.60	14.88	13.68	12.10	10.02
6	10.38	13.57	12.80	10.69	9.04
7	14.50	15.98	15.42	14.40	12.69
8	5.98	6.10	6.16	6.09	5.90
9	11.68	14.93	13.75	11.90	10.08
10	9.90	11.60	11.54	10.18	8.77

[a]Data are presented as mean value for each measurement of subject.





VOL. X, NO. X, XXXXXXXX ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

B. Vessel wall elasticity

From the B-mode ultrasound image, the edge detector algorithm chosen was applied. The edge detection algorithms chosen was the combination of Canny and Robert's algorithm since it has the smallest MSE and largest value of PSNR. This edge detection implementation to the B-mode ultrasound image is important for the measurement of the wall displacement of the popliteal vein because of the requirement to measure the elasticity of the blood vessel. Based on the Hooke's Law anology, which describes the relationship between stress and strain (Walter F. Boron, 2008):

$$E\ (Pa) = \frac{Stress}{Strain} = \frac{\sigma}{\varepsilon} = \frac{\frac{F}{A_0}}{\frac{L-L_0}{L_0}} = \frac{FL_0}{A_0 \Delta L}, \qquad (7)$$

where

E : Young's modulus (modulus of elasticity)

F : Force exerted on an object under tension

A_0: Original cross-sectional area through which the force is applied

ΔL: Amount by which the length of the object changes

L_0 : Original length of the object

Based on this equation, the strain, ε measurement is the changes of the vessel wall displacement. Therefore, the edge detection of the vessel wall which is for the wall displacement measurement is crucial for this particular purpose of the elasticity measurement. The elasticity of the blood vessel is an important parameter for the early detection of the Deep Vein Thrombosis condition. A number of subjects will be examined using the ultrasound and the assessement of the vessel wall elasticity for the subjects will be done. Thus, the measurement of the vessel wall elasticity of the subjects will be compared to the vessel wall elasticity of the subject with Deep Vein Thrombosis condition.

Based on Figure 10, shows an example of the vessel wall elasticity measurement for a subject with no history of Deep Vein Thrombosis with the implementation of the combination Canny and Robert's algorithm. Based on the result obtained, the average range of the strain and elasticity measurement were 1.05% and 0.420MPa respectively. In addition, for the future development of this study, more subjects will be examined to differentiate the difference of the vessel wall elasticity measurement for the subject with no history of Deep Vein Thrombosis and the subject that has Deep Vein Thrombosis condition.

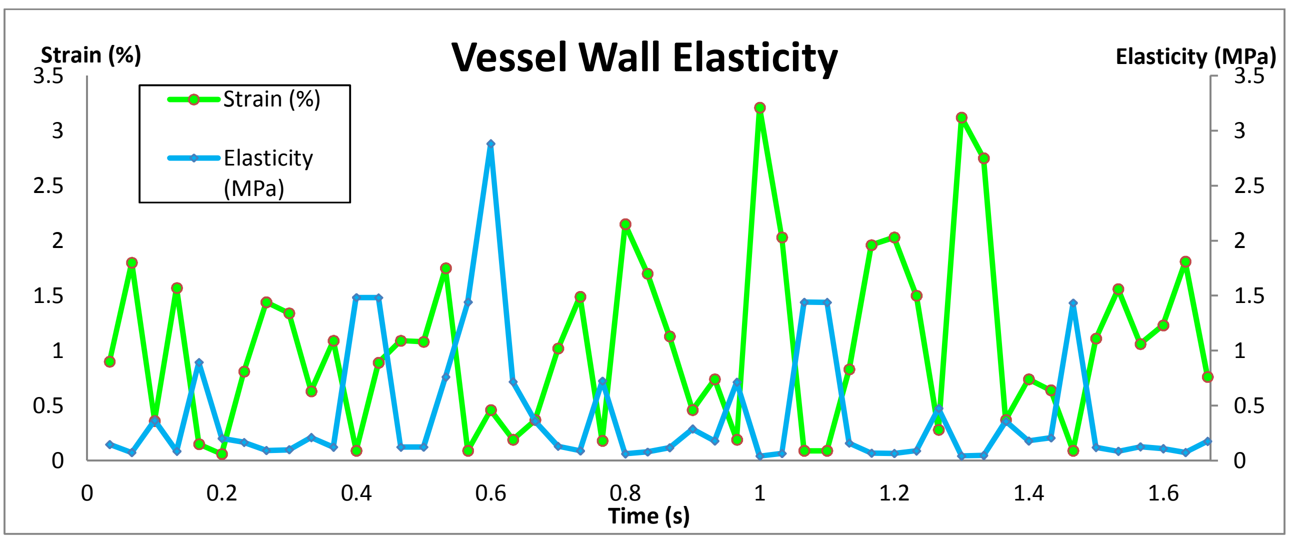


Figure 10 : Edge detection Canny with Roberts for vessel wall elasticity measurement.

CONCLUSION

This paper discussed five different resultant images of five condition edge detection algorithms. The evaluation of the performance measured based on the Mean Squared Error (MSE) and also the Peak Signal to Noise Ratio (PSNR). The results show that image with higher levels of PSNR and low level of MSE, produced a better image visualization for analysis. As a result, the image combination of Canny and Robert's edge detection method produced an approximate value of vessel wall elasticity measurement at the popliteal vein. Therefore, the combination of the Canny and Robert's edge detection method can be an alternative in analysing the B-mode the ultrasound image instead of measurement from the raw image of ultrasound. In the near future, more alternatives in analyzing the ultrasound image can be present to realize the efficiency of the image analysis for early detection of Deep Vein Thrombosis condition.

ACKNOWLEDGEMENT

The authors like to thank Research Acculturation Grant Scheme (RAGS: no. of R031) for the sponsorship doing this project.They also gratefully acknowledged the support and generosity from Universiti Tun Hussein Onn Malaysia (UTHM), Medical Imaging in Laboratory Electrical and Electronic engineering faculty and Microelectronics and Nanotechnology-Shamsuddin Research Centre (MiNT- SRC) for having the space doing the experiment and analysis for this project.

REFERENCES

D. Poobathy and R. Chezian, “Edge Detection Operators: Peak Signal to Noise Ratio Based Comparison”, I. J. Image, Graph. Signal Processing, no 10. September, pp. 55–61, 2014.

Jie Yanga, Ran Yanga, Shigao Lib, S.Shoujing Yina, and Qianqing Qina, “A Novel Edge Detection Based Segmentation Algorithm for Polarimetric Sar Images”, The International Archives of the Photogrammetry, Remote sensing and Spatial Information, Sciences. Vol. XXXVII, Part B7.Beijing, 2008.

J. N. Useche, A. M. F. de Castro, G. E. Galvis, R. A. Mantilla, and A. Ariza, “Use of US in the evaluation of patients with symptoms of deep venous thrombosis of the lower extremities.,” Radiographics, vol. 28, no. 6, pp. 1785–1797, 2008.

M. Juneja and P. S. Sandhu, “Performance evaluation of edge detection techniques for images in spatial domain,” Int. J. Comput. Theory Eng., vol. 1, no. 5, pp. 614–621, 2009.

N. Hafizzatul, M. Harun, N. Ibrahim, W. Nurshazwani, W. Zakaria, N. Farhan, and N. Shazilah, “Study of Vessel Conditions in Different Categories of Weight for Early-Stage of Deep Vein Thrombosis (DVT) Diagnosis,” vol. 6, no. 3, pp. 57–64, 2014.

O. Marques, “Practical Image and Video Processing Using MATLAB”, IEEE Press, John Wiley & Sons, Inc, Hoboken, New Jersey, pp. 335-364, 2011.

Peter Kellman and Elliot R. McVeigh, “Image Reconstruction in SNR Units: A General Method for SNR Measurement”, Magn Reson Med. Author manuscript, Magn Reson Med. Volume 54(6) pp. 1439–1447, December 2005.

Pinaki Pratim Acharjya, Ritaban Das and Dibyendu Ghoshal, “Study and Comparison of Different Edge Detectors for Image Segmentation”, Global Journal of Computer Science and Technology Graphics & Vision, Volume 12 Issue 13, pp. 28- 32, 2012.

Pushpajit A. Khaire and Dr. N. V. Thakur, “A Fuzzy Set Approach for Edge Detection”, International Journal of Image Processing (IJIP), Volume 6 Issue 6, pp. 403-412, 2012.

P. Vidya, S. Veni and K.A. Narayanankutty, “Performance Analysis of Edge Detection Methods on Hexagonal Sampling Grid”, International Journal of Electronic Engineering Research, Volume 1, pp. 313–328, Number 4 2009.

S. Khaladkar, D. Thakkar, K. Shinde, D. Thakkar, H. Shrotri, and V. Kulkarni, “Deep vein thrombosis of the lower limbs: A retrospective analysis of doppler ultrasound findings,” Med. J. Dr. D.Y. Patil Univ., vol. 7, no. 5, p. 612, 2014.

Stephanie Sippel, Krithika Muruganandan, Adam Levine and Sachita Shah, 2011, „Review Article: Use Of Ultrasound In The Developing World‟, International Journal Of Emergency

Walter F. Boron, Emile L. Boulpaep, 2008, ‘Elastic Properties Of Blood Vessels’, Medical Physiology, Saunders, ISBN-10: 1416031154 ISBN-13: 978-1416031154.