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Hybrid Filter for Removal of Speckle Noise in Digital Images

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Abstract: Speckle is a granular type of noise which degrades the quality of information (Synthetic Aperture Radar) SAR images and Medical images. So reduction of speckle noise act as a preprocessing step and it should be carefully designed to avoid spoiling of useful information. Adaptive filters such as Lee filter, Kuan filter, improved Kuan are some of the existing filters used to eliminate the multiplicative noise in SAR images and Medical images. A new method is proposed which uses the hybrid technique which involves the combination of Wiener filter along with the Adaptive Center Pixel Weighted Median Exponential Filter (ACPWMEF). The combination results in the proposed Hybrid Wiener Adaptive Center Weighted Median Filter (HWACWMF) are also determined. The proposed HWACWMF shows better results when compared to the ACPWMEF. The proposed filter is tested using the SAR images, Ultrasound (US) images and Magnetic Resonance Images (MRI). The simulation results are obtained using MATLAB R2013. The performance metrics are also measured and the quantity and quality of the images are improved using the proposed algorithm.

Keywords: Speckle Noise, Adaptive filters, Wiener filter, Performance metric.

I. INTRODUCTION

Speckle noise is a type of Multiplicative noise which has complex amplitude[1] and as discussed it is usually exist in images such as SAR images, ultrasound images etc. The filters used for the removal of Speckle noise is classified as Non Adaptive filters and Adaptive filters. The filters such as Lee sigma, Lee Forst, Median, Mean and Gamma MAP are the traditional filters used for the removal of Speckle noise.

The speckle denoising algorithm follows Homomorphic filtering, which converts the Multiplicative noise into Additive noise and then the noise reduction is done., Wavelet based Denoising methods are adopted. For the removal of additional noises there are different methods like least mean squares, averaging filter, wiener filtering. The filter proposed by Lee (1981), is based on variance over an area and smoothing will be performed only if the variance is low and constant in that area.

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The Edge Enhanced Lee filter, Modified Kuan Filter and Fast Bilateral Filter are different types of Adaptive filters developed for the removal of speckle noise. In 1987 Kuan, developed a filter for speckle noise removal which is considered to be superior to the Lee filter. It performs spatial filtering on each individual pixel in an image in a square window.

II. SPECKLE NOISE

Speckle noise which is a signal dependent noise i.e. if the image pixel value is high the noise level is also high. Hence termed as Multiplicative Noise in which the intensity values of the image pixels are multiplied by the random values. The Mathematical model for the multiplicative noise is represented as

$$W(i,j)= f(i,j).\ \eta(i,j) \quad (1)$$

Where $f(i,j)$ represents the original image and $\eta(i,j)$ is the noise introduced in to the image and $W(i,j)$ represents the corrupted image. This type of noise occur in all coherent imaging system like laser, Acoustics, Synthetic Aperture Radar (SAR) images and in Biomedical images. Speckle is significant in SAR images and ultrasound images. While capturing the SAR images, the device may contain scatters that return the signals and the returned signals are distributed randomly which leads to a multiplicative noise. They looks like a bright and dark spots on the image. In ultrasound image a probe is used to capture the image which transmits a high frequency signals in to the body. While transmitting echoes rebound from the body structures and introduces noise in the image captured which decreases the ability of diagnosis.

II. ADAPTIVE CENTER PIXEL WEIGHTED MEDIAN EXPONENTIAL FILTER (ACPWMEF)

The proposed filter uses the concept of homomorphic filtering. The Homomorphic filtering [2] is one which uses the logarithmic function for the reduction of speckle noise. It takes the advantage of the logarithmic transformation which helps to convert the multiplicative noise to the additive noise.

If f(x,y) is the original image and it is corrupted by the speckle noise u(x,y), then the noisy image is represented by g(x,y) and it is given by

$$g(x,y)=f(x,y)u(x,y) \quad (2)$$

The logarithm of the equation is 3 given as
Log [g(x,y)]=log[f(x,y)u(x,y)]
log[g(x,y)]=log[f(x,y)]+log[u(x,y)] (3)
Step 1: The Additive noise model is obtained from the Multiplicative noise by
using logarithmic transformation Step 2: Normalization is the process done to bring the range of intensity to a normal distribution. Normalized image has Zero mean and one variance.
Step 3: Performs Adaptive Median filter operation
An adaptive filter is a spatial processing filter. The adaptive median filter uses threshold value and size of the image for comparison. It detects the noise based on the comparison between the centre pixel value with its neighboring pixels. During comparison, when the centre pixel has majority difference between the surrounding pixel and it is not aligned properly with the neighbors then it is termed as noise pixel. Now the noise pixel is replaced by the weighted median value of the pixels in the mask The basic idea is that the window of finite size and shape is considered. The convolution kernel is given the output pixel value is the weighted sum of the input pixels within the window where the weights are the values of the filter assigned to every pixel of the window itself. The output of the logarithmic transformation image is convoluted with the kernel filter. It uses an averaging filter for denoising. The filtering in the spatial domain demands a filter mask (it is also referred as kernel or convolution filter). The mask value is multiplied by the pixel value of the image in the center position. Then the original value of the center pixel is replaced by the sum of the multiplied value. Now the steps are repeated for every pixel value in the image. The Adaptive centre weighted median filter works by having a moving centred pixel of the moving window H(x,y) is h(x,y) for the image size M*N whose upper left location is set at(1,1).

Then the Maximum and Minimum gray scale values of the image are found out and it is denoted as max (m*n) and min (m*n). By using the max and min gray scale values the average sum value is determined using the formula

Average Sum=

$$\frac{1}{m*n}\sum_{x=1}^{m}\sum_{y=1}^{n}h(x,y) \quad (4)$$

where h(x,y) is the centre pixel of this window.

IV. HYBRID WIENER ADAPTIVE CENTER WEIGHTED MEDIAN FILTER (HWACWMF)

The Wiener filter is a one which is able to handle both the degradation function and noise as well. It is very efficient in removing the additional noises in the images. It can be used either in spatial domain or in frequency domain. The result of the wiener filter is given by

$$y(i,j)=\sum_{m=-N}^{N}\sum_{n=-N}^{N}w(m,n)\,x(i+m,j+n) \quad (5)$$

the weights of the wiener filter w(m,n) can be found by reducing the error between the obtained output and desired output which is given by

$$e=E\left(\{d(i,j)-y(i,j)\}^2\right) \quad (6)$$

where E denotes Expectation. The solution for w(m,n) is obtained as the vector form denoted as

$$W=A^{-1}R \quad (7)$$

These equations are called as Wiener- Hopf equation. The A(m,n) represents the autocorrelation of x(i,j) and R(m,n) represents the cross correlation between d(i,j) and x(i,j).

The main function of combining Wiener filter with ACPWMEF is to minimize the mean square error between the denoised image and the original image.

V. SIMULATION RESULTS

The algorithm is tested over the standard test images like SAR images, US images and MRI images. The proposed algorithm shows better results when compared to the existing Median filter and adaptive filter. This algorithm has been implemented in MATLAB R2013a and the simulation results are obtained.

The simulation results are shown from Fig.1 to Fig.2 for different types of images at noise density of about 20%. The figure shows that the proposed HWACWMF provides better results in terms of quality.

The output has been related with the ACPWMEF algorithm, in which the Hybrid filter removes the noise effectively but it blurs the image.

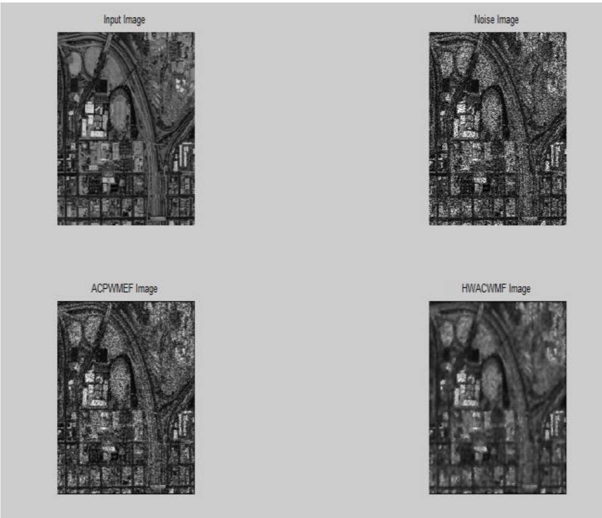

Figure 1: Performance of HWACWMF on SAR image at noise variance 20%

a. Input Image b. Noisy Image c. ACPWMEF d. HWACWMF

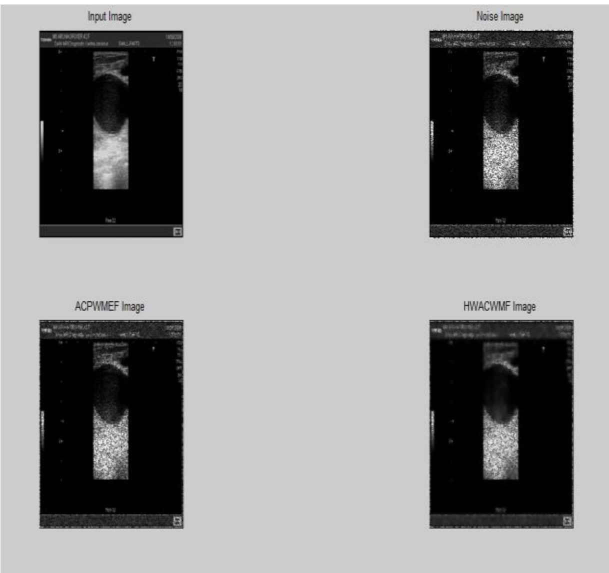

Figure 2: Performance of HWACWMF on US image at variance 20%

a. Input Image b. Noisy Image c. ACPWMEF d. HWACWMF

VI. PERFORMANCE METRICS

The performances of Speckle denoising algorithms are analyzed by various parameters like PSNR, MSE, AD, SSIM and RMSE [6,7]. The above metrics are compared for six types of standard SAR image, US image and MRI image. From table 1 to 2 shows the performance analyzes of the proposed algorithm from noise density varying from 20% to 80% is shown.

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Table 1: Comparison of filters for SAR image

Parameters	Noise density	ACPWMEF	HWACWMF
PSNR	20%	64.9	65.2
	40%	62.3	63.0
	60%	61.2	61.9
	80%	60.3	61.1
MSE	20%	0.021	0.019
	40%	0.037	0.032
	60%	0.049	0.041
	80%	0.059	0.049
AD	20%	0.01	0.005
	40%	0.01	0.009
	60%	0.02	0.01
	80%	0.02	0.01
SSIM	20%	0.99	0.999
	40%	0.98	0.99
	60%	0.90	0.99
	80%	0.90	0.99
RMSE	20%	0.14	0.13
	40%	0.19	0.17
	60%	0.22	0.20
	80%	0.24	0.22

Table 1: Comparison of filters for US image

Parameters	Noise density	ACPWMEF	HWACWMF
PSNR	20%	67.5	71.8
	40%	66.0	70.08
	60%	65.2	69.2
	80%	64.7	68.6
MSE	20%	0.011	0.004
	40%	0.016	0.006
	60%	0.019	0.007
	80%	0.02	0.008
AD	20%	0.007	0.003
	40%	0.008	0.004
	60%	0.009	0.005
	80%	0.01	0.005
SSIM	20%	0.9994	0.9998
	40%	0.9993	0.9997
	60%	0.9991	0.9997
	80%	0.9991	0.9996
RMSE	20%	0.09	0.05
	40%	0.10	0.07
	60%	0.12	0.07
	80%	0.12	0.08

The Performance metrics for the proposed algorithm are tabulated for the noise density varying from 20% to 80%. The values obtained conclude that the noise has been removed efficiently when compared to the first algorithm ACPWMEF. The PSNR value has been increased and the error value is minimized at a rate of 0.1% when noise density is about 80%

VII. CONCLUSION

The Proposed Hybrid Wiener filter along with the Adaptive Centre weighted median filter shows better results when compared to the Adaptive Center Pixel Weighted Median Exponential Filter in terms of Performance metrics, but it blurs the images. So the visual perception of the denoised image is decreased. To improve and rectify the drawback, an optimization technique is used along with the Hybrid Wiener Adaptive Centre Weighted Median filter. Since images used for the analysis are satellite images and Medical images, it needs better resolution in terms of visual perception.

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M**rs.D.Devasena** has received her Master’s Degree in Communication Systems from Anna University, Coimbatore in 2010 has received her Bachelor’s Degree in Electronics and Instrumentation Engineering from Maharaja Engineering College, Anna University Chennai in 2006. Currently she is pursuing her Doctoral Degree in the Faculty of Information and Communication Engineering from Anna University Chennai. She has 8 years of experience in teaching. Her research interests are in Denoising in Image Processing, VLSI Implementation. She has presented papers in two National Conferences, seven international conference and in Eight International Journals.

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