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Refinement for Ocular Ultrasound Images Quality by Utilizing Combination of Enhancement Techniques

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Abstract

Ultrasound has been used as a diagnostic modality for many intraocular diseases, due its safety, low cost, real time and wide availability. Unfortunately, ultrasound images suffer from speckle artifact that is tissue dependent. In this work, we will offer a method to reduce speckle noise and improve ultrasound image to raise the human diagnostic performance. This method combined undecimated wavelet transform with a wavelet coefficient mapping function: where UDWT used to eliminate the noise and a wavelet coefficient mapping function used to enhance the contrast of denoised images obtained from the first component. This methods can be used not only as a means for improving visual quality of medical images but also as a preprocessing module for computer-aided detection/diagnosis systems to improve the performance of screening and detecting regions of interest in images. The proposed method is experimentally evaluated via 60 ultrasound images of eye. It is demonstrated that the proposed method can further improve the image quality of ocular ultrasound; the results reveal the effectiveness and superiority of the proposed method.

Keywords: contrast enhancement, denoising, ocular ultrasound, undecimated wavelet transform

1. Introduction

Ocular ultrasound is an easy way to use modality for visualization of ocular pathology and anatomy (Chaudhari, et al., 2013). It is very helpful in diagnosing patients by direct visualization of structures obscured by opaque substances, such as dense cataracts or vitreous hemorrhage; Real time information is available to the practitioner regarding conditions such as retinal detachment. Ultrasound is a valuable non-invasive tool for imaging the eye and is an essential way to diagnose eye diseases. It is important to recognize, however, that ultrasound examination is safe, does not expose the patient to radiation, widely accessible, and low cost. With the wide spread use of ultrasound imaging of eye, the quality of these images becomes very important issue. For achieving the best result in diagnosing disease, ultrasound image must have good quality and without noise and artifact. However, all ultrasound images have visual noise that come from variety of sources acquisition, transmission storage and display device. With improvement in technologies used acquiring images, the noise has not been removed completely. Noise in these images could cover and blur important features. Therefore, denoising techniques were used to make the most important features more easily visible.

Denoising and contrast enhancement operations are two of the most common and important techniques for ultrasound image quality improvement. Many researchers relied on different ways, wavelet transform is mostly used because of its efficient properties especially the De-Correlation property of components of image with the high and low frequency content (Übeyl & Inan, 2004) (Agnew et al., 2011) (Florian & Thierry, 2007) (Akhilesh, 2012). Some researchers used discrete wavelet transform (DWT) (Fodor & Kamath, 2003) (Ferreira & Borges, 2003) in ultrasound images. The DWT is very efficient from a computational point of view, but it has main disadvantages that it is shift variant.

Therefore, its denoising performance can change if the starting position of the signal is shifted. To achieve the shift invariance, researchers have proposed the undecimated Wavelet Transform (UDWT) (Zaid, Mariam, & Issa, 2015) (Fowler, 2005). (Zaid, Mariam, & Issa, 2015) Proposed a modified UDWT approach to fetal ultrasound image denoising. (Fowler, 2005) Study the derivation of precise relationship between UDWT-domain and original-signal-domain distortion for additive white noise in the UDWT domain. The results demonstrated that the method could further improve image quality.

Contrast enhancement could be implemented by various techniques; these techniques can be divided into several categories, including histogram equalization (Kim, You, & Jeong, 2012) (Papadopoulos, Fotiadis, & Costaridou, 2008), fuzzy (Jiang, Yao, & Wason, 2005), and adaptive methodology (Tsai, Lee, & Chiba, 2005). (Lee, Tsai, & Suzuki, 2008) Use a sigmoid-type mapping function for wavelet coefficient weighting adjustment to enhance the contrast of medical images. The method was applied to chest radiographs, it showed a statistically significant superiority over the exponential-type mapping function. In this work, undecimated Wavelet Transform used and combined it with the sigmoid-type mapping function (Lee, Tsai, & Suzuki, 2008). By combining the two methods, an effective algorithm obtained for both image denoising and enhancement. First, original images were denoised using the modified UDWT, followed by image enhancement using the wavelet coefficient mapping function. Then, a denoised and enhanced image was reconstructed by the inverse wavelet transform.

2. Method

The ultrasound images of eye contain considerable speckle noise, which is harmful for the medical diagnosis. Reduce speckle noise and contrast enhancement to improve the ultrasound images in terms of visual appearance and this in turn raises the performance of medical diagnosis. In this work, undecimated wavelet transform has been used for signal denoising then wavelet coefficient mapping function used for image enhancement. First, the undecimated wavelet transform designed to overcome the lack of translation invariance of the decimated wavelet transform. Undecimated Wavelet Transform is based on the idea of no decimation; it applies the wavelet transform and omits both down sampling in the forward and up sampling in the inverse transform. It applies the transform at each point of the image, saves the detail coefficients, and uses the low-frequency cofficients for the next level. The size of the coefficients array do not decreased from level to level. By using all coefficients at each level, we get good allocated high-frequency information. From level to level, there is very small step in the width of the scaling filter; in level three of DWT, we use five pixels instead of eight pixels as width. This step is not a power of two but a sum with two; this is good for noise removal because the noise is usually spread over small number of neighboring pixels. The frequency and spatial information become more precise because the transform of the number of pixels involved in computing a given coefficient grows. In the best case, this means remove the noise only at the places that it really exists, without affecting the neighboring pixels. This method could give the best results in terms of visual quality with less blurring for larger noise removal. Latter, perform the inverse wavelet transform to reconstruct the denoised image with the approximation coefficient of first level and the three newly obtained detailed coefficients.

Second stage implement Wavelet Coefficient Mapping. A sigmoid-type transfer curve with a one-to-one mapping function was used for enhance the contrast of image. The mapping function was determined based on the following: (a) wavelet coefficients having high values are heavily weighted because they carry information that is more useful; (b) the coefficients at low levels are heavily weighted because they carry detailed information like edge information; and (c) the approximation coefficients are not manipulated to prevent image distortion (Lee, et al., 2008).

The input coefficient $W_{input}^{j}(m,n)$ of level j at position $(m,\ n)$ was manipulated using the sigmoid-type transfer curves of wavelet coefficients. The mapping function is given by.

$$w_{\text{output}}^{j}(m,n) = a \times \frac{1}{1 + \left\{1/\exp\left[\left(w_{\text{input}}^{j}(m,n) - c\right)/b\right]\right\}} \times w_{\text{input}}^{j}(m,n),$$

Where $W_{input}^{j}(m,n)$ represents output coefficient, and a, b and c are constant. The values of the coefficients expressed in terms of percentage for the ease of computation:

$$w_{\text{output}}^{j} = a \times \frac{1}{1 + \left[1/\exp\left(\left(w_{\text{input}}^{j} - c\right)/b\right)\right]} \times w_{\text{input}}^{j}\ [\%] .$$

Here, $W_{input}^{j}(m,n)$ is the input value expressed in terms of percentage.

This value presents the mean of the absolute values of the coefficients at level j equal to 50%. Notation $W_{input}^{j}(m,n)$ is the percentage of corresponding output value. By utilization of percentage, the constants a, b, and c could be used independent of image characteristics.

3. Results

Our test consists of Visual Perceptual Evaluation. Five experienced Ophthalmologists, their experience ranging from 5 to 10 years, made the visual evaluation. We obtained 60 ocular ultrasound images from different patient with different diseases. Each observer reviewed the images independently. The observers independently evaluated one pair of images, which were shown on the monitor one at a time, using a 5-point grading scale (1 to 5 points). Giving two images at a time: one image show the original ultrasound image of eye; and the other showing the image after applying our enhancement method. Each ophthalmologist test different 15 images by seeing both images original and processed one, then evaluate the visual diagnosis for each one. Unfortunately, due to the limited nature of previous published systems and the differences in methods used, we cannot compare our results with it numerically. To validate our method, we depend on the evaluation of expert Ophthalmologists. Figure 1 shows two sets of example images of ultrasound images of eye. Original images are shown in the upper row of the figure and corresponding images are shown in the lower row. The results of visual assessment indicated that the images processed with the UDWT method combined with wavelet coefficient mapping function showed statistically significant superior image quality that could reduce the errors in diagnosis.

4. Conclusion

In this work, we proposed a method, which combines the Undecimated Wavelet Transform UDWT method and the sigmoid-type wavelet coefficient mapping method. UDWT used to eliminate the noise and a wavelet coefficient mapping function used to enhance the contrast of denoised images obtained from the first component. The small number of pixels five instead of eight that involved in computing gives highly precise information. The effectiveness of the method evaluated by specialist, where they evaluate the improvement of image quality and how this improvement could help in diagnosis. The results of visual evaluation, suggested that the proposed method was significantly promising, demonstrated the superiority and effectiveness of the proposed method. It combines the advantages of the two methods: denoising and contrast enhancement. This methodology can be used not only as a means for improving visual quality of medical images but also as a preprocessing module for computer-aided detection/diagnosis systems to improve the performance of screening and detecting regions of interest in medical images.

Unfortunately, this work has several limitations. First, we only applied the proposed method to ocular ultrasound image, in order to validate the versatility of the proposed algorithm, application of the proposed method to other images obtained from different modalities, such as echocardiograph is needed. Second, the dataset contained only 60 images. A larger dataset may enable us to better evaluate the performance of the proposed method. Finally, the evaluation depend on visual perception only, may in the future use numerical method to evaluate the method more precisely.

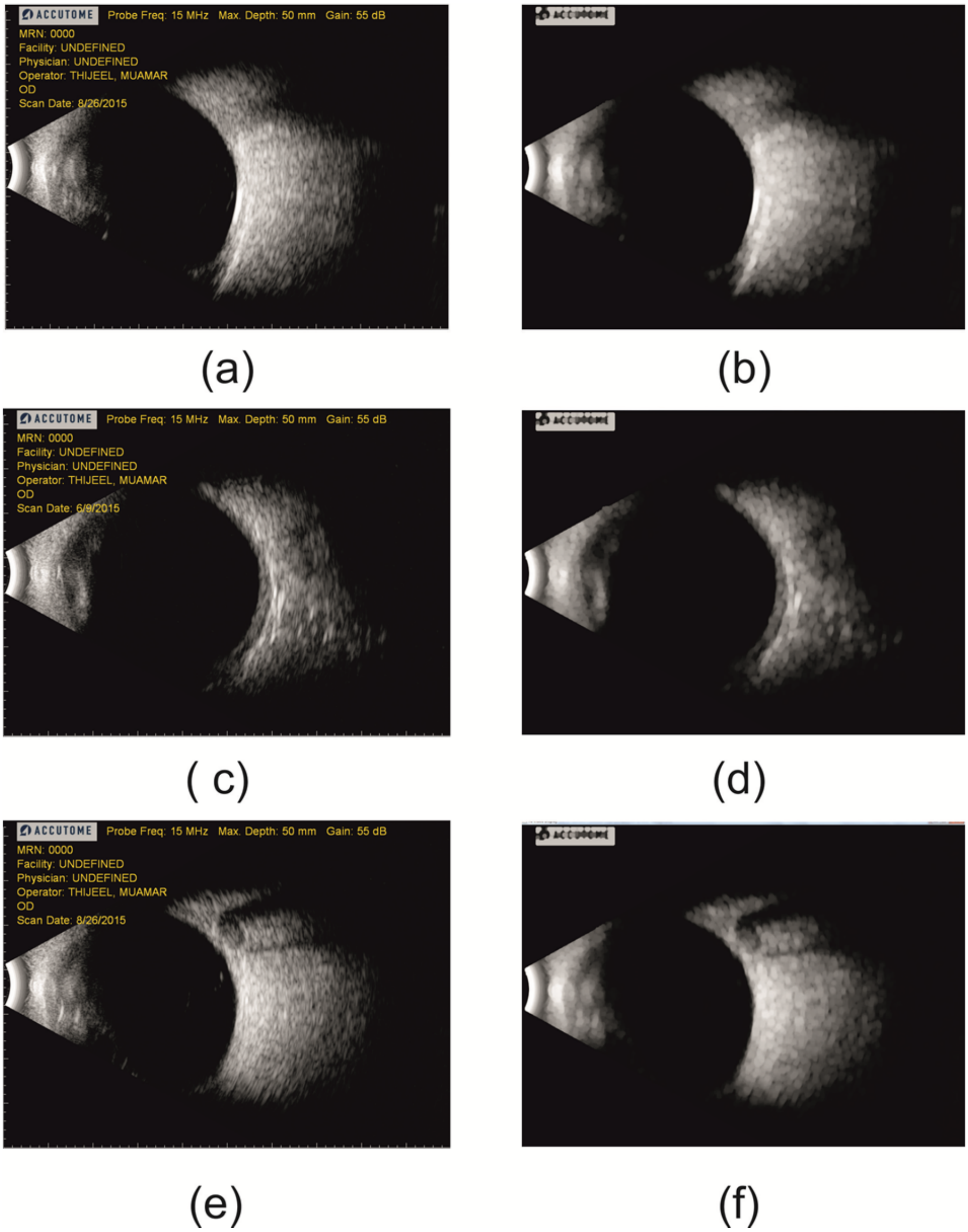

Figure 1. Shows three ocular ultrasound images; the left side contains the original images; and the right side contains processed images

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