Analysis of Wavelet based Techniques for Image denoising

Avinash A. Talole, Sachin B. Patel, Dr. Ameya K. Naik,

***Abstract*— Wavelet based de-noising methods are used for removing the noise present in the image while preserving the main features of the image. The method is based on threshold estimation for each sub band of the wavelet decomposition of a noise contaminated image, by considering that the sub band coefficients have a Speckle noise. The wavelet transformation (WT) has been used to transform the noisy image, as the main application of WT is de-noising. We compare methods which are based on threshold value. The experiment has been conducted on various test images and compared the performance in terms of peak signal to noise ratio with the establish threshold parameters.**

***Index Terms*— De-noising, Wavelet transform, VisuShrink, NeighShrinkSURE, Suggested Method for Speckle noise.**

I. Introduction

One of the main tasks of image processing is to distinguish between noise and actual contents so that the un-wanted noise from the image signal can be removed. The distortion of an image by noise is very common that gets introduced during its acquisition, processing, compression, transmission, and reproduction.

The image usually has noise which is not easily eliminated in image processing. According to actual image characteristic, noise statistical property and frequency spectrum distribution rule, people have developed many methods of eliminating noises, which approximately are divided into space and transformation fields. The space field is data operation carried on the original image, and processes the image grey value, like Neighborhood average method, wiener filter, center value filter and so on. The transformation field is management in the transformation field of images, and the coefficients after transformation are processed. Then the aim of eliminating noise is achieved by inverse transformation, like wavelet transform [1], [2]. Successful exploitation of wavelet transform might lessen the noise effect or even overcome it completely [3].

In recent years there has been fair amount of work on wavelet thresholding [4-8]. Donoho and Johnstone proposed a non-linear method to remove the noise [4, 5].This approach is now widely used in statistics, particularly in signal processing and image analysis. In statistical context this can be referred as the estimation of the true curve from data contaminated with the noise usually assumed to be Gaussian noise but in this paper we deal with speckle noise.

Manuscript received April 22, 2015.

Avinash A. Talole, Department of Electronics & Telecommunication, K. J. Somaiya College of Engineering, Mumbai, India, 9833474332.

Sachin B. Patel, Department of Electronics & Telecommunication, K. J. Somaiya College of Engineering, Mumbai, India, 9892266096.

Dr. Ameya K. Naik, Department of Electronics & Telecommunication, K. J. Somaiya College of Engineering, Mumbai, India, 9833275939.

The methods based on wavelet representations yield very simple algorithms that are often more powerful and easy to work with than traditional methods of function estimation. It consists of decomposing the observed signal into wavelets and using thresholds to select the coefficients, from which a signal is synthesized. There are number of methods are available for threshold detection like VisuShrink, NeighShrink, Bayes Shrink, etc. In this paper we deal a new method for Speckle noise methods.

The paper is organized as follows: Section II deals with the general approach to denoising and gives a survey of existing techniques. Section III discusses the results and analysis of denoising techniques. This is followed by conclusions.

II. Denoising and it's applications

Removing noise from an image effectively and retaining the actual content of the image is still a challenge in field of Image denoising. Image denoising algorithm consists of few steps; consider an input signal $x(t)$and noisy signal $n(t)$. Add these components to get noisy data $y(t)$ i.e.

$$y(t) = x(t) + n(t) \qquad (1)$$

Here the noise can be Gaussian, Poisson's and Salt and pepper, then apply wavelet transform to get$w(t)$.

$$y(t) \xrightarrow{Wavelet\ Transform} x(t) \qquad (2)$$

Modify the wavelet coefficient $w(t)$ using different threshold algorithm and take inverse wavelet transform to get denoising image $\bar{x}(t)$

$$w(t) \xrightarrow{Inverse\ Wavelet\ Transform} \bar{x}(t) \qquad (3)$$

The system is expressed in Fig. 1.

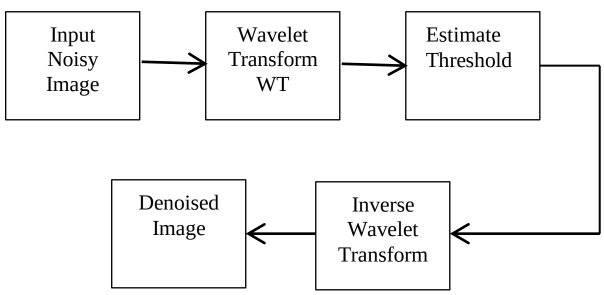

Fig. 1: Block diagram of Image denoising using wavelet transform.

The main task of wavelet thresholding is the selection of threshold value and the effect of denoising depends on the selected threshold. A bigger threshold will throw off useful information and noise components at the same time while a smaller threshold cannot eliminate the noise effectively. The two thresholding functions frequently used are hard and soft thresholding. The hard thresholding eliminates coefficients that are smaller than a threshold; the soft thresholding shrinks the coefficients that are larger than the threshold as well. The hard and soft thresholding functions are given by (1) and (2).

$$T_{hard}(w) = \begin{cases} w, |w| > T \\ 0, Otherwise \end{cases} \tag{4}$$

$$T_{soft}(w) = \begin{cases} w - T; if\ w > T \\ w + T; if\ w < T \\ o; otherwise \end{cases} \tag{5}$$

Where T is the threshold value and w is the wavelet coefficient.
The performance of various speckle reduction techniques is evaluated using the following standard image quality assessment metrics:

Peak Signal to Noise Ratio (PSNR)

$$\text{PSNR}= \quad 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{6}$$

Where MSE stands for Mean squared Error between two Images, which is given by

$$MSE = \frac{\sum_{M,N}[I_1(m,n)-I_2(m,n)]^2}{M*N} \tag{7}$$

Two methods used for denoising are given as follows:

A. *VisuShrink*

VisuShrink uses universal threshold given in (8)

$$V = \sigma_n\sqrt{2\ \log L} \tag{8}$$

Where, σ_n denotes the noise standard deviation and L is the total number of pixels in an image. This technique yields overly smoothened images with less preserved details. This is due to the fact that the universal threshold with high probability yields an estimate that is at least as smooth as the signal. So the threshold value tends to be high for large values of L, and that may kill many signal coefficients along with noise. Hence this does not adapt good with discontinuities in the signal.

B. *NeighShrinkSURE*

NeighShrinkSURE, an image denoising method proposed in [9] is an improved version of NeighShrink. The NeighShrink uses a suboptimal universal threshold and identical window size in all wavelet sub-bands, whereas the improved version of it determines an optimal threshold and neighboring window size for every sub-band by the Stein's unbiased risk estimate (SURE) as given in (8).

$$(T^s, K^s) = arg\ \min_{T,K} SURE(W_s, T, K) \tag{9}$$

Where T is the threshold, k is the window size and s denotes the sub band.

C. *Suggested Method for Speckle Noise*

As an alternative to VisuShrink and NeighShrinkSURE, we proposed a method [5] for image de-noising using threshold value

$$\lambda_p = \hat{\sigma}\sqrt{2J} - \sqrt{\frac{J}{0.1\hat{\sigma}}} \tag{10}$$

Where, J is the power of 2 in the sample of size $N = 2^J X\ 2^J$. This threshold value is assumed based on the experiments on various images of different sizes using the soft threshold rule. For a given threshold $\lambda > 0$ the soft threshold value is given by,

$$\delta^s(w, \lambda) = sign(w)(|w| - \lambda) \tag{11}$$

This is known as shrink or kill rule.
The proposed threshold value which depends on the size of the data is asymptotically optical and simpler to implement. Compared to the universal this threshold value is low hence including some important features in the estimated image.
In all the above estimation process, the noise standard deviation $\hat{\sigma}$ can be calculated using following equation (12)

$$\hat{\sigma} = \frac{median|Y_{ij}|}{0.6745} \tag{12}$$

Where Y_{ij} belong to the sub band in the first level of decomposition, which gives the diagonal details of the image.

III. Results and Analysis

Following images are the experimental results of the VisuShrink, NeighShrinkSURE and Suggested method for Speckle noise. Fig. 2 and Fig. 3 show the output for VisuShrink for σ=15 and σ=30, Fig. 4 and Fig. 5 show the output for NeighShrinkSURE for σ=15 and σ=30 whereas Fig. 6 and Fig. 7 show the output for the suggested method for Speckle noise for σ=15 and σ=30.

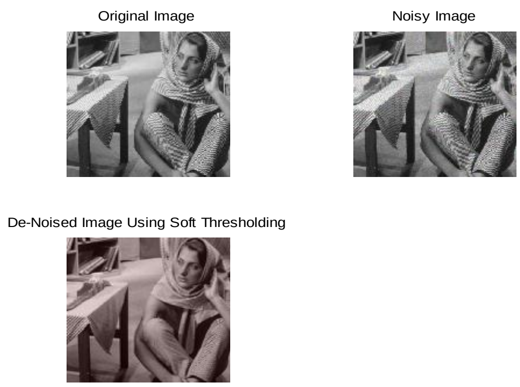

Fig. 2: Original image, noisy image and De-noised image using VisuShrink method for σ=15.

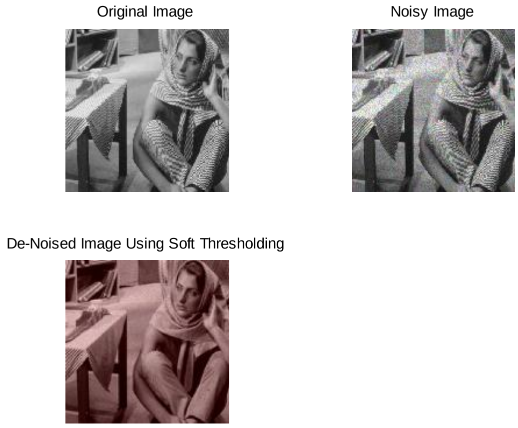

Fig. 3: Original image, noisy image and De-noised image using VisuShrink method for σ=30.

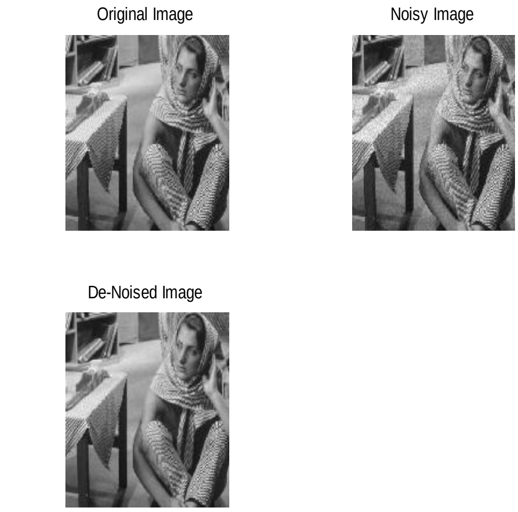

Fig. 4: Original image, noisy image and De-noised image using NeighShrinkSURE method for σ=15.

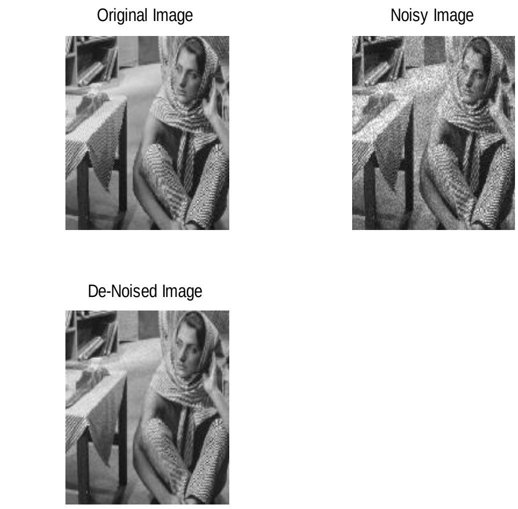

Fig. 5: Original image, noisy image and De-noised image using NeighShrinkSURE method for σ=30.

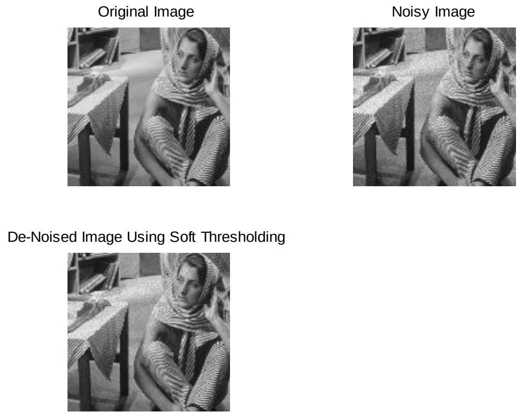

Fig. 6: Original image, noisy image and De-noised image using Suggested method for Speckle noise for σ=15.

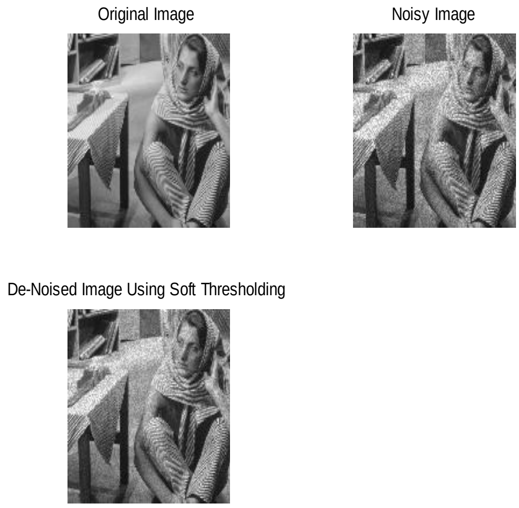

Fig. 7: Original image, noisy image and De-noised image using Suggested method for Speckle noise for σ=30.

VisuShrink, NeighShrinkSURE and Suggested Method for Spackle noise methods are applied to various test images and for different wavelets. First we added a Speckle noise to various test images to obtain the noisy image. While denoising, we used different wavelets for both methods with 2nd level of decomposition and the results were obtained. In Table I Results for VisuShrink is given, Table II Results for NeighShrinkSURE is given and Table III Results for Suggested Method for Speckle noise is given for different wavelets.

Table I: Results for VisuShrink

Wavelet Used	**Image/PSNR**			
	Barbara	**Boat**	**Pepper**	**Baboon**
db4	21.462	21.964	22.446	20.666
bior2.4	21.513	22.136	22.597	20.751
bior2.6	21.542	22.192	22.626	20.822
bior6.8	21.541	22.064	22.475	20.658

Table II: Results for NeighShrinkSURE

Wavelet Used	Image/PSNR			
	Barbara	Boat	Pepper	Baboon
db4	31.788	31.762	32.194	29.653
bior2.4	30.983	31.638	32.193	28.494
bior2.6	31.103	31.72	32.169	28.444
bior6.8	31.921	31.834	32.321	28.927

Table III: Results for Suggested method for Speckle noise

Wavelet Used	Image/PSNR			
	Barbara	Boat	Pepper	Baboon
db4	32.616	32.121	32.328	32.653
bior2.4	32.654	32.155	32.363	32.693
bior2.6	32.611	32.115	32.327	32.642
bior6.8	32.544	32.044	32.25	32.575

As maximum is the PSNR value more is the co-relation between original image and de-noised image. From Table I, Table II and Table III we observe that the PSNR value for Suggested Method for Speckle noise is higher than NeighShrinkSURE and VisuShrink.

IV. CONCLUSION

This paper presented a comparison between three Denoising methods for Speckle noise based on the PSNR value. We observe that Suggested Method for Speckle noise for de-noising having a better result than NeighShrinkSURE and VisuShrink. PSNR value is also higher for Suggested Method for Speckle noise and the main content of the image are also retained which usually get affected while denoising.

REFERENCES

[1] Donoho.D.L,Johnstone.I.M, “Ideal spatial adaptation via wavelet shrinkage”,Biometrika,81,pp.425-455,1994.
[2] GaoZhing, Yu Xiaohai, “Theory and application of MATLAB Wavelet analysis tools”, National defense industry publisher,Beijing,pp.108-116,2004.
[3] AglikaGyaourovaUndecimated wavelet transforms for image denoising,November 19,2002.
[4] D. L. Donoho, “De-Noising by Soft Thresholding,” IEEE Transactions on Information Theory, Vol. 41, No. 3, 1995, pp.613-627.
[5] Ismail B. and Anjum Khan, “Image De-noising with Stationary Wavelet Transform,” Vol. 7, Number 2(2013), pp 81-86.
[6] D. L. Donoho and I. M. Johnstone, “Adapting to Un-known Smoothness via Wavelet Shrinkage,” Journal of American Statistical Association, Vol. 90, No. 432, 1995, pp. 1200-1224.
[7] M. Jansen, “Noise Reduction by Wavelet Thresholding,” Springer Verlag Inc., New York, 2001.
[8] Martin Vetterli, S.G, Chang =, BinYu., 2000,”Adaptive wavelet thresholding for image de-noising and compression”. IEEE Transaction on image processing 9(9):1532-1546.
[9] Z. Dengwen and C.Wengang, “Denoising with an optimal threshold and neighboring window”, Pattern Recognition Letters, pp.1694-1697,2008.

First Author – Avinash A. Talole,
Post-Graduate Student
Electronics & Telecommunications Engineering,
K. J. Somaiya College of Engineering, Mumbai.

Second Author – Sachin B. Patel,
Post-Graduate Student
Electronics & Telecommunications Engineering,
K. J. Somaiya College of Engineering, Mumbai.

Third Author – Dr. Ameya K. Naik,
Asst. Dean(R & D)
Electronics & Telecommunications Engineering,
K. J. Somaiya College of Engineering, Mumbai.