BL_Wiener Denoising Method for Removal of Speckle Noise in Ultrasound Image

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Abstract: Medical imaging techniques are extremely important tools in medical diagnosis. One of these important imaging techniques is ultrasound imaging. However, during ultrasound image acquisition process, the quality of image can be degraded due to corruption by speckle noise. The enhancement of ultrasound images quality from the 2D ultrasound imaging machines is expected to provide medical practitioners more reliable medical images in their patients' diagnosis. However, developing a denoising technique which could remove noise effectively without eliminating the image's edges and details is still an ongoing issue. The objective of this paper is to develop a new method that is capable to remove speckle noise from the ultrasound image effectively. Therefore, in this paper we proposed the utilization of Bilateral Filter and Adaptive Wiener Filter (BL_Wiener denoising method) for images corrupted by speckle noise. Bilateral Filter is a non-linear filter effective in removing noise, while Adaptive Wiener Filter balances the tradeoff between inverse filtering and noise smoothing by removing additive noise while inverting blurring. From our simulation results, it is found that the BL_Wiener method has improved between 0.89 [dB] to 3.35 [dB] in terms of PSNR for test images in different noise levels in comparison to conventional methods.

Keywords: Ultrasound imaging, denosing technique, speckle noise, Bilateral Filter, Adaptive Wiener Filter; BL_Wiener

1. Introduction

Medical imaging techniques are extremely important tools in medical diagnosis. One of these important imaging techniques is ultrasound imaging. Ultrasound is a form of non-ionizing radiation and considered safe to users. Ultrasound imaging is highly non-invasive where it will not entering or penetrating into body or disturbing body tissue especially in a diagnosis [1]. Ultrasound imaging is based on the transmission towards human body of longitudinal acoustic waves with a frequency and the reception of produced echo [2]. The signal is created and then detected by piezo-electric effect. Ultrasound imaging has several advantages over some other medical imaging techniques in terms of cost, safety and allows real time imaging. However, during ultrasound image acquisition process, the quality of image can be degraded due to corruption by noise. Noise may be generated due to imperfect instruments used in image processing, problems with data acquisition process and interferences and as well as the influence of the anatomy of the tissues in the body as fat. In ultrasound imaging, images are usually corrupted by speckle noise, which is a type of multiplicative noise. Speckle noise is generated due to scattering phenomenon. A number of elementary scatterers reflect the sound waves towards the sensor. The degradation effects including suppression of edges, and structural details, which may affect image-based diagnosis decision. Therefore, noise reduction for medical images is important to improve the image. Even though there are sophisticated technologies such as 3D and 4D ultrasound imaging machine, MRI and CT scan machines, the availability of these machines are limited to certain medical centers. These sophisticated machines are mostly available only at public medical centers or university's hospitals in capital urban areas and private medical centers. Furthermore, the cost for these medical imaging is significantly higher in comparison to 2D ultrasound imaging. The enhancement of ultrasound images quality from the 2D ultrasound imaging machines is expected to provide medical practitioners more reliable medical images in their patients' diagnosis. Through a more accessible medical facility, it will benefit the public for earlier and faster preventions and treatments.

Many denoising methods have been proposed over the years, such as the Wiener Filter, Wavelet Thresholding [3] [4], anisotropic filtering [5], Total Variation method [6], and Non-Local Means methods [7].

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However, developing a denoising technique which could remove noise effectively without eliminating the image's edges and details is still an ongoing issue in image processing. In the Wavelet Threshold, a signal is decomposed into approximation and detail subbands, and the coefficients in the detail subbands are processed via hard or soft thresholding [8]. The main task of the wavelet thresholding is the selection of threshold value. The Bilateral Filter was proposed by Tomasi et al [9]. It applies spatially weighted averaging. Bilateral Filter is capable to denoise noise from a corrupted image while preserving the edge of the image through the non-linear combination of adjacent images. This technique is non-iterative, local and easily produced. Bilateral filter provides good filtering performance for grayscale images and color images. Referring to Zhang [10], Adaptive Bilateral Filter (ABF) is proposed. According to G.R. Sinha [11] in 2012, the bilateral filter has been applied to denoise medical image.

Combination of Bilateral Filter and other filter to denoise image has been introduced in many papers. Bilateral Filter and Wavelet Thresholding was applied by Zhang and Guntruk to eliminate noise in real noisy images [12]. This method is also used by Sudipta Roy, NidulSinha and Asoke K. Sen to eliminate noise in medical image [13]. Through these researches, the combination of BF with other denoising technique has proven significant improvement in noise reduction. Therefore, in this paper we proposed the utilization of BF and Wiener filter for images corrupted by speckle noise.

The Wiener filter is an established filtering method and is best known for linear image denoising [14]. It balances the tradeoff between inverse filtering and noise smoothing by removing additive noise while inverting blurring. The Wiener filter was proposed by Nobert Wiener [15]; since then, it has been improved and implemented in various domains such as the spatial [16], frequency [17], [18] domains.

The objective of this paper is to develop a new method that is capable to remove speckle noise from the ultrasound image effectively. This proposed method utilizes the advantages of both Bilateral Filter and Wiener Filter. Therefore the proposed method is expected to contribute effective preservation of fine details and edges in the image while removing the noise. The proposed method is denoted as BL_Wiener method, hereafter. The denoising is performed to 2D ultrasound images corrupted by speckle noise by using MATLAB software.

The paper is organized as follows. The proposed BL_Wiener method is described in Section 2. The results and analysis are discussed in Section 3. Finally, concluding remarks are drawn in Section 4.

2. Proposed BL_Wiener Denoising Method

Bilateral filter (BF) [9] has been proposed for gray scale images and color images. BF is an effective filter in smoothing noise especially in smooth regions in a corrupted image. BF is achieved by the combinations of spatial Gaussian filters. One of filter works in spatial domain and second filter works in intensity domain. This filter applies spatially weighted averaging smoothing edges. It replaces the pixel value at corresponding pixel with an average of similar and nearby pixel values. The BF is defined as:

$$I^{filtered}(x) = \sum_{x_i \in \Omega} I(x_i) f_r(\|I(x_i) - I(x)\|) g_s(\|x_i - x\|) \quad (1)$$

where
I^{filtered} is the filtered image
I is the original input image to be filtered
x is the coordinates of the current pixel to be filtered
Ω is the window centered in x
f_r is the range kernel for smoothing differences in intensities. This function can be a Gaussian function
g_s is the spatial kernel for smoothing differences in coordinates. This function can be a Gaussian function

Several characteristics of BF which explains its success are (i) BF is simple to formulate it. Each pixel is replaced by a weighted average of its neighbors, (ii) BF depends only on two parameters that indicate the size and contrast of the features to preserve, (iii) BF is a non-iterative technique. It is easy to set so that the parameters effect is not cumulative over several iterations. Although BF is effective in removing noise, however the drawback of this filter is that it may oversmoothes the edges and details at the same time.

Due to this shortcome, Wiener Filter (WF) [15] is proposed to be used to further denoising while preserving remaining edges and details. The WF is first introduced for Gaussian noise removal. It plays an important role in a variety of applications such as linear prediction, image processing, echo cancellation, signal recovery, channel equalization and system identification. WF coefficients are calculated to minimize the average squared distance between the filter output and the desired signal. Basically, Wiener theory assumes that the signal is stationary process. However, if the filter coefficients are periodically recalculated for each block of signal samples N then filter adapt to the characteristics of the average signal in the block and the block-adaptive, which is namely Adaptive Wiener Filter (AWF) [19]. This low pass filter is applied in a local neighborhood of 3 × 3 pixels blocks of the image. The AWF estimated the local mean and variance around each corresponding pixel. The AWF is defined as:

$$S(i,j) = W(i,j) * X(i,j) \quad (2)$$

where
$S(i, j)$: Images that have been filtered
$W(i, j)$: Wiener filter
$X(i, j)$: Image corrupted by noise

The utilization of both techniques is expected to provide a better denoising performance which is capable to remove noise effectively while preserving edges and details.

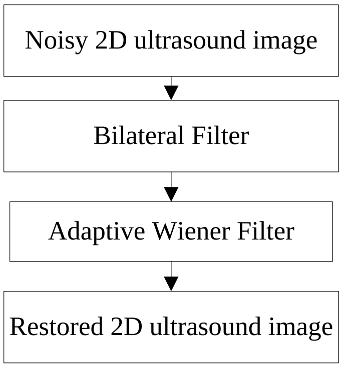


Fig. 1 Block diagram of BL_Wiener denoising method.

The BL_Wiener technique is tested to ultrasound images. The analysis for restored images is performed by objective and subjective evaluation methods. The subjective evaluation method is performed by evaluating the visual effects. The objective evaluation method is using the Peak Signal to Noise Ratio (PSNR) [11]. The calculation of PSNR is calculated by using two images; of the original image (clean) and the denoised image. Higher PSNR value means higher image quality produced, conversely lower MSE means better quality restored image. The PSNR is defined as:

$$\text{PSNR [dB]} = 10 \log 10 \frac{(255 \text{ X } 255)}{\text{MSE}} \quad (3)$$

$$\text{MSE} = \frac{\sum (\text{predicted value} - \text{real value})^2}{\text{resolution x} \times \text{resolution y}} \quad (4)$$

where
MSE: mean squared error

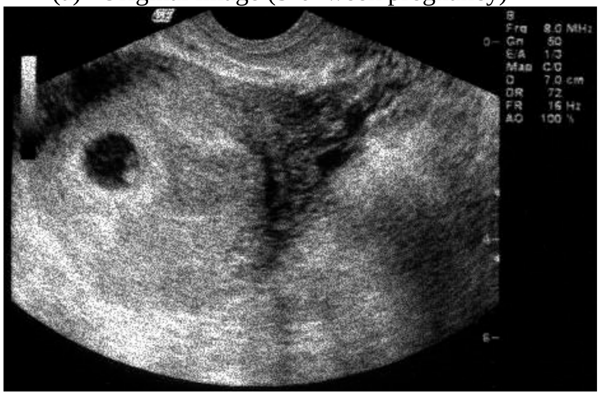
3. Results and Discussion

In this paper, the performance of the BL_Wiener is compared with conventional denoising methods, which are BF and AWF by using MATLAB software. The parameter settings for BF are Ω = 10, g = 2, f = 0.2, respectively. On the other hand, the adaptive filter size for the AWF is set to 3 x3. The BL_Wiener utilized the similar parameter settings as the BF and AWF. For simulation, original 2D ultrasound images (i.e. image captured without corrupting with additional noise) are corrupted with speckle noise in different levels: low (2e2), medium (7e11) and high (8e20) noise.

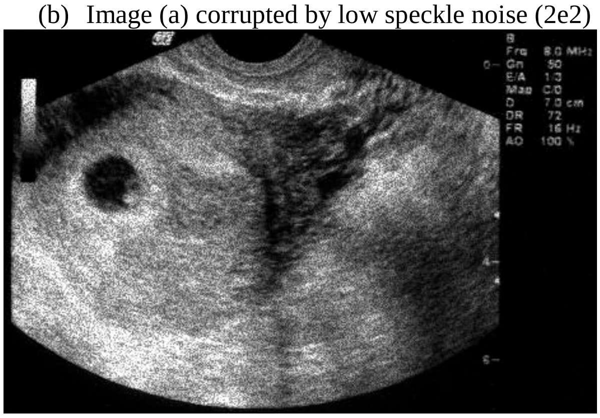
In this simulation, several 2D ultrasound images have been used to represent different type ultrasound images. The examples of the test images are 5-6 week pregnancy image and kidney image.

Figure 2 shows the image of 5-6 pregnancy that has been corrupted with different level of speckle noise, used as test images to investigate the effectiveness of proposed technique. The objective evaluation results are represented in Tables 1 and 2.

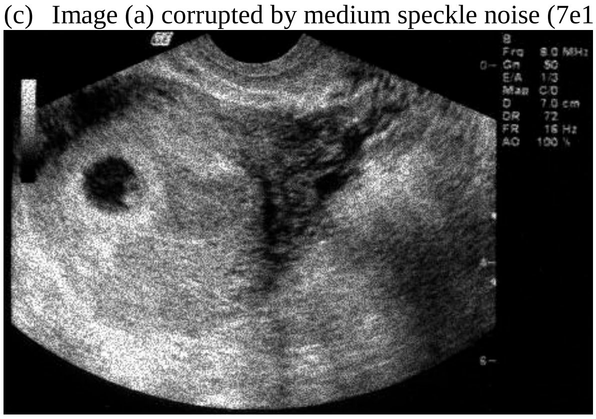
(a) Original image (5-6 week pregnancy)



(b) Image (a) corrupted by low speckle noise (2e2)



(c) Image (a) corrupted by medium speckle noise (7e11)



(d) Image (a) corrupted by high speckle noise (8e20)

Fig. 2 (a) Original image (i.e. image captured without corrupting with additional noise) and corrupted with speckle noise in different levels.

Table 1. Comparison of denoising performance for 5-6 week pregnancy 2D ultrasound image in terms of PSNR.

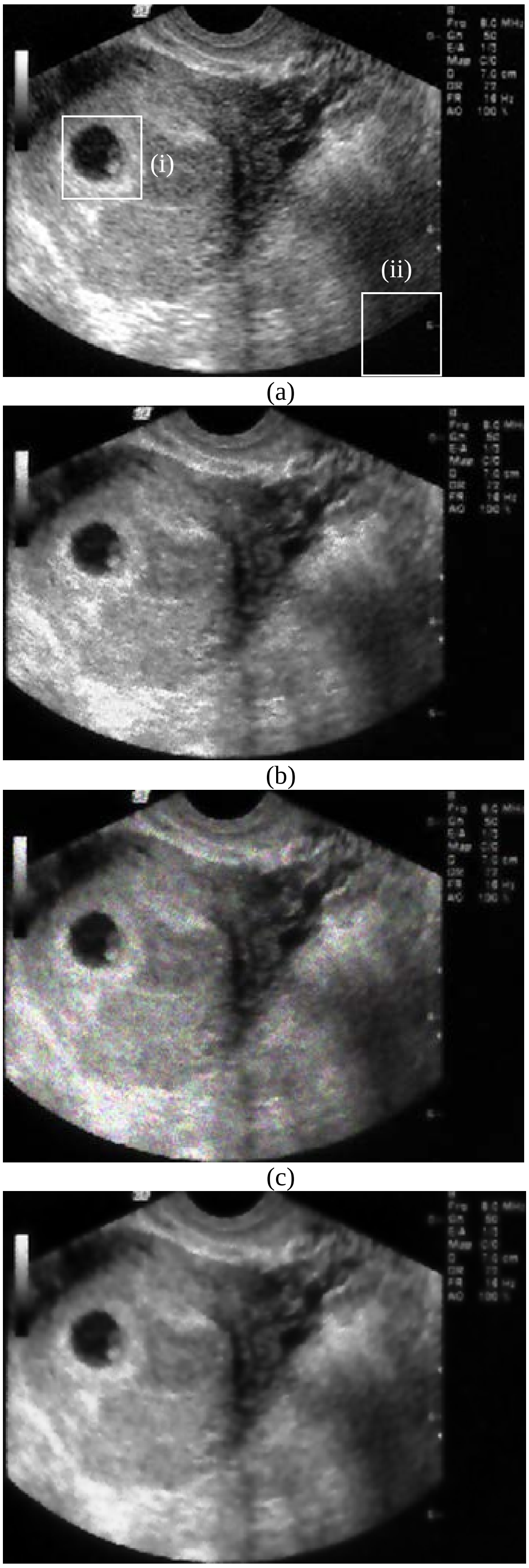
Types of denoising method	Speckle noise level	PSNR [dB]	Ave-rage	Difference (Proposed-Compared method)[dB]
BF	2e2	75.62	75.60	1.09
	7e11	75.59		
	8e20	75.58		
AWF	2e2	73.35	73.33	3.35
	7e11	73.31		
	8e20	73.34		
BL_ Wiener	2e2	76.66	76.69	0.00
	7e11	76.69		
	8e20	76.71		

From Table 1, it is clear that the BL_Wiener provided better performance to remove the speckle noise. BL_Wiener produced higher PSNR in comparison with conventional methods (Average of 3.35 [dB] better than AWF and 1.09 [dB] higher than BF, respectively).

Table 2. Comparison of denoising performance for kidney 2D ultrasound image in terms of PSNR.

Types of denoising method	Speckle noise level	PSNR [dB]	Ave-rage	Difference (Proposed-Compared method)[dB]
BF	2e2	70.33	70.31	0.89
	7e11	70.31		
	8e20	70.29		
AWF	2e2	69.88	69.87	1.32
	7e11	69.88		
	8e20	69.85		
BL_ Wiener	2e2	71.20	71.19	0
	7e11	71.20		
	8e20	71.18		

From Table 2, it is clear that the BL_Wiener provided better performance to remove the speckle noise. BL_Wiener produced higher PSNR in comparison with conventional methods (Average of 1.32 [dB] improved than AWF and 0.89 [dB] higher than BF, respectively).



(d)

Fig. 3 (a) Original image (i.e. image captured without corrupting with additional noise) for 5-6 week pregnancy 2D ultrasound image, (b) denoised image using AWF, (c) denoised image using BF, (d) denoised image using BL_Wiener technique.

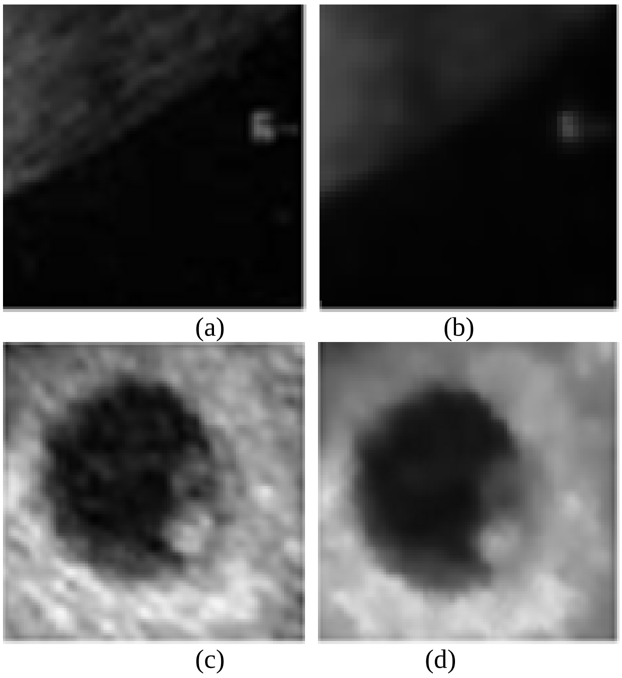


Fig. 4 (a) Enlarged smooth region in Fig. 3(a), (b) enlarged smooth region in Fig. 3(d), (c) enlarged edges region in Fig. 3(a), (d) enlarged edges region in Fig. 3(d).

Fig. 3 and 4 show the image of 5-6 pregnancy (image captured without corrupting with additional noise) that has been used as a test image in this study. This type of image is chosen because to make sure that this method can be applied to trimester pregnancy image diagnosis. From visual observation, overall image noise has been smoothed compared in result of BL_Wiener (Fig. 3(d) and Fig. 4(b)) but at same time strong edges and details are still preserved (Fig. 3(d) and Fig. 4(d)).

Figure 5 shows the image of kidney (image captured without corrupting with additional noise) that has been used as a test image in this study. This types of image is chosen to investigate the whether this method can be applied to detect the location of tumor for diagnosis. From visual inspection, we can observe that noise is reduced but at the same time it still preserves the strong edges and details of the image.

From our investigation, we found that by applying both Bilateral Filter and Adaptive Wiener Filter to a 2D ultrasound image, it has produced a less noisy but edges and detail preserved output image. Moreover, our BL_Wiener has higher performance in terms of PSNR evaluation in comparison to conventional denoising methods.

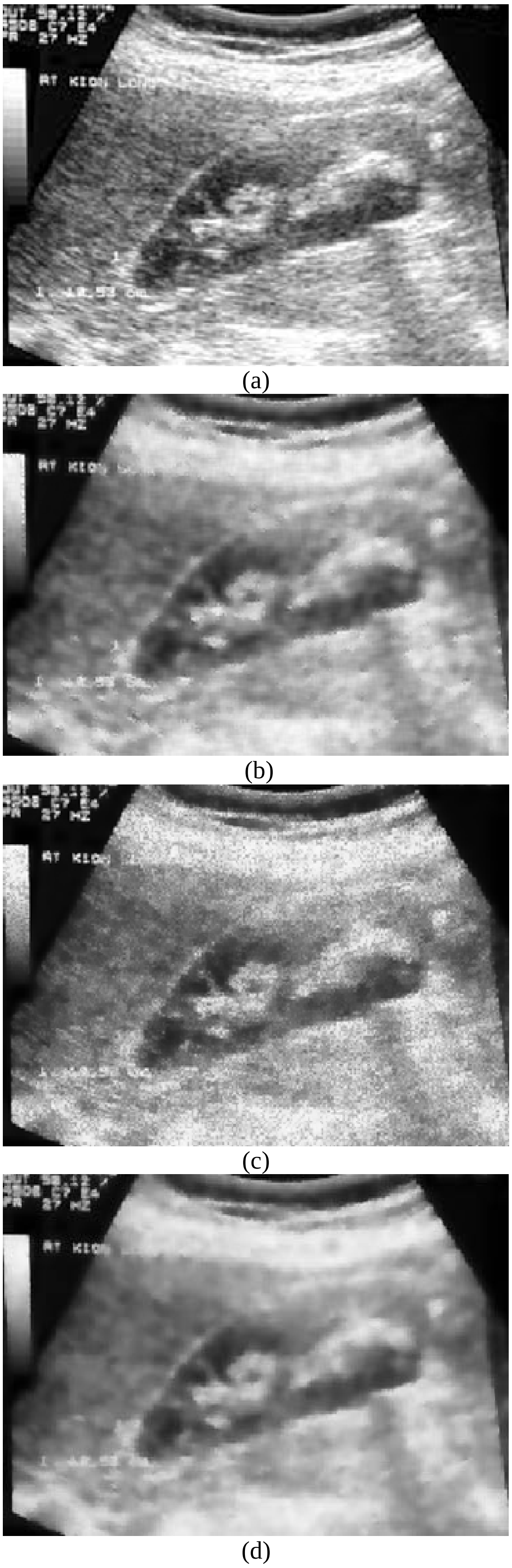


Fig. 5 (a) Original image (i.e. image captured without corrupting with additional noise) for kidney 2D ultrasound image, (b) denoised image using AWF, (c) denoised image using BF, (d) denoised image using BL_Wiener technique.

4. Summary

In conclusion, the BL_Wiener is proposed to denoise speckle noise existing in 2D ultrasound images while preserving the original image edges and details by the utilization of Bilateral Filter and Adaptive Wiener Filter. From our investigation, it is found that the BL_Wiener has improved between 0.89 [dB] to 3.35 [dB] in terms of PSNR for test images in different noise levels in comparison to conventional methods.

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