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Restoration of Correct Pixel Value via Proposed Adaptive Filter

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Abstract

This paper proposes a new repetitive based Non-linear edge preserving filter which restores the image corrupted by speckle noise in two steps. First a speckle detection algorithm is used before filtering, which separates out the corrupted pixels, and hence only a certain percentage of the pixels will be filtered. Secondly, both speckle detection and noise filtering schemes are applied in progressive fashion through several iterations. Results obtained both by numerical measures such as MAE, MSE, PSNR, ISNR, IEF and manual observation shows that the proposed filter has an appreciably high Peak Signal to Noise Ratio (PSNR) value and at the same time preserves the edges and fine information in images. This method works well for highly corrupted images.

Keywords: Corrupted images, Speckle, Noise filtering, PSNR value.

Introduction

Speckle noise commonly affects all coherent imaging systems and hence the images generated using Ultrasound technique appears to be much inferior to other imaging modalities [1]. Without speckle, it may be possible to observe small differences in mean image brightness, Small high contrast targets, low contrast objects and changes in image texture. Speckle filtering in diagnostic ultrasound represents an important preprocessing step which provides the experts with enhanced diagnostic visibility. Hence it is important that speckle should be removed before subjecting the image to any further clinical processing. But it is vital that the Region of Interest (ROI) should not be compromised during speckle removal. Speckle suppression schemes can be classified into multi-look averaging category and filtering type. In Multi-look process, several looks obtained from the same scene which is similar to low pass filtering. This method may be successful in eliminating the speckle, but results in poor performance because these methods suppress both speckle and texture information at the same time [2]. In filtering method, diagnostic ultrasound is enhanced after the image has been formed. The filter described in this paper falls under the second category. Many research groups have reported their works on speckle noise reduction filters in the recent past. Typical non-linear filters are implemented uniformly across the image, and they tend to modify both speckle affected pixels (bad) and unaffected pixels (good). These adaptive nonlinear filters whose design were based on different criteria and parameters, have achieved some Degree of suppressing speckle. But most of the filters fail in preserving the texture or the fine details in diagnostic ultrasound. This is due to lack of measurement which avoids the propagation of noise from one level to the other. Among the speckle reduction filters proposed in the past decade, LEE [3], Kaun [4] and Frost [5] filters are worth mentioning. LEE filter, based on Minimum Mean Square Error (MMSE) approach identifies regions with low and constant variance as areas for noise reduction [3]. Kaun filter, a modified form of Lee filter is also based on MMSE but makes a different weighting function, which can be directly derived by applying the MMSE criterion to the multiplicative model [4]. In Frost filter, the impulse response is calculated by minimizing the mean square error between the observed image and the scene reflectivity model, assumed to be an autoregressive process [5]. The improved frost filter, which preserves the edges, divides the areas in the image into homogeneous areas, heterogeneous areas and region containing point targets [9]. But, here the filter responses are exaggerated by introducing a hyperbolic function to satisfy the requirement that more heterogeneous the area is, the less it has to be smoothed. The filter proposed in this paper, detail preserving iterative Non-linear de-speckling filter, detects speckle noise first using speckle detection scheme and then acts at the corrupted pixels alone. Experimental results show that this method preserves the fine details much as it doesn't disturb the good

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pixels and at the same time removes speckle in an appreciable manner.

Mathematical Modeling of De-Speckling Filter

The speckle detection scheme proposed and implemented in this paper is primarily developed by deploying the prior knowledge about the image, i.e., in the absence of noise, the pixel variation is smooth and is distinguished by edges. Also, it is well known fact that not all pixels, but only a portion of the pixels in the entire image will be corrupted. So when we employ typical image processing filters, they tend to modify both good and bad pixels. Secondly, a noisy pixel will have a comparatively high gray level value when compared to its neighbors.
Two sets of sub-images are synthesized during speckle detection procedure. The first sequence is a set of images $\{\{I_i^{(0)}\}, \{I_i^{(1)}\}, \{I_i^{(2)}\}, \{I_i^{(3)}\} \ldots\ldots \{I_i^{(n)}\}\}$, where the first sub-image, $\{I_i^{(1)}\}$ is the HH decomposed image which is the noisy image to be detected. $\{I_i^{(n)}\}$ represents the sub-image after n^{th} level of decomposition and. The second is a sub-image set, $\{\{B_i^{(0)}\}, \{B_i^{(1)}\}, \{B_i^{(2)}\}, \{B_i^{(3)}\} \ldots\ldots \{B_i^{(n)}\}\}$ with de-speckling coefficients, which determines whether the pixel in the first set sub-image is affected by speckle or not. If at any point in the entire sub image set $\{B_i^{(n)}\}$ is set to 1, the gray level value at that point is considered to be a speckle noise affected pixel. All other coefficients in $\{B_i^{(n)}\}$ which are set to zero are considered to be unaffected. Before the first iteration, we consider that the image is not corrupted by speckle noise and set all $\{B_i^{(n)}\}$ to zero. For speckle detection, a median filter with a sliding window $S_w x S_w$ is generated and then the median for the pixel centered about 'p' is to be determined, where p is the pixel to be detected as good or bad (w is normally an odd number). If $S_w x S_w$ is a window centered about $P_{(i,j)}$, then

$$m_i^{(n-1)} = Med\{\, P_j^{(n-1)}, j \in \Psi_i^{Sw} \,\} \quad (1)$$

and Ψ_i^{Sw} is given by

$$\Psi_i^{Sw} = \{P_i^{j+1}, P_{i+1}^{j+1}, P_{i+1}^{j}, P_{i+1}^{j-1}, P_i^{j-1}, \quad (2)$$

The speckle detection sub image sequence is generated using the expression given below.

$$B_i^{(n)} = \begin{cases} B_i^{(n-1)}, & £ < Td \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

Where $£ = m_i^{(n-1)} - \Psi_i^{Sw}$ (4)

and T_d is the threshold. If the value of $B_i^{(n)}$ exceeds the threshold value, the co-efficient of second sub-image set or the decision making set is set to 1 or else it is set to 0. Of the two sets of images, only the second set is utilized for noise filtering process.
Similar to the speckle detecting scheme, the noise filtering procedure also forms two sequences of sub-images. The first set of sub images, denoted as $\{\{N_i^{(0)}\}, \{N_i^{(1)}\}, \{N_i^{(2)}\}, \{N_i^{(3)}\} \ldots\ldots \{N_i^{(n)}\}\}$, is produced by low pass filtering at each Iteration levels. The second subset or the speckle detection subset, denoted by $\{\{S_i^{(0)}\}, \{S_i^{(1)}\}, \{S_i^{(2)}\}, \{S_i^{(3)}\} \ldots\ldots \{S_i^{(n)}\}\}$, is a binary set similar to that of the speckle detection scheme, where the good pixels are denoted by '0' and speckle corrupted pixels are marked as'0'. The only difference between the Speckle detection scheme and the speckle filtering scheme is that in speckle filtering step, all values in the first binary flag image is set to '0'. But in Speckle filtering process, the first sub image is speckle detection binary sequence, $\{B_i^{(n)}\}$. For all gray level values in $\{N_i^{(n)}\}$ the filter coefficients are determined using a sliding window of size $F_w x F_w$ just by calculating the median of all gray level values in the window region surrounded by the corresponding pixel. The main difference between conventional methods and this method is that for finding the filter co-efficients, only the good pixels are taken into consideration. Once the speckle is detected and replaced with the filter coefficient, the gray level value is considered to be a good one in the next iteration. The procedure continues till all flag values in the binary sub-image sequence, $\{B_i^{(n)}\}$ is set to '0'. When all gray levels in $\{B_i^{(n)}\}$ set to '0', after the n^{th} iteration, $\{I_i^{(n)}\}$ is the enhanced filter output. Sample results by applying the algorithm on Ultrasound images is shown in fig 1.

Results and Discussion

The performance of the proposed filter was tested on an Ultrasound fetus image taken using B (brightness) mode. For analysis, speckle noise by a factor of 20%, 40% and 50% were added and the performance was analyzed based on Peak Signal to Noise Ratio (PSNR), Mean Absolute error (MAE), Mean Squared Error (MSE), Image Enhancement Factor (IEF) and Graded Peak Signal to Noise Ratio (GSNR). The response of the filter was appreciable for increased level of corruption than other filters. By trial and error method, the optimal filter window size for best restoration is found to be 7x7 with 7 iterations for removing speckle noise. As the window size is increased beyond 7, the information in the edges is lost, resulting in blurring of edges. Also, as the number of Iterations is increased beyond 7, the PSNR begins to deteriorate indicating that the quality of output image is being reduced. Hence a trade off should be there between Window size selection and number of Iterations for getting better quality of output. The experimental results show that a window size of 7x7 with 7 iterations, gives the best output with improved PSNR.

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(a) Original Image

(b) 40% Corrupted

(a)7x7 Window, IL=7

(d)5x5 Window, IL=7

Fig 1 (a) to (d) show the test image, corrupted image and the filtered output using proposed filter for the test image. Its clearly seen that a window size of 7x7 for IL value of 7 yields the best result.

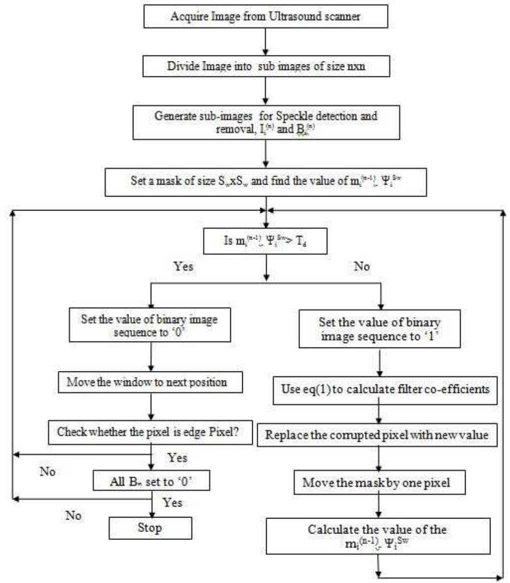

Fig 2 Flow Diagram for the Proposed Filter

TABLE 1:Performance measure for Window Size : 3 x 3 Noise : 0.2

IL	PSNR	MAE	MSE	IEF	GSNR
3	18.550	24.257	1010.7	1.815	4.739
5	18.607	22.920	829.06	4.112	5.292
7	**18.651**	**22.864**	**886.89**	**6.796**	**5.358**
9	18.591	23.015	899.27	5.416	5.416

MAE : Mean Absolute Error
PSNR : Peak signal to Noise Ratio
IEF : Image Enhancement Factor
IL : Iteration Level
GSNR : Graded Signal to Noise Ratio

TABLE 2 :Performance measure for Window Size : 5 x 5 Noise : 0.2

IL	PSNR	MAE	MSE	IEF	GSNR
3	20.268	18.454	611.24	2.489	6.972
5	20.463	17.972	584.24	1.876	7.154
7	**20.520**	**17.843**	**576.84**	**3.094**	**7.217**
9	20.509	17.873	578.21	1.101	7.192

TABLE 3:Performance measure for Window Size :7 x7 Noise : 0.2

IL	PSNR	MAE	MSE	IEF	GSNR
3	20.729	16.906	549.72	-2.5	7.443
5	20.747	16.688	547.45	-4.4	7.444
7	**20.791**	**16.581**	**544.97**	**-3.6**	**7.488**
9	20.771	16.490	544.40	-4.1	7.459

TABLE 4 Performance measure for Window Size : 3 x3 Noise : 0.4

IL	PSNR	MAE	MSE	IEF	GSNR
3	15.821	30.729	1701.9	3.812	5.03
5	16.933	27.66	1317.3	8.929	6.145
7	**16.941**	**27.685**	**1315.4**	**10.145**	**6.155**
9	16.913	27.77	1321.6	10.023	6.151

TABLE 5 Performance measure for Window Size :5 x5 Noise : 0.4

IL	PSNR	MAE	MSE	IEF	GSNR
3	18.769	21.483	863.27	12.84	7.973
5	19.027	20.913	813.42	13.66	8.251
7	**19.185**	**20.4262**	**784.38**	**11.81**	**8.385**
9	19.191	20.467	783.26	14.39	8.384

TABLE 6 Performance measure for Window Size : 7 x7 Noise : 0.4

IL	PSNR	MAE	MSE	IEF	GSNR
3	19.476	18.767	733.609	7.772	8.69
5	19.579	18.540	716.403	7.076	8.805
7	**19.654**	**18.375**	**704.16**	**7.88**	**8.857**
9	19.531	18.598	724.254	9.652	8.738

From the above tables, it's clearly seen that for a window size of seven all the evaluation parameters gives the best result irrespective of the percentage of noise added in the image. Fig 3 shows the de-noised output of the corrupted US image by conventional filters and the proposed filter. The performance of the de-noising algorithms measured using quantitative measures such as PSNR, MAE, MSE as well as the visual quality of the image shows that the proposed filter performs much better compared to conventional non-linear filters.

(a)Frost Filter

(b) Kaun Filter

(c) Lee Filter

(d) proposed Filter

Fig 3 output

Fig 3 (a) to (d) shows the filtered output obtained using Frost, Kaun, Lee and proposed filter. Proposed filter output is taken for optimum window size and IL Level. From the simulation results it is clearly inferred that the proposed filter works better in removing the noise and at the same time it preserves the fine details in the images also.

TABLE 7 Comparison of the performance of proposed filter with other conventional filters.

Filter	**PSNR**	**MAE**	**MSE**
Kaun	16.476	18.767	733.609
Lee	18.579	18.540	776.403
Frost	20.654	18.375	714.16
proposed	21.531	18.598	704.254

The above table shows the performance comparison of the proposed filter with other conventional filters. It shows that the proposed filter has marginally higher PSNR value and good MSE compared to other de-speckling filters.

Conclusion

From the results it is clear that the performance of the repetitive median speckle detection algorithm discussed in this paper performs well compared to other conventional speckle detection algorithms. Although the PSNR ratio of some speckle detection schemes are higher, the details of the edges are lost in those filtering methods. But the proposed scheme has got appreciably high PSNR value and at the same time preserves the edges well. The numerical measure such as MAE, MSE, IAE and visual observation of the images shows convincing results. As this method also preserves the edges, it can be used for de-speckling diagnostic ultrasounds effectively, increasing the efficiency of the Computer Aided Diagnosis Systems. This is the future scope of the paper.

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