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Ovary ultrasound image edge detection analysis: A tutorial using MATLAB

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Abstract— Ultrasound imaging has been used over several years and has an excellent safety record. The problem of edge detection is fundamental to many image processing systems. Besides that, the existing of the sparkle noise creates difficulties in a diagnosis image captured by the ultrasound modality. The purpose of this study is to overcome the boundary problem by using several methods in image processing. The methods include image segmentation, morphological technique and image filtering. The ovary image captured from the ultrasound modality is used in this study. The results show that, by combining the region of interest method with threshold and morphological method, the edges and the border of the ovary can be detected.

Keywords— **Ovary , ultrasound , speckle noise, image segmentation, morphological technique.**

I. INTRODUCTION

Ultrasound has been used in a variety of clinical settings, including obstetrics and gynaecology. The main advantage of ultrasound is that certain structures can be detected without using radiation. Ultrasound also can operate much faster than X-rays or other radiographic techniques. According to [1], the ultrasound is non hazardous and non ionizing machine. Ultrasound sonography method will not give biohazard effect to the pregnant woman or to the baby itself. Ultrasound is more effective than X-ray in producing good quality of soft tissue image. Since it can capture the soft tissue well, the image can help the researchers and medical staff to diagnose and predict early disease during the prenatal stage.

There is a lot of discrepancy when applying the ultrasound technologies such as speckle, the condition of tissue texture, artifacts from the ultrasound image process and the edge are not clear. Due to these problems, many researchers still investigate the best ways to overcome the problem. Their focus consists of improvement in the machine design or concerning on the image quality captured and produces during scanning. Until these issues still under development, the images produce is hardly notified due to the edge. Edge detective is useful for medical practitioners to determine the condition of the patient's health where a lot of important information laying there to be probed.

It was so hard to figure out the shape of the ovary because its size is depending on the patient menstrual stage and scanning technique. Thousand of experiments had been done by the radiography and doctor to justify the shape of the ovary [6-12]. Relative to the problem occur, the study is focused on the detection of the edge or boundaries of the ovary using basic image processing involving image segmentation, morphological technique and image filtering. In doing so, the theoretical values were practically applied using MATLAB. Speckle noise easily can be filtered directly using frequency domain filtering.

II. LITERATURE REVIEW

A. *Medical Literature*

Ovary is a paired organ and it represents the reproductive organ for female. It is located at the in lateral wall of the pelvis region known as ovarian fossa and one on the other side or beside the uterus [2].

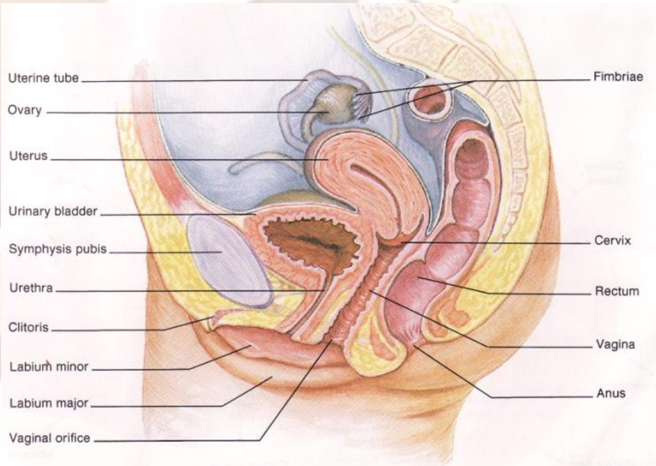

Fig. 1 Female Reproductive System

It is oval in shaped and the size is approximately one inch. The ovaries aren't attached to the fallopian tubes but to the outer layer of the uterus via the ovarian ligaments. The ovaries produce two types of hormones which are estrogen and progesterone. Estrogen is function to help the female to be mature and maintaining the reproductive organ and as for progesterone it related to pregnancy hormones which work as the lining of the uterus for the arrival of a fertilized egg [2].

B. Image Processing

Several images processing techniques are applied. One of the recommended techniques is morphological and Butterworth low pass filter. Morphological image processing is an image processing technique that deals with the shape of features on the image. Fundamentally, morphological image processing is quite similar like spatial filtering where the structuring element is moved across every pixel in the original images to give a pixel in a new processed image.

The operation depends on the performed either dilation or erosion. Each operation has their own advantages; dilation can repair break and intrusions and for erosion it can split apart joined objects and strip away the extrusions. In applying this method, some precautions have to keep in mind. The erosion may cause the object to shrink and vice versa for dilation method.

For frequency domain, first, the image from spatial domain is transformed into frequency domain using the FFT function. Then, to apply a filter to the image, we need to construct a Butterworth low-pass frequency filter which will filter out the high image frequency and result in an image smoothing operation. Finally, to apply the filter, the image from the frequency domain is inverse-transformed to the spatial domain and the filtered image is displayed.

III. MATERIAL AND METHODOLOGY

In this section, we describe about how the data collecting has been done from the ultrasound machine. In obtaining the desired image, an Toshiba ultrasound machine being used with a transducer of 3.5 MHz freeze frame capability [3]. The ovary scanning required two points of view that is sagittal and coronal view. For data collecting purpose, five patients were involved in this project. They were asked to fill the form before scanning and all procedure for clinical being proceed on this project. Several scanning being made for the image processing procedure. Each patient required almost four pictures per scan. From the image captured, optical analysis has been made since the aim of this paper is to locate the ovary boundaries with several algorithm techniques and slowly recognize the region of interest along the image analysis.

The ovary image formation shows a weakness and unconnected boundary which influences the resulting outcomes towards the end of the project. Since this kind of problem occurs several methods of image processing being applied. The methods applied for this study are:

A. Region of Interest

We decide to use cropping command to select only the region which locates the ovary as the main image being processed. By doing that, we can minimize the noise appear in the image. The general command represents the cropping of the image is

J = imcrop (picture,[X_{MIN} Y_{MIN} Width Height]);

B. Image Segmentation

In image segmentation, we apply two kinds of method which are; threshold and edge detection using both boundaries and Sobel formula. The equation involves are:

a) Thresholding

$$g(x,y)=\begin{cases}1 \text{ if } f(x,y)>T\\ 0 \text{ if } f(x,y)\le T\end{cases} \qquad (1)$$

This is general thresholding formula which T is applied to whole image and known as global threshold.

b) Edge detection

We choose ***bwtraceboundary*** command because it can relocate the location of the ovary. Besides that, we can also change the location depending on the image referring as shown in the following command

Dim = size(BW);
Col = round(dim(2)/2)-90;
Row = min (find(BWC;Col));

In Sobel edge detection, the magnitude of the gradient vector with 3×3 operator was chosen for finding the maximum rate of change of *f* at coordinates point of *(x,y)*. The equations are

$$\nabla f = \left[G_x{}^2 + G_y{}^2\right]^{\frac{1}{2}} \qquad (2)$$

$$\nabla f \approx \left[\left\{(z_3+2z_6+z_9)-(z_1+2z_4+z_7)\right\}^2+\left\{(z_7+2z_8+z_9)-(z_1+2z_2+z_3)\right\}^2\right]^{\frac{1}{2}} \quad (3)$$

which help to smooth the edge and reduce the noise as much as possible.

C. Image Enhancement

The images also have to undergo the image enhancement method that involves histogram equalization and linear gray scale level which knows as image negative.

a) Histogram Equalization

The general equation is

$$g(x,y)=\begin{cases}H(x_{i,j})+k(x_{i,j}-m_{i,j}) & 0\le x_{i,j}\le 255\\ H(x_{i,j})\end{cases} \qquad (4)$$

The equation can be elaborate that

- The image gray value before and after image transform be represent as $x_{i,j}$ and $x'_{i,j}$
- The mean of the neighbor filed window as $m_{i,j}$

- H is the transfer function of histogram equalization and play role as the adjusted of histogram dynamic range
- The local contra be enhanced by the value by $k(x_{i,j} - m_{i,j})$

b) Image negative

When involve with negative image it means the one of the three types of gray level will be applied. The negative image is included in linear group. The equation is

$$S = L - 1 - r \quad (5)$$

where *L* is implied as the image pixels and the value of *r* is related to the value of the pixel at the each point located at the image. The equation help to enhance the pixel gray scale colour either white or grey that embedded in the dark region of image.

D. Filtering Image

Two conditions of filtering process can be done either directly to the image (which is called spatial-domain filtering) or in its transform domain (known as frequency domain filtering). In general, spatial filtering is performed by convolving the image with a mask or a kernel. This includes sharpening, smoothing, edge detection, and noise removal. On the other hand, Median filtering is a very good method at conserving edges. This technique is done by replacing each median value with the median of its neighbors. The equation is

$$Q_c(j_1, j_2) = \sum_{n_1}\sum_{n_2} F(n_1, n_2) H(j_1 - n_1 + L_c, j_2 - n_2 + L_c) \quad (6)$$

where *H* in the equation is denoted as the impulse response array of limited spatial invariant extent. *Q* is denoted as spatial linear operation that produces an output image array. The general term of the centered convolution operation can be written explicitly as:

$$\begin{aligned} Q_c(j_1, j_2) = {} & H(3,3)F(j_1-1, j_2-1) + H(3,2)F(j_1-1, j_2) \\ & + H(3,1)F(j_1-1, j_2+1) + H(2,3)F(j_1, j_2-1) \\ & + H(2,2)F(j_1, j_2) + H(2,1)F(j_1, j_2+1) \\ & + H(1,3)F(j_1+1, j_2-1) + H(1,2)F(j_1+1, j_2) \quad (7) \\ & + H(1,1)F(j_1+1, j_2+1) \end{aligned}$$

Moreover the general idea of frequency domain is that the image (*f (x, y)* of size *M x N*) in spatial domain will be represented in the frequency domain *(F (u, v))*. The equation for the two-dimensional discrete Fourier transform (DFT) is:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) e^{-j2\pi(ux|M+vy|N)} \quad (8)$$

The exponential in equation (8) can be expanded into sines and cosines with the variables of *u* and *v* determining the frequencies. The inverse of the above discrete Fourier Transform is given by the following equation:

$$f(x,y) = \frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v) e^{-j2\pi(ux|M+vy|N)} \quad (9)$$

Thus, if we have *F(u,v)*, we can obtain the corresponding image *(f(x,y))* using the inverse, discrete Fourier transform. In addition, the fast Fourier Transform (FFT) is a fast algorithm for computing the discrete Fourier transform. MATLAB has three functions that compute the inverse DFT which are ***ifft, ifft2, ifftn.***

E. Morphological operation

As mention earlier in the literature review, two operation performances are used in this tutorial. The operations are

a) Dilation

The mathematical operation is written as

$$A \oplus B = \left\{ z \,\middle|\, \left(\hat{B}\right)_z \; A \neq \varnothing \right\} \quad (10)$$

The equation will conduct a result which the element in *B* is overlapping with element in *A*. In this case *B* is representing the structuring element and the size is much smaller than size of *A*. Fundamentally, *B* helps to enlarge the size of *A*.

b) Erosion

The erosion algebraic formula is written as

$$A \Theta B = \{ z \,|\, (B)_z \subseteq A \} \quad (11)$$

where *B* is the structuring element and the changes in *B* shape will lead to a different result. The process may shrink the size of the set *A*.

F. Flow Chart of the Method

The flow chart of implementation is shown in Figure 2. The methodology consists of threshold, morphological operation, negative image and edge detection.

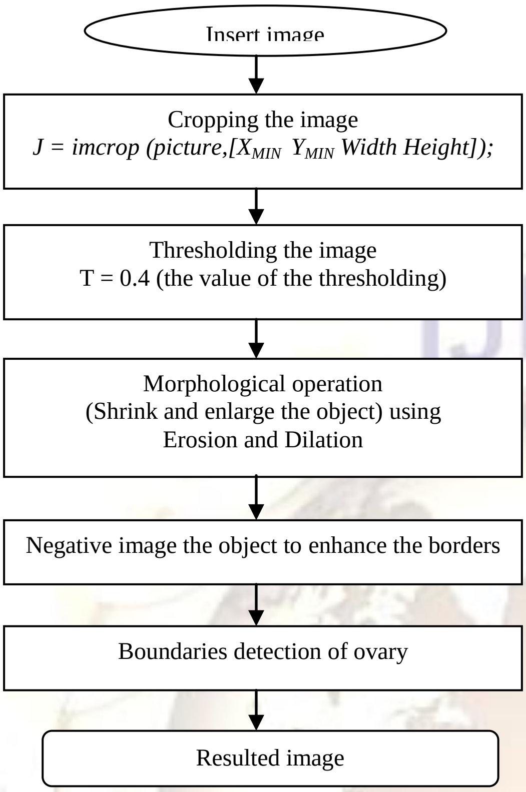

Fig. 2 Flow chart of the methodology

IV. RESULT AND DISCUSSION

Figure 3 shows the original sonography picture taken from the Toshiba Ultrasound machine.

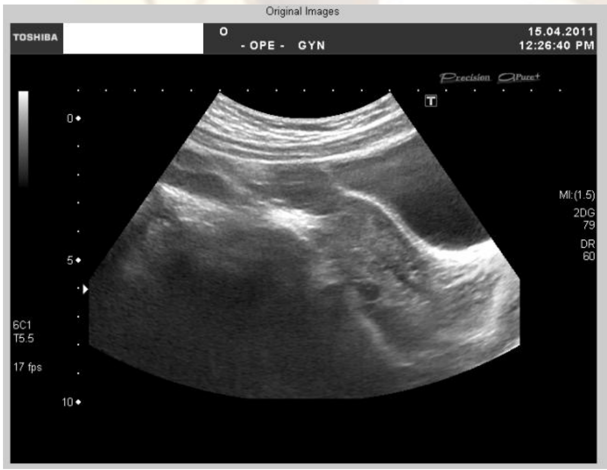

Fig. 3 The Ultrasound image Using Toshiba Ultrasound

As a starting point, the image is cropped to identify the region of interest.

Fig. 4 The Ultrasound Image After Cropped

Figure 4 consists of ovary, uterus and a small apart of urinary bladder. The histogram representation for Figure 4 is shown in Figure 5.

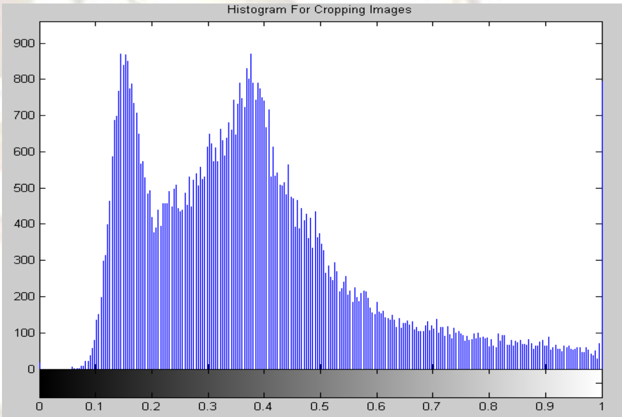

Fig. 5 The Histogram of Cropping Images

From the histogram, we decides to choose the value of threshold, T= 0.4. Thus, the outcome is shown in Figure 6.

Fig. 6 The Image After Thresholding

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Figure 6 shows some brief view of the ovary where it is still connected with the boundary of the uterus. Then morphology technique is applied to shrink, enlarge and split apart the connected boundary as shown in Figure 7 and Figure 8.

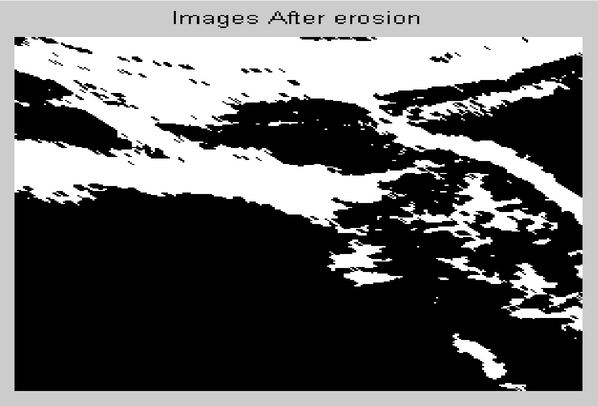

Fig.7 The Image After Erosion

Fig. 8 The Image After Dilation

From the processed image, we can see that the morphological dilation help to recombine the structure and the erosion will deal with the sparkle noise. Before the image undergoes the boundary technique, the image has to be in negative image to make the boundary connection are clearly seen and connected. The negative image is shown in Figure 9. The final result of ovary edge detection is shown in Figure 10.

Fig. 9 The Image Undergoes the Negative Image Process

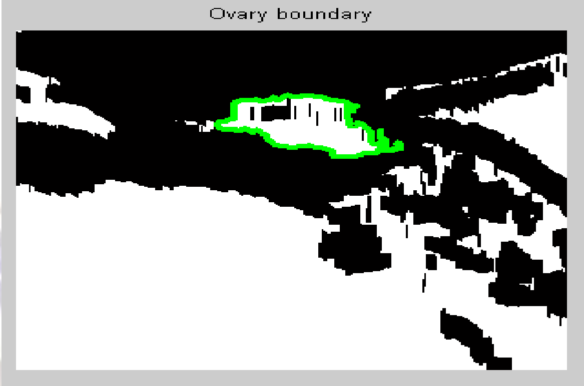

Fig. 10 The Result of The Detection of Ovary Boundaries Using Edge detection technique.

To reduce the sparkle noises that appear in the image, some improvements are added. The original image after cropping process is filtered up using a Butterworth low pass filter with order of n=17 and cut off of D_0=1000. The chosen value is to help better reduction of sparkle noise inside the image but it turns the image to be blurred compared to the original images. The result after filtering process is shown in Figure 11 and Figure 12 respectively.

Fig. 11 The Ultrasound Image After Butterworth Low Pass Filtering

Fig. 12 The Ultrasound Image After Filtering in the Frequency Domain.

The sparkle is not affected by the filtering so we can add a Salt and Pepper noise to influence the existing of sparkle noise. By adding the noise, we can minimize the sparkle noise effect towards the images. The command applied in adding the noise is ***J = imnoise (C1,'salt & pepper',0.09);*** where 0.09 is the intensity of applied salt and pepper noise introduce in the image. Figure 13 is the image with Salt and Pepper noise.

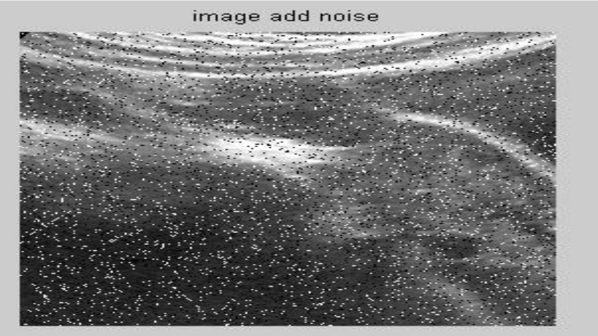

Fig. 13 Shown the Image with Salt and Pepper Noise Be Added

Furthermore, Salt and pepper noise can be reduced by using the median filter. The advantages using the median filter are capable to minimize the noise and influence the edge to remain sharp. A median filter with 3×3 filter mask is chosen as it gives a better view of ovary boundaries compare to the other spatial filter such as averaging and Gaussian. The median filter mask operation only involves the rearrangement of real pixel on the picture with combining of convolution method. The result after applying Median filter is shown in Figure 14.

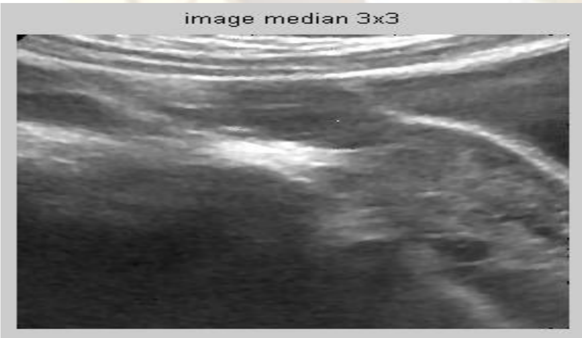

Fig. 14 The Ultrasound Image After Filtering using Median filter

Fig. 15 The Ultrasound Image After Histogram Equalization

Furthermore, the image in Figure 14 will undergo histogram equalization as shown in Figure 15 to give a view which part of the image is the ovary. It can be said that the ovary gray scale is in between 250 until 255.The command is ***K = histeq(L,[250,255]);***.The image undergoes erosion for twice to diminish the noise and enlarge the darker colour of the ovary region as shown in Figure 16 and Figure 17.

Fig. 16 The Image After Erosion for the First Time

Fig. 17 The Image After Erosion for the Second Times

Next, we produce the negative the images as shown in Figure 18 turn to give clear view which part of the image represents ovary.

Fig. 18 The Image After Negative Images

Sobel edge detection was used towards the image for grid the boundaries that appear in the images as shown in Figure 19. The images still have sparkle images although the erosion was applied several times. From the point of view, the ovary is located almost at the top of images and the ovary boundaries are connected.

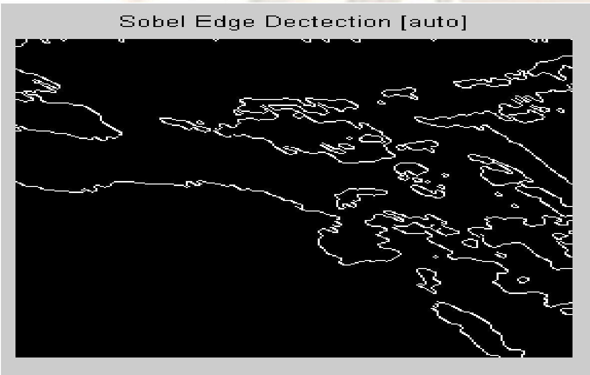

Fig. 19 The Image is Detected Using Sobel Edge Detection

Final result of ovary detection is shown in Figure 20 after several morphological operations were attempts.

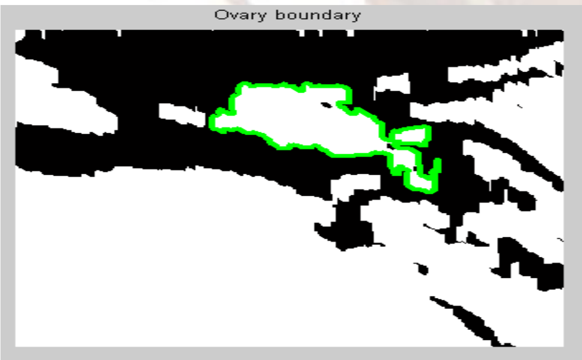

Fig. 20 The Result of the Detection of Ovary Boundaries Using Second Method

Looking at the results perceptively, the methods successfully remove the sparkle but, on the other hand, the result on the ovary detection image is still have plenty room for further improvements.

The recommendation that can be made to improve the method is by applying the technique implemented by [3] and [4]. The technique introduce are directly interacting with the borders and give more accurate boundaries although the gray scale between ovary and uterus are not very clear to be distinguished. Through this study, using Bandstop for filtering in the frequency domain are much more convenient than using either Butterworth or Gaussian filter as the pixel of the ovary is in between the range of black and white. Since the sparkle noise is not a periodic signal, it is hard to remove it directly the in the range frequency domain. If it is implemented, the picture produce were unclear and the boundaries become harder to notified when combining it with Sobel, Canny or Prewitt edge detection method due to the existing of sparkle noise. It was proved that image segmentation by single thresholding or edge detection was not significant in giving optimal result. The algebraic proposed by equation [5] is the best solution to be applied in this study. The technique gives the researcher better understanding in plotting the boundaries.

V. CONCLUSION

Through this tutorial, the techniques used for detecting the boundaries of ovary were successfully achieved. Our aim is to expose the new learners in biomedical image processing enhance their understanding on how to detect the ovary of ultrasound images. The unfavourable results lay in the area of image segmentation. The further research should be made into this area or creating software that can automatically detect the ovary without doing the classical method of segmentation.

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