Image Processing Analysis for Ultrasound Retinal Detachment Images

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Abstract: - Ultrasound has been used as a diagnostic modality for many intraocular diseases, due to its safety and wide availability. Retinal detachment is a condition where the retina separate from its underlying tissue and cause destructive visual consequences to the patient and is readily diagnosed. Sometimes, the poor quality of ultrasound image captured would cause misinterpretation during eye examination. This paper presents analysis of ultrasound ocular medical images through an image extraction and identification approach to improve the quality of the retinal detachment image. The proposed approach calculated the number of connected region existed in the image and successfully identified the location of retinal detachment - using distance measure.

Key-Words: - Ultrasound, eye anatomy, retinal detachment, ocular ultrasound, image quality

1 Introduction

Ultrasound is a tomographic modality that provides an image which is a cross section of the tissue volume under study [2],[3]. Ultrasound is a useful diagnostic tool in the evaluation of various ocular abnormalities or injuries. It is very helpful in diagnosing patients with vitreous opacity, in which direct visualization of the posterior pole of the eye is impossible [4]. In the past years, diagnostic criteria of B-mode ultrasound for the differentiation of retinal detachment from vitreous membrane produced by vitreous hemorrhage are also well established [5], [6] [7].

Retina is in the innermost layer which gets its circulation from the vessels of the choroid and the retinal vessels. Within these layers are the aqueous humor, the vitreous humor and the lens [8], [9].RD is a separation of the retina, which is the light-sensitive membrane from its attachments to the underlying tissue within the eye. On occasion retinal tears are also accompanied by vitreous haemorrhages. If the retina is not reattached soon, permanent vision loss may result [10].

A variety of methods have been used to diagnose RD. Several studies show the use of ocular ultrasound in the trauma patient for optic nerve sheath diameter as a proxy for elevated intracranial pressure, RD and vitreous haemorrhage [12].The use of ultrasound by emergency physicians has greatly expanded over the last decade, and one of its potential applications in the emergency department (ED) is in the diagnosis of intraocular disease [13]. RD typically appears on ultrasound as a bright, continuous, smooth and somewhat folded membrane within the vitreous, which is reflective and freely moving on real time imaging movements become less pronounced in long standing detachments when total or extensive, the detached retina has a typical triangular shape with insertion into the optic disc and ora serrate. However, RD is examined based on the subjective assessment of technicians and has less obvious physical findings, yet if missed, often results in devastating sequence [14].

In this study, we aimed to apply an approach of image extraction and identification to improve quality of retinal detachment image using some image processing techniques. The theoretical values were practically applied by using MATLAB in order to achieve the objective of the study. Furthermore, several image processing techniques were implemented to trace the position of retinal detachment in ultrasound images.

2 Material and Methods

2.1 Image Acquisition

In this study, the Aplio MX (Toshiba) ultrasound has been used for eye examination. Eight normal ocular ultrasound images from students were investigated. Another two normal and two ocular ultrasound images diagnosed with retinal detachment were retrieved from internet [15, 16]. The ocular ultrasonography was performed using a closed-eye technique in both eyes. Image processing and analysis has been carried out based on the image captured.

For the purpose of increasing the frame rate, the depth of the field of interest was reduced as an important step to be used for increasing the spatial resolution to visualize a very small structure.

2.2 Image Processing

In order to detect the case of retinal detachment from ocular ultrasound images, the sequences of image processing has been developed as shown in Fig 1.

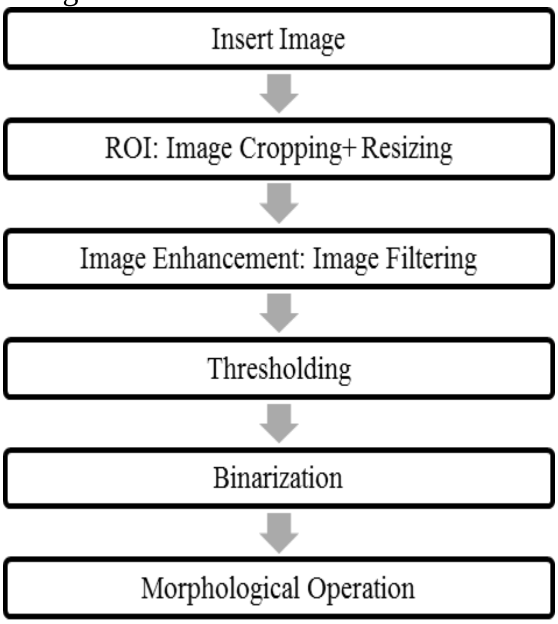
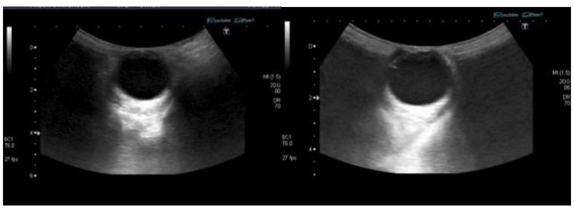


Figure.1**:** Flowchart of an ocular ultrasound image Processing

2.2.1 Image/ Data Collection

A total of 12 ocular ultrasound images originated from three different groups were used for accuracy testing of the proposed approach. Group A contained the normal ocular ultrasound images that have been collected in UTM (Fig. 2)., ocular ultrasound images that were retrieved from Internet were categorized into group B or C (Fig.3) which represented normal condition or abnormal condition respectively [15-17]. The ultrasound images were transformed into gray scale images for further processing.



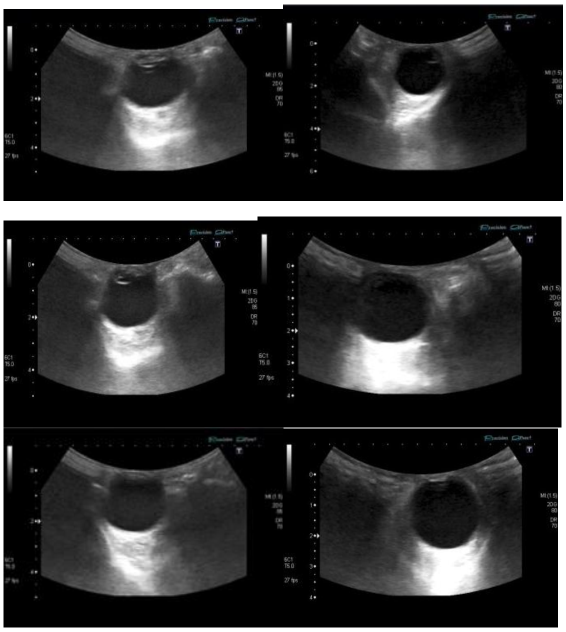


Figure 2: Eight normal ocular ultrasound images

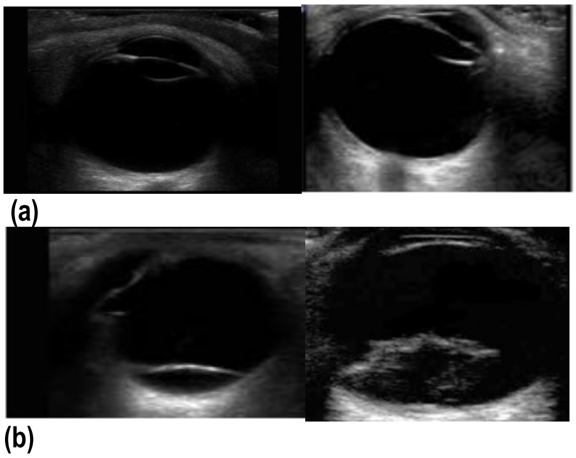


Figure 3: Four ocular ultrasound images were retrieved from Internet, (a) normal condition (b) retinal detachment

2.2.2 Determine the region of interest

In this study, the eyeball was the region of interest thus it was cropped for the purpose of minimizing the noise appeared in the image. Each image was resized to dimension of 100 x 100 pixels to compare between images, Fig.6.

I1 = imcrop (Image1);
I_1 = imresize (I1, [100 100]) (1)

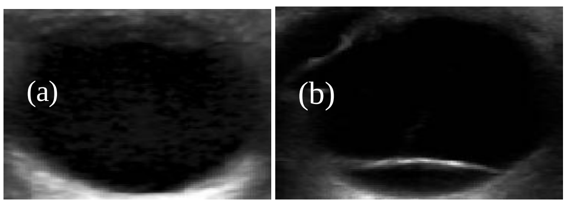


Figure.4: Ocular ultrasound image after the process of cropping and resizing, (a) normal condition, (b) retinal detachment

2.2.3 Image Enhancement

Filtering method has been adopted at this step to improve the characteristics or quality of the image. In general, the image enhancement techniques can be classified as spatial domain filtering (e.g. order filters, mean filters and adaptive filters), frequency domain filtering (e.g. highpass, lowpass and bandpass), wavelet-based filtering, histogram equalization and morphological filtering [18].

In this study, spatial domain filtering has been applied to provide better quality of image. The MATLAB function (2) shows that the spatial filtering was performed by convolving the image (I_1) with a mask or a kernel (h) according to the specificied 2-D spatial filters, e.g. Gaussian, Disk, Laplacian, Sobel and Prewit [19].

h=f special('type');
Filtered_image=filter2(h,I_1)/255; (2)

According to Equation (3) and MATLAB function (4), Wiener filter (adaptive filter type) has also been applied in this study. It is frequently used in the removal of additive noise as well as to restore an unclear image.

$$W(f1,f2) = \frac{H*(f1,f2)Sxx(f1,f2)}{H(f1,f2)2Sxx(f1,f2)+S\eta\eta(f1,f2)} \quad (3)$$

Filtered_image =wiener 2 (I_1,[3 3]); (4)

Atotal of six types of different spatial domain filters have been compared and the most suitable filter would be chosen for further analysis. The performance of filter was measured by using Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) as shown in (5) and (6) respectively. The quality of the images between the original and filtered images has been measured using these two equations.

$$MSE = \frac{\sum_{i=1}^{M}\sum_{i=1}^{N}|u(i,j)-\hat{u}(i,j)|^2}{MN} \quad (5)$$

Where u(i,j) is the original image, û(i,j) is the filtered image after enhancement and MN is the size of the image.

$$PSNR = 20log_{10}\left[\frac{(2^n-1)}{\sqrt{MSE}}\right][dB] \quad (6)$$

2.2.4 Thresholding

Otsu's method is suitable to be used in the condition where the image has fairly distinct of desired object and background . Eq. 7 indicates the MATLAB function used to determine the global image threshold using Otsu's method.

level_1 = graythresh(Filtered_image) (7)

Normally, the basic Otsu's method involves many complex iterative computation steps. Therefore, the simplified formula was generated for obtaining the optimal threshold as shown in (8).

$$t *= Arg \underbrace{Max}_{0\ll t<L} \{\omega_1(t)\mu_1{}^2(t) + \omega_2(t)\mu_2{}^2(t)\} \quad (8)$$

Where and ω_2 are the probabilities and μ_1 and μ_2 are the mean gray-level values of the two distinct classes 'desired object and background'.

2.2.1 Binarization

Binarization process is one of the most crucial steps in determining the accuracy of the proposed image extraction and identification approach is highly dependent on binarization process due to its accuracy . In general, it is an operation that converts a gray scale image into a binary image (9).The level of binarization was set by employing the optimal threshold value which was calculated from (8).

2.2.2 Morphological Operation

The MATLAB function (10) shows the image inversion process that was conducted before the morphological operation.

ibw = 1-bw (10)

The examples of two fundamental operations in mathematical morphology are erosion and dilation. The derived operators are widely used for the purposes of edge detection, image enhancement and image segmentation. In this study, image erosion was applied in the analysis of binary images. The erosion algebraic formula is written as:

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

2.3 Feature Extraction

The image feature in this study was represented as the number of region (connected area) existed in the image after all image processing techniques has been conducted. Every region of the processed ultrasound image was obtained and their properties (area and centroid) were stored using REGIONPROPS function. For normal eye detection, there should be only one region to be perceived. Otherwise, it had a high possibility to be the occurrence of retinal detachment. For the case of more than one detected region, the distance path was generated from the centroid of major region (with largest area) to the centroid of minor region (smaller area) by applying the distance measure technique. This technique could be used to identify and indicate the possible location of retinal detachment. The distance measure algebraic formula is written as:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$\theta = tan^{-1}(^{y}/_{x}) \qquad (12)$$

2.3.1 Feature Extraction and Identification Algorithm

The standard ratio of 0.01 was determined by choosing the smallest area ratio value derived from the images with retinal detachment that have been used in this study. In addition, the orientation tracing of minor region was conducted in a clockwise manner and the starting point located at east direction. Therefore, the range of 0º < m <180 º has been set to ensure the location of minor region located underneath the major region in order to prevent the anterior chamber to be mistaken as the site of retinal detachment.

3 Result and Analysis

In this study, The threshold value that was divided by half as in Fig 7 (b) gave better result as it produced a more similar shape of eye image to the original image compared to the image resulted from an original threshold value Fig 5 (a)after the binarization process.

bw = im2bw(Filtered_image,level_1/2) (9)

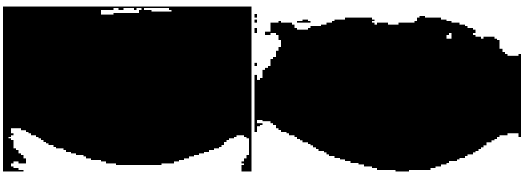


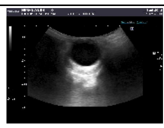
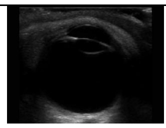
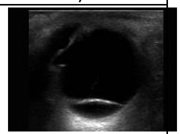
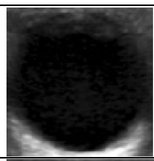
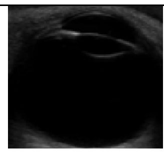
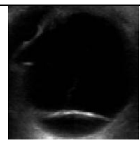
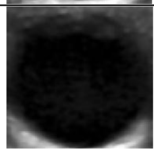
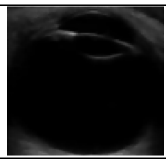
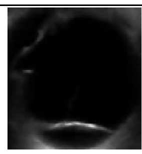
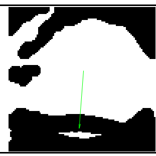
Figure.5: Results of the eye images after binarization process based on (a) original optimal threshold value, (b) original optimal threshold value implied by halves

As illustrated in Fig. 6(b), the morphology technique of erosion was applied for the purpose of connecting and repairing the breaks or empty spaces in the image.

(a) (b)

Figure.6: Results of the eye images after (a) inversion process, (b) erosion process

Table 1: The test results after Group A, B and C underwent the procedures of image processing and feature extraction

Process	Group A (normal, from own database)	Group B (normal, retrieved from Internet)	Group C (retinal detachment, retrieved from Internet)
Load image			
ROI (Cropping, Resizing)			
Filtering			
Thresholding and Binarization			
Inversion			
Morphological Operation			
*Estimation of RD Location	-	-	
Display Result	1.JPG is normal.	2.JPG is normal.	3.JPG has retinal detachment.

* RD location would be estimated if there was more than one region detected and the minor region was located underneath the major region. The green arrow indicated the possible location of retinal detachment.

Figure.7 shows the results of ocular ultrasound images after the filtering process with specified spatial domain filter types. This enhancement step was applied to improve the overall image contrast and brightness characteristics, reduce its noise content, and reveal the details of image for better image analysis.

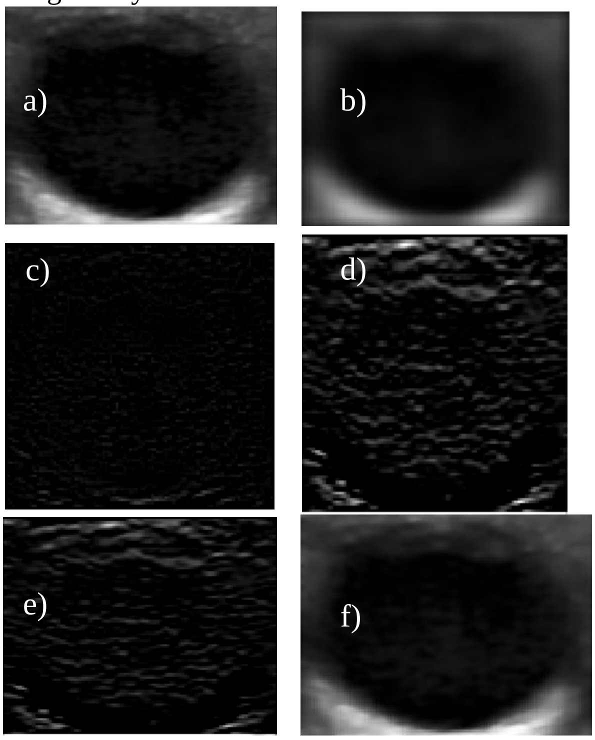


Figure.7: Ocular ultrasound image: a) enhanced using Gaussian filter, b) Disk filter, c) Laplacian filter, d) Sobel filter, e) Prewit filter, f) Wiener filter

Wiener filter has been chosen for the image enhancement step as it possessed the lowest average value of MSE and highest average value PSNR among six types of spatial domain filters. Higher PSNR implies that the image comprises of more useful signal or information than the noise existed in the image. Wiener filter type shows a significant peak in the Fig. 8.

Table 2: The average result of MSE and PSNR according to six types of filters

Filter type	MSE	PSNR
Gaussian	2.90×10^3	2687.9189
Disk	2.90×10^3	2692.0104
Laplacian	2.92×10^3	2708.4072
Sobel	2.92×10^3	2708.821
Prewit	2.92×10^3	2708.7332
Wiener	8.0072157	7.8917927

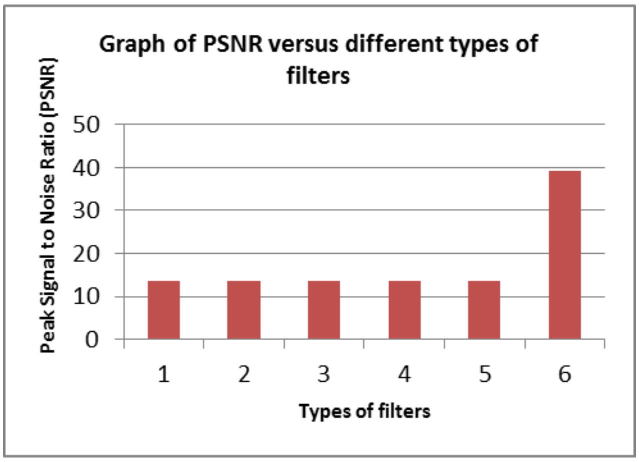


Figure.8: The results of PSNR according to different types of filters

After the binarization process, it can be seen that the ultrasound images with retinal detachment would be transformed into two separate regions (refer Fig. 13). The region with largest area would be appointed as major region. It usually represents the region of vitreous humor of eye. Meanwhile, the small region located beneath the major region/retinal layer shows the possible occurrence of retinal detachment. However, only the regions that meet the following requirements are to be considered as candidates of retinal detachment in the identification process:

$$\frac{\text{Area of minor region}}{\text{Area of major region}} > 0.01$$

Otherwise, the region is considered to be noise and rejected. This is due to the fact that the proposed approach has high sensitivity in detecting the connected region (image feature) and this may lead to the misdetection of noise scattered around the image as the desired result.

For the orientation estimation, the distance measure technique was used to identify the possible orientation of the minor region in the image. From the result obtained in Fig. 13, the location of retinal detachment was determined successfully by the indication of green arrow.

Figure. 13: The orientation estimation of minor region in the abnormal ocular ultrasound image

The objectives of this study have been achieved based on the results stated above. However, the

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proposed approach was limited only for the detection of retinal detachment. The extension and validation of the proposed approach for other parameters of ocular abnormalities are out of the scope of this preliminary paper.

4 Conclusions

In summary the initial research has demonstrated the distance measure technique used to indicate the possible location of retinal detachment. The proposed algorithm could be improved to become a built-in function in ultrasound machine and provide automatic detection of retinal detachment. Furthermore, it is possible to be utilized as a diagnostic decision support system for helping the ophthalmologist or emergency physician in making their critical decisions during eye examination.

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