Speckle Noise Reduction using Multi-scan Total Variation Median Filter

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ABSTRACT
This paper proposes a two-stage multiple-scan Total Variation (TV) median filter for speckle noise reduction. In the first stage, the total variation method is applied to the speckled image. It is based on the principle that signals with excessive and possibly spurious detail have high total variation, that is, the integral of the absolute gradient of the signal is high. In the second stage, the image is scanned from three other directions also and the above mentioned method is applied to all the scans. The value of each pixel in the final output is then calculated by taking the median of the corresponding pixel in the four scans. The proposed technique is very effective for both low and high level speckle noise corrupted images. Extensive computer simulations indicate that this technique provides significant improvement over many other existing techniques in terms of PSNR.

Keywords
Speckle noise, Total Variation method, multiple-scan, median filter

1. INTRODUCTION
Images are often corrupted by speckle noise that inherently exists in and degrades the quality of the synthetic aperture radar (SAR) and ultrasound images. The speckle noise is generally more difficult to remove from images than additive noise because the intensity of the noise varies with the signal intensity[1-4].

Ultrasonic imaging is a widely used medical imaging procedure as it is economical, safer, transferable, and adaptable. However, one of its main shortcomings is the poor quality of images, which are affected by speckle noise. Speckle in ultrasound B-scans is seen as a granular structure which is caused by the constructive and destructive coherent interferences of back scattered echoes from the scatterers that are typically much smaller than the spatial resolution of medical ultrasound system. Speckle pattern is a form of multiplicative noise and it depends on the structure of imaged tissue and various imaging parameters. Speckle degrades the target delectability in B-scan images and reduces the contrast, resolutions which affect the human ability to identify normal and pathological tissue. It also degrades the speed and accuracy of ultrasound image processing tasks such as segmentation and registration. There are two main purposes for speckle reduction in medical ultrasound imaging (1) to improve the human interpretation of ultrasound images, (2) despeckling is the preprocessing step for many ultrasound image processing tasks such as feature extraction, analysis, recognition, segmentation and registration in medical imagery [5].

A wide variety of techniques[6-9] have been proposed in the literature to remove speckle noise while preserving image fidelity including spatial filters, wavelets and variational methods.

Among variational approaches, a classical variational denoising algorithm is the total variation minimization problem of Rudin-Osher-Fatemi ROF) [10]:
$\inf_u \{J(u) + (2\lambda)^{-1} \|f-u\|_{L^2}^2\}$, where f is the noisy image, u is the image we want to restore from f. The constant $\lambda > 0$ is a turning parameter. $J(u) = \int|\nabla_u|$ is often referred to as total variation (TV). Because of its virtue of preserving sharp edges, it is widely used in many applications of image processing. Chambolle's projection algorithm [11] is a recent and fast method to solve the ROF model, which is solved by:

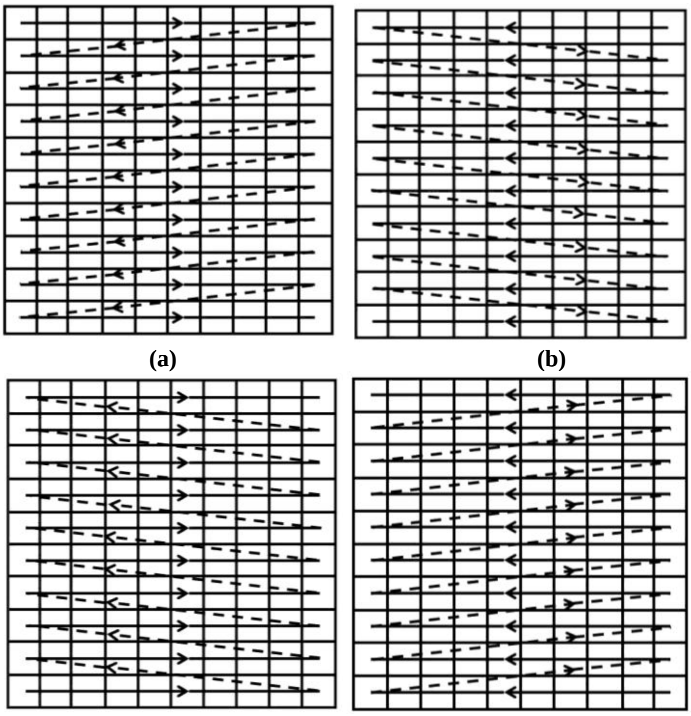
$$u = f - P_{G_\lambda}(f) \tag{1}$$

where $G_\lambda = \{v \in G/ \ \|v\|_G\}$, $P_{G_\lambda}(f)$ is the orthogonal projection of f on G_λ and the space G is proposed by Meyer for modeling oscillating patterns.
The proposed filter applies the total variation method to the noisy image. The image is then scanned from three other directions also and the above mentioned process is applied to all the three scans. The value of each pixel in the final output is then calculated by taking the median of the corresponding pixel in the four scans. Computational simulation indicates that the proposed technique provides significant improvement over many other existing techniques in terms of PSNR.
The rest of the paper is organized as follows. The proposed methodology is introduced in Section II. The experimental results and comparison table are presented in Section III. The conclusions are provided in Section IV.

2. PROPOSED METHODOLOGY
The proposed filter employs the multiple-scan and median concept in conjunction with the TV based denoising filter. The proposed scheme of multiple scanning aims to effectively utilize the corrected pixels in the determination of the values of subsequent corrupted pixels. Another purpose of multiple scanning is to attempt to include different possible views while working with the reduced neighborhood of four pixels. Hence, after implementing the total variation method for the top left scan, it is repeated for the image scanned in the other three directions viz. top right, bottom left and bottom right, as shown in Fig. 1. The original scanning direction has also been shown for reference. The results obtained from these scans are preserved in the intermediate variables Y_{TL}, Y_{TR}, Y_{BL} and Y_{BR}. When the scanning is completed in all the four directions, the value of each pixel in the final output is calculated by taking the median of the corresponding pixel in the four scans as given by the following equation:

$$Y(i,j) = \text{median}[Y_{TL}(i,j), Y_{TR}(i,j), Y_{BL}(i,j), Y_{BR}(i,j)] \tag{2}$$

where $Y(i,j)$ is the final output image pixel, $Y_{TL}(i,j)$ is the output pixel obtained for the image scanned in the top left (TL), $Y_{TR}(i,j)$ in the top right (TR), $Y_{BL}(i,j)$ in the bottom left (BL) and $Y_{BR}(i,j)$) in the bottom right (BR).
The proposed scheme can therefore be divided into two stages:



(a) **(b)** **(c)** **(d)**

Fig. 1. Multiple Scanning Diagram for Four Directions (a) Top left (TL) (b) Top right (TR) (c) Bottom left (BL) (d) Bottom right (BR)

Stage 1: Application of the TV method to the speckled image scanned in the four directions viz. top left, top right, bottom left and bottom right (fig.1) to obtain four denoised output images. The results obtained from these scans are preserved in the intermediate variables $Y_{TL}(i,j)$, $Y_{TR}(i,j)$, $Y_{BL}(i,j)$ and $Y_{BR}(i,j)$.

Stage 2: When the scanning is completed in all the four directions, the value of each pixel in the final output is calculated by taking the median of the corresponding pixel in the four scans as given by eqn.(1).

3. EXPERIMENTAL RESULTS

To demonstrate the performance of this technique, it is compared with other existing techniques based on their simulation results. Peak signal-to-noise ratio (PSNR) is used to assess the restoration results which measures how close the restored image is to the original image. The PSNR (dB) is defined as

$$\text{PSNR}= 10log_{10}\frac{(L-1)^2}{\frac{1}{MxN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(X(i,j)-Y(i,j))^2} \quad (3)$$

where L is the maximum possible number of intensity levels, M x N is the size of the image, *X(i, j)* refers to the original image and *Y(i, j)* refers to the denoised image. In order to explore the visual quality, visual inspection is also carried out on the filtered images so as to judge the effectiveness of the filters in removing impulse noise. A wide range of noise variance ranging from 0.02 to 0.1 in steps of 0.01 have been tested for comparison of results.

Table 1 lists the restoration result in PSNR (dB) of the MSTVMF while Fig. 2 and 3 show the results graphically and quantitatively. The simulation results demonstrate that the proposed filter (MSTVMF) performs better than the Median, Wiener, VisuShrink, Lee, Kuan and Frost filter at both low and high noise levels.

Table 1
Comparison of restoration results of Multi-scan TV Median Filter in PSNR(dB) for the ultrasound image

Noise variance (σ^2)→ / Filtering technique↓	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**	**0.1**
INPUT PSNR	25.49	23.82	22.64	21.68	20.93	20.35	19.76	19.34	18.89
VISUSHRINK	28.73	27.61	26.80	26.16	25.66	25.18	24.78	24.50	24.20
MEDIAN	29.34	28.00	27.14	26.29	25.71	25.16	24.53	24.18	23.79
WIENER [5]	29.19	27.63	26.45	25.58	24.81	24.14	23.57	23.14	22.74
KUAN[12]	30.79	29.86	29.15	28.51	27.93	27.41	27.07	26.79	26.42
FROST[13]	30.84	29.99	29.31	28.67	28.20	27.73	27.10	26.96	26.36
LEE [14]	30.84	30.00	29.29	28.59	28.13	27.55	27.15	26.92	26.42
MSTVMF	**31.8**	**31.46**	**30.93**	**30.11**	**29.85**	**29.21**	**28.75**	**27.95**	**27.59**

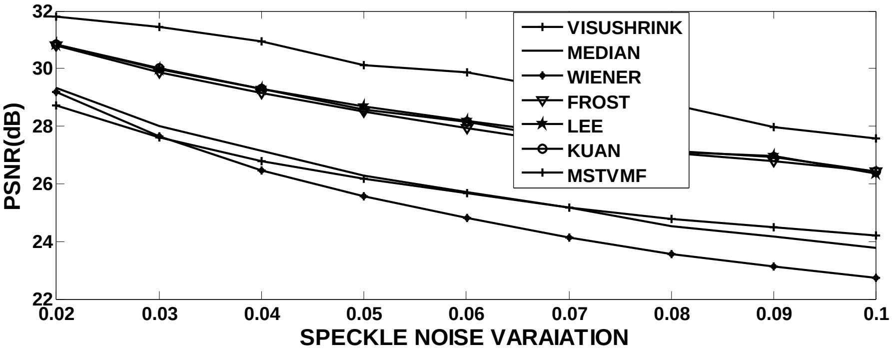
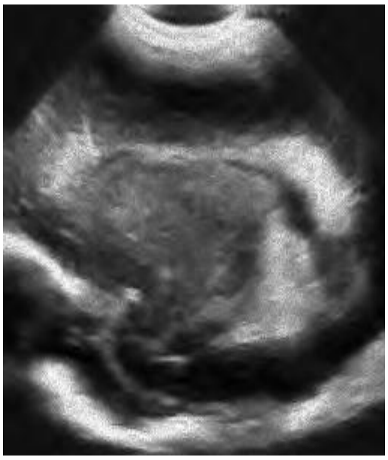


Fig. 2. Comparison of various methods for Reduction of Speckle Noise in 'Ultrasound" image on the basis of PSNR

(a)



(b)

(c)

(d)

(e)

(f)

(g)

(h)

Fig.3. Restoration results for ultrasound image corrupted with speckle noise of variance 0.1. a) corrupted image b) Visushrink c) Median d) Weiner e) Kuan f) Frost g) Lee (h) MSTVMF

4. CONCLUSION

A novel denoising technique for removing speckle noise is proposed in this paper which is suitable for both low and high noise levels. The experimental results demonstrate that the proposed approach performs much better than other existing techniques in terms of both quantitative evaluation and visual quality.

It is suggested that future research should focus on reducing the processing time when the image is corrupted with high level of speckle noise.

5. REFERENCES

[1] R. C. Gonzalez and R. E. Woods, “Digital Image Processing”, 2nd edition, *Prentice Hall*, 2002.

[2] R. C. Gonzalez, R. E. Woods and S. L. Eddins, “Digital Image Processing Using MATLAB”, *Pearson*, 2004.

[3] B. Chanda and D. D. Majumdar, “Digital Image Processing and Analysis”, *Prentice Hall of India*, 1996.

[4] A.K. Jain, “Fundamentals of Digital Image Processing”, *Prentice Hall of India*, 1989.

[5] A.Bovik, Handbook of Image and Video Processing. New York: Academic, 2000.

[6] X. Zong, A. F. Laine and E. A. Geiser, ” Speckle reduction and contrast enhancement of echocardiograms via multiscale nonlinear processing”, *IEEE Transactions on. Medical Imaging*, Vol. 17, pp. 532–540, 1998.

[7] A.Bezerianos and P.Tsakalides, “Novel Bayesian Multiscale for Speckle Removal in Medical Ultrasound Images”, IEEE Transactions on Medical Imaging Journal, Vol. 20, No.8, pp. 772-783, 2001.

[8] S.Gupta, L.Kaur, R.C.Chauhan and S.C.Saxena, “A wavelet based statistical approach for speckle reduction in medical ultrasound images”, *TENCON 2003. DOI: 10.1119/TENCON*.2003.1273218.

[9] S.Guadalupe, V.Vidal and G.Verdu, “Medical image restoration with different type of noise”, *34th Annual International Conference of the IEEE EMBS, USA, 2012. DOI: 10.1119/EMBC.2012.6346937.*

[10] L. Rudin, S. Osher and E. Fatemi, "Nonlinear Total Variation Based Noise Removal Algorithms," *Physica D.*, Vol. 60, pp. 259-268, 1992.

[11] A.Chambolle “An Algorithm for Total Variation Minimization and Applications”, *Journal of Math. Imaging and Vision*, Vol. 20, pp. 89-97, 2004.

[12] D.T.Kaun, Sowchauk, T. C.Strand, P.Chavel. “Adaptive noise smoothing filters for images with signal dependent Noise”, *IEEE Transaction on Pattern Analysis and Machine Intelligence*, Vol. PMAI -7, pp.165-177, 1985.

[13] V.S. Frost, J. A. Stiles, K. S. Shanmugam, J.C.Holtzman, “A model for radar image & its application to Adaptive digital filtering for multiplicative noise”, *IEEE Transaction on pattern analysis and machine intelligence*, Vol.PAMI-4, No.2, pp.157-166,1982.

[14] J.S. Lee, “Refined filtering of image noise using local statistics”, *Computer Vision, Graphics, and Image Processing*, Vol.15, Issue 4, April 1981, Pages 380-389