SPECKLE NOISE REDUCTION USING 2-D FFT IN ULTRASOUND IMAGES

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ABSTRACT

This paper presents a 2-D FFT removal algorithm for reducing the speckle noise in ultrasound images. We apply the 2-D FFT on the ultrasound images to extract and remove the peaks which are corresponding to speckle noise in the frequency domain. The performance of the proposed method is tested on ultrasound images. The results of proposed method significantly improved for the noise removal.

KEYWORDS: *speckle Noise Removal; 2-D FFT; ultrasound Images*

I. INTRODUCTION

A. Motivation

Digital images play an important role in daily life application such as television, ultrasound imaging, magnetic resonance imaging, computer tomography as Well as in areas of research and technology. Image acquisition is the process of obtaining a digitized image from a real world source. Each step in the acquisition process may introduce random changes into the values of pixels in the image. These changes are called noise. Let F'(x, y) be the noisy digitized version of the ideal image, F(x,y) and n(x,y) be a noise function which returns random values coming from an arbitrary distribution. Then additive noise can be described by Eq. (1)

$$F(x,y)= F'(x,y)+ n(x,y) \qquad (1)$$

Speckle is not a noise in an image but noise-like variation in contrast. It arises from random variations in the strength of the backscattered waves from objects and is seen mostly in RADAR and US imaging. Speckle noise is defined as multiplicative noise, having a granular pattern it is the inherent property of ultrasound image and SAR image. Due to incorrect assumption that the ultrasound pulse always travel in a straight line, to and fro from the reflecting interference. Another source of reverberations is that a small portion of the returning sound pulse may be reflected back into the tissues by the transducer surface itself, and generate a new echo at twice the depth. Speckle is the result of the diffuse scattering, which occurs when an ultrasound pulse randomly interferes with the small particles or objects on a scale comparable to the sound wavelength. The backscattered echoes from unresolvable random tissue inhomogenities in ultrasound imaging and from objects in Radar imaging undergo constructive and destructive interferences resulting in mottled b-scan image. 2-D Fourier transform (FT) artifact suppression algorithm to be proposed that applies the 2-D FFT in the Ultrasound image to extract and remove the peaks which are corresponding to the artifacts in the frequency domain. The 2-D FFT can provide the information in one more dimension compared with the 1-D FFT from which we can be better to differentiate the real artifacts and some useful information.

C. Main Contribution

The 2-D FFT removal algorithm for reducing the speckle noise in ultrasound images is proposed in this paper. For the speckle pattern of the artifacts, we apply the 2-D FFT on the ultrasound images to extract and remove the peaks which are corresponding to speckle noise in the frequency domain. Performance of each filter is compared using parameter PSNR (Peak Signal to Noise Ratio).

The organization of the paper as follows: Section I, a brief review of image denoising and related work is given. Section II, presents a concise review of image artifact noise reduction. Presents the noise removal algorithm and proposed system framework. Section III, Experimental results and discussions are given. Based on above work conclusions are derived in Section IV.

II. IMAGING ARTIFACT NOISE REDUCTION

A. Image Restoration in Frequency Domains

According to the principle of Fourier transform, a spatial image size in M*N will be stored as a 2-D array, with the size of M*2N where each column has 2N numbers of real and imaginary parts alternating.

***Algorithms 1*: Peak detection in the frequency domain.**

1. Define a detection route such that the detected peaks are stored in an ascending order in terms of the distance to the origin (where the origin is the centre of the spectrum domain). Note that if only processes in the right half space of the centre because of the symmetry of the peaks (impulses) in the spectrum domain.
2. Define a local window of the size X*Y (where X and Y are odd) and find the maximum from the window pixels.
3. If the current pixel is just the same as the local maximum and also it is above a given threshold, it will be a new detected peak.

To remove the speckle pattern of an image, we can first take the 2-D FFT to the image and detect the positions of the impulses in spectrum, see Algorithm 1. The image is then restored by using a band-reject filter with a proper dimension around the impulses. The restoration algorithm for a single impulse is as follows:

***Algorithms 2*: Image restoration from frequency domain to spatial domain.**

1. Define the position of the impulse as P (Δx, Δy) where Δx and Δy are the relative positions to the origin in the spectrum domain.
2. In the real/imaginary frequency domain, define the following four areas according to the sign of Δy (set a positive Δx due to the symmetric of the impulses):
   a) D1: centre at (Δx, $2\Delta y$) with the dimension of $2\delta x \times 4\delta y$ only if $\Delta y > 0$.
   b) D2: centre at (Xdim- Δx, 2Ydim- $2\Delta y$) with the dimension of $2\delta x \times 4\delta y$ only if $\Delta y > 0$. (The image will be stored as a 2-D array, with the size of dim dim Xdim ×2Ydim after Fourier Transform)

c) E1: center at (Δx, 2Ydim+$2\Delta y$) with the dimension of $2\delta x \times 4\delta y$ only if $\Delta y < 0$.
d) E2: center at (Xdim-Δx, -$2\Delta y$) with the dimension of $2\delta x \times 4\delta y$ only if $\Delta y < 0$ 3. Set all the real and imaginary values to be zero in areas D1 and D2 if $\Delta y > 0$, or in areas E1 and E2 if $\Delta y < 0$.

Take the inverse 2-D FFT and back to the spatial domain.

***Algorithm3*: proposed method**

1) Take a 2-D FFT to the processing image
2) Use Algorithm 1 for local peaks detection in the frequency domain
3) Remove the selected impulses by using Algorithm 2, and then take the inverse 2-D FFT back to the spatial domain.
4) Normalize the updated pixels to obtain the same mean as the old.

B. Evaluation Measure

Removal of noises from the images is a critical issue in the field of digital image processing. The phrase Peak Signal to Noise Ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupted noise that affects the fidelity of its representation. As many signals have wide dynamic. The MSE and PSNR is defined as:

$$PSNR = 20\log 10\left(\frac{255}{MSE}\right) \tag{2}$$

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left\| I(i,j) - k(i,j)\right\|^2 \tag{3}$$

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The results of the proposed method are tested on ultrasound images. The collected testing images are corrupted by speckle noise and then these are used for speckle noise removal.

Fig. 1 to Fig. 5 illustrates the performance of the proposed method on five test ultrasound images.

TABLE I: Comparison of PSNR values for noise and denoised images

Fig. no.	PSNR value of Original (noise) image	PSNR value of processed (Denoised) image
1	0.0673	18.2955
2	0.0667	18.2248
3	0.0676	18.3357
4	0.0679	18.4077
5	0.0659	18.0841

Original image **Noisy image** **Denoise image**

(a) (b) (c)

Fig. 1: (a) original image, (b) image corrupted with speckle noise,(PSNR=0.0673) (c) filtered image by proposed method (PSNR=18.2955)

Original image **Noisy image** **Denoise image**

(a) (b) (c)

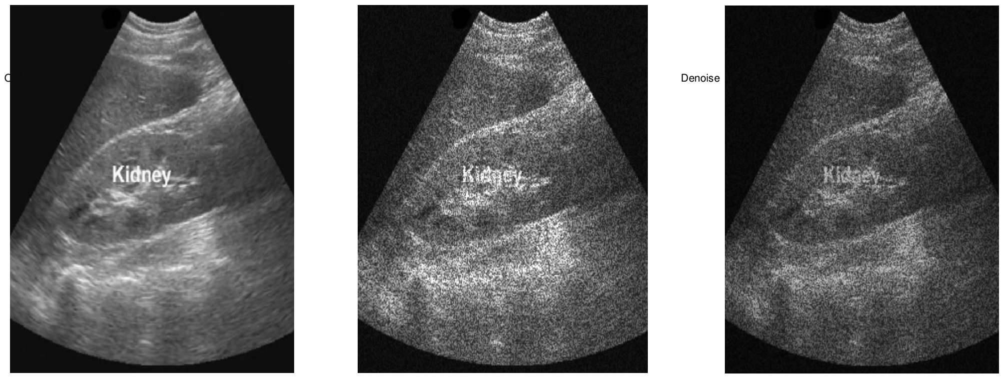
Fig. 2: (a) original image, (b) image corrupted with speckle noise,(PSNR=0.0667) (c) filtered image by proposed method (PSNR=18.2248)

Original image **Noisy image** **Denoise image**

(a) (b) (c)

Fig. 3: (a) original image, (b) image corrupted with speckle noise,(PSNR=0.0676) (c) filtered image by proposed method (PSNR=18.3357)

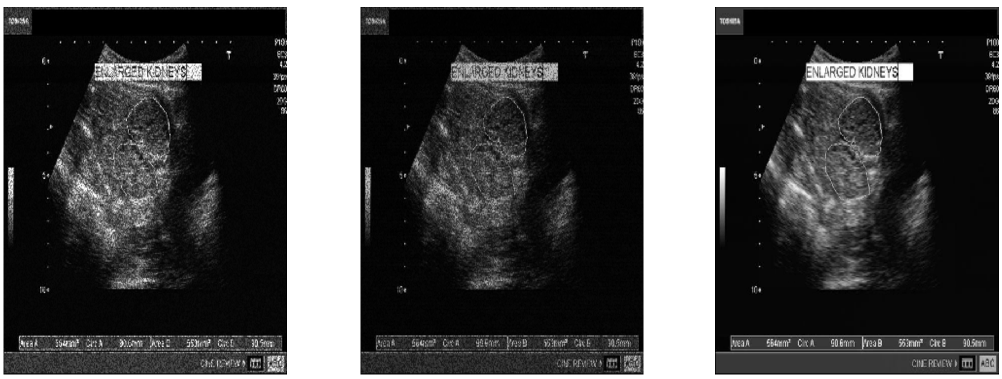
Original image **Noisy image** **Denoise image**



(a) (b) (c)

Fig. 4: (a) original image, (b) image corrupted with speckle noise,(PSNR=0.0679) (c) filtered image by proposed method (PSNR=18.4077)

Original image **Noisy image** **Denoise image**



(a) (b) (c)

Fig. 5: (a) original image, (b) image corrupted with speckle noise,(PSNR=0.0659) (c) filtered image by proposed method (PSNR=18.0841

IV. CONCLUSIONS

The 2-D FFT removal algorithm for reducing the speckle noise in ultrasound images is proposed in this paper. For the speckle pattern of the artifacts, we apply the 2-D FFT on the ultrasound images to extract and remove the peaks which are corresponding to speckle noise in the frequency domain. The performance of each filter is compared using parameter PSNR (Peak Signal to Noise Ratio). The performance of the proposed method is tested on ultrasound images. The results of proposed method found that the proposed method significantly improved for the noise removal.

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