

SPECKLE NOISE REDUCTION BY USING WAVELETS

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Abstract: In image processing, image is corrupted by different type of noises. But generally medical image is corrupted by speckle noise. So image de-noising has become a very essential exercise all through the diagnose. Noises are of two type additive and multiplicative noise. Speckle noise is multiplicative noise, so it's difficult to remove the multiplicative noise as compared to additive noise. The traditional techniques are not very good for especially speckle noise reduction. So we have focused on speckle noise reduction using wavelets. In this paper, we present image de-noising procedure by using wavelet based techniques. Wavelet based techniques has been explored and used for speckle noise reduction. The results obtained by the wavelets based techniques are compared with other speckle noise reduction techniques to demonstrate its higher performance for speckle noise reduction.

Keywords: speckle noise, lee, frost, kaun, SRAD, wavelets.

1. INTRODUCTION

An image is often corrupted by noise since its acquisition or transmission. The goal of de-noising is to remove the noise while retaining as much as possible the important signal features of an image. Traditionally, this is achieved by linear processing such as Wiener filtering [1]-[3]. A vast literature has emerged recently on signal de-noising using nonlinear techniques, in the setting of additive white Gaussian noise. The image analysis process can be broken into three primary stages which are pre-processing, data reduction, and features analysis. Removal of noise from an image is the one of the important tasks in image processing. Depending on nature of the noise, such as additive or multiplicative noise, there are several approaches for removal of noise from an image [1]-[2].

2. MATHEMATICAL MODEL OF NOISE

Mathematically the image noise can be represented with the help of these equations below:

$$V(x, y) = g[u(x, y)] + \eta(x, y) \quad (1)$$

$$g[u(x,y)] = \iint h(x, y; x', y') u'(x', y') dx' dy' \quad (2)$$

$$D(x, y) = f [g(u(x, y))] \eta_1(x, y) + \eta_2(x, y) \quad (3)$$

Here $u(x, y)$ represents the objects (means the original image) and $v(x, y)$ is the observed image. Here $h(x, y; x', y')$ represents the impulse response of the image acquiring process. The term $\eta(x, y)$ represents the additive noise which has an image dependent random components $f [g(w)]$ and an image independent random component. A different type of noise in the coherent imaging of

objects is called speckle noise. Speckle noise can be modeled as

$$V(x, y) = u(x, y)s(x, y) + \eta(x, y) \quad (4)$$

Where the speckle noise intensity is given by $s(x, y)$ and $\eta(x, y)$ is a white Gaussian noise [1]-[3]. The main objective of image-de-noising techniques is to remove such noises while retaining as much as possible the important signal features. One of its main shortcomings is the poor quality of images, which are affected by speckle noise. The existence of speckle is unattractive since it disgraces image quality and affects the tasks of individual interpretation and diagnosis. An appropriate method for speckle reduction is one which enhances the signal-to-noise ratio while conserving the edges and lines in the image. Weiner filter was adopted for filtering in the spectral domain, but the classical Wiener filter is not adequate as it is designed primarily for additive noise suppression. Recently there have been many challenges to reduce the speckle noise using wavelet transform as a multi-resolution image-processing tool. Speckle noise is a high-frequency component of the image and appears in wavelet coefficients. One widespread method exploited for speckle reduction is wavelet shrinkage [7].

3. MODEL OF SPECKLE NOISE

The most critical part of developing a method for -recovering a signal from its noisy environment seems to be choosing a reasonable statistical (or analytic) description of the physical phenomena underlying the data-formation process. The availability of an accurate and reliable model of speckle noise formation is a prerequisite for development of a valuable de-speckling algorithm. In ultrasound

imaging, however, the unified definition of such a model still remains arguable. Yet, there exist a number of possible formulae whose probability was verified via their practical use. A possible generalized model of the speckle imaging is

$$g(n, m) = f(n, m)u(n, m) + \zeta(n, m) \quad (5)$$

Where g , f , u and ζ stand for the observed image, original image, multiplicative component and additive component of the speckle noise basically. Here (n, m) denotes the axial and lateral indices of the image samples or, alternatively, the angular and range indices for B-scan images. When applied to ultrasound images, only the multiplicative component of the noise is to be considered; and thus, the model can be considerably simplified by disregarding the additive term, so that the simplified version of (5) becomes

$$g(n, m) = f(n, m)u(n, m) \quad (6)$$

Homomorphic de-speckling methods take advantage of the logarithmic transformation, which, when applied it converts the multiplicative noise to an additive one. Denoting the logarithms of g , f and u by gl , fl , and ul , respectively, the measurement model becomes

$$g_l(n, m) = f_l(n, m)u_l(n, m) \quad (7)$$

At this stage, the problem of de-speckling is reduced to the problem of rejecting an additive noise, and a variety of noise-suppression techniques could be evoked in order to perform this task [1]-[14].

4. BRIEF INTRODUCTION OF WAVELETS

Wavelets are basically mathematical functions which break up the data into different frequency components, and then we study each component with a resolution matched to its scale. Wavelets have some advantages over traditional Fourier methods in analyzing physical situations where the signal contains discontinuities and sharp spikes. Wavelets are the better technique to handle the different type of noises which is present in an image[4]. There are different wavelet families which shown different results when they are applied in image processing field. Recently wavelets analysis [7] is widely applied in the image de-noising due to its multi-resolution and locality property.

Dilations and translations of the "Mother function," or "analyzing wavelet" $\Phi(x)$; define an orthogonal basis, our wavelet basis:

$$\Phi_{(s,l)}(x) = 2^{-s/2} \Phi(2^{-s}x - l) \quad (8)$$

The variables s and l are integers that scale and dilate the mother function Φ to generate wavelets, such as a Daubechies wavelet family. The scale index s

indicates the wavelet's width, and the location index l gives its position. The mother functions are rescaled, or "dilated" by powers of two, and translated by integers [2].

$$\varphi(x, y) = \varphi(x)\varphi(y) \quad (9)$$

$$\psi^H(x, y) = \psi(x)\psi(y) \quad (10)$$

$$\psi^V(x, y) = \psi(x)\psi(y) \quad (11)$$

$$\psi^D(x, y) = \psi(x)\psi(y) \quad (12)$$

These four products produce the separable scaling functions and separable, "directionally sensitive" wavelets. These wavelets measures functional variations-intensity variations for images- along different directions: ψ^H measures the variations along columns for example horizontal edges. ψ^V responds to variations along rows like vertical edges, ψ^D corresponds to variations along diagonals.

There are many conventional image filtering techniques, such as mean, median filtering, and other adaptive filtering techniques as lee, Kaun or frost ones and new version of these filters, have been purposed to reduce the speckle noise. The lee filter method is basically used as a reference, because it combines an efficient noise reduction, while maintaining the sharpness and some characteristics or we say useful information about the image. The lee and the Kaun filters generate their output images by computing a linear combination of the centre pixel intensity in the filter window with the average intensity of the window [9].

5. REVIEW OF SPECKLE FILTERS

An appropriate method for speckle reduction is one which enhances the signal to noise ratio while preserving the edges and lines in the image. To address the multiplicative nature of speckle noise, Jain developed a homomorphic approach, which is obtained by taking the logarithm of an image, translates the multiplicative noise into additive noise, and consequently applies the Wiener filtering.

Recently many techniques have been purposed to reduce the speckle noise using wavelet transform as a multi-resolution image processing tool. Speckle noise is a high-frequency component of the image and appears in wavelet coefficients. One of the widespread method which is mainly exploited for speckle reduction is the wavelet shrinkage method. A comparative study between wavelet coefficient shrinkage filter and several standard speckle filters that are being largely used for speckle noise suppression which shows that the wavelet-based approach is deployed among the best for speckle removal[7][8].

6. SPECKLE FILTERING

In speckle filtering a kernel is being moved over each pixel in the image and applying some mathematical calculation by using these pixel values under the kernel and replaced the central pixel with calculated value. The kernel is moved along the image only one pixel at a time until the whole image covered. By applying these filters smoothing effect is achieved and speckle noise has been reduced to certain extent [9].

6.1 Median filter [3]: The best known order-statistics filter is the median filter in image processing. The median filter is also the simpler technique and it also removes the speckle noise from an image and also removes pulse or spike noise[1]-[3].

6.2 Lee filter [10]: The lee filter is basically used for speckle noise reduction. The lee filter is based on the assumption that the mean and variance of the pixel of the interest is equal to the local mean and variance of all pixels with in the moving kernel. The formula for the lee filter for speckle noise reduction is given as:

$$\widehat{R}(t) = I(t)W(t) + \bar{I}(t)(1 - W(t)) \quad (13)$$

Where $W(t) = 1 - \frac{c_u^2}{c_l^2(t)}$ is the weighted function
(14)

and

$$C_u = \frac{\sigma_u}{u}, C_l(t) = \frac{\sigma_l(t)}{I(t)} \quad (15)$$

are the various coefficients of the speckle $u(t)$ and the image $I(t)$, respectively.

6.3 Kaun filter [11]: In this filter given kaun et al., the multiplicative noise model is first transformed into a signal-dependent additive noise model. Then the MMSE criterion was applied to this model. The resulting filter has the same form as the lee filter but with the different weighting function which is given as

$$W(t) = \frac{1 - C_u^2 / C_l^2(t)}{1 + C_u^2} \quad (16)$$

Kaun filter is much better than the lee filter.

6.4 The srad filter [13]: SRAD filter is known as speckle reducing anisotropic diffusion. The SRAD can eliminate speckle without distorting useful image information and without destroying the important image edges. The SRAD PDE exploits the instantaneous coefficient of variation in reducing the speckle. The results which are given below tells the SRAD algorithm provides superior performance in comparison to the conventional techniques like lee, frost, kaun filters in terms of smoothing and preserving the edges and features.

6.5 Wiener filtering [1]-[3]: Wiener filter was purposed in the year of 1942, after N.Wiener. Wiener filter (a type of linear filter) is applied to an image *adaptively*, tailoring itself to the local image variance. Where the variance is large, Wiener filter performs little smoothing. Where the variance is small, Wiener performs more smoothing. This approach often produces better results than linear filtering. The adaptive filter is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. However, wiener filter require more computation time than linear filtering.

7. WAVELET BASED DENOISING PROCEDURE

Recently there has been significant investigations in medical imaging area using the wavelet transform as a tool for improving medical images from noisy data. Wavelet de-noising attempts to remove the noise present in the signal while preserving the signal characteristics, regardless of its frequency content.

7.1 Wavelets based noise thresholding algorithm
All the wavelet filters use wavelet thresholding operation for de-noising [2]-[7]-[8]. Speckle noise is a high-frequency component of the image and appears in wavelet coefficients. One widespread method exploited for speckle reduction is wavelet thresholding procedure. The basic Procedure for all thresholding method is as follows:

- Calculate the DWT of the image.
- Threshold the wavelet coefficients. (Threshold may be universal or sub band adaptive)
- Compute the IDWT to get the denoised estimate.
- There are two thresholding functions frequently used, i.e. a hard threshold, a soft threshold.

Table I
 COMPARISON OF STD OF DIFFERENT DENOISING FILTERS FOR TEST T1 IMAGES CORRUPTED BY
 SPECKLE NOISE.

Standard deviation (STD)	Lee filter	kaun	SRAD	Median	Weiner	Wavelet Based
0.2	45.3381	50.5006	44.0347	46.2414	45.1226	21.47
0.3	45.2986	50.2201	44.1445	47.0284	45.2675	25.94
0.4	45.1865	50.2868	43.8973	47.4242	45.2400	29.53
0.5	45.3225	50.1465	44.2146	48.4075	45.5557	32.9
0.6	45.0297	49.8765	44.0560	48.7498	45.4733	35.77
0.7	45.1545	49.8188	44.3704	49.8189	45.8479	38.23
0.8	44.7395	49.7839	44.0207	49.6640	45.4376	40.84
0.9	44.9961	49.9391	44.3976	50.6198	45.8794	43.06



Fig (1) Speckle noise with variance 0.09
 T1



(1.1) Result of lee filter on test image T1



(1.2) Result of kaun filter on test image T1



(1.3) Result of SRAD filter on test image T1



(1.4) Result of Wiener filter by taking 3*3
 On test image T1



(1.5) Result of median filter by taking 3*3
 Window on test image T1



(1.6) Result of wavelet based Thresholding
 Techniques applied on test image T1



(2) Test image T2 0.09 variance(speckle)
 Result of wiener filter



(2.1)



(2.2) Result of lee filter (2.3) Result of median filter



(2.4) Result of SRAD filter



(2.5) Result of wavelet based algorithm



(2.6) Result of kaun filter

8. CONCLUSION

In this paper, we experimented various techniques for speckle noise reduction like lee, kaun, frost, SRAD, wiener and median filtering techniques and seen that speckle noise has been reduced as shown result below. But in case of wavelets based techniques we should adopt the Jain homomorphic approach to convert the multiplicative noise to additive noise, so that we can easily removed the speckles from the image. But the optimum threshold estimation plays an important role in it. So the future works to get the optimum threshold for removal the speckle noise by preserving the edges and useful information of an image.

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