Color Image Denoising Using Wavelet Thresholding

Tarun Kumar Sahu, Shweta Choubey, Ritesh Beohar

Abstract— **In this paper we proposed a new approach for color Image denoising using wavelet thresholding. The denoising process rejects noise by thresholding in the wavelet domain. Wavelet analysis is powerful tool for Image Denoising when Image are to be viewed or processed at multiple resolution Wavelet Transform is the mathematical tool of choice. Discrete wavelet transform has the benefit of giving a joint time frequency representation of the signal. Also it is suitable for both stationary and non-stationary signals and is the most appropriate system in the field of signal detection. Discrete wavelet transform is implemented through multi resolution analysis and digital filter banks. The proposed method was applied by using MATLAB R2013a with color images contaminated by white Gaussian noise.**

Index Terms—**Gaussian, Salt & Pepper, Poisson & speckle Noise, 2D filtering, Wavelet Thresholding.**

I. Introduction

Images acquired through sensors [charge- coupled device (CCD)] cameras may be contaminated by noise sources. Image processing technique also corrupts image with noise, leading to significant reduction in quality. Traditionally, linear filters (mean, median, and wiener filter) are used for removing noise from images, but it blurs data [1]. It is well known that wavelet transform is a signal processing technique which can display the signals on in both time and frequency domain. Wavelet transform is superior approach to other time-frequency analysis tools because its time scale width of the window can be stretched to match the original signal, especially in image processing studies. This makes it particularly useful for non-stationary signal analysis, such as noises and transients. For a discrete signal, a fast algorithm of discrete wavelet transform (DWT) is multi-resolution analysis, which is a non-redundant decomposition [2]. One of the most popular method consists of thresholding the wavelet coefficients (using hard threshold or the soft threshold) as introduced by Donoho [3]. Elyasi and Zarmehi [4] proposed several methods of noise removal from degraded images with Gaussian noise by using adaptive wavelet threshold (Bayes Shrink, Modified Bayes Shrink and Normal Shrink). Jacob and Martin [5] performed wiener filtering on the wavelet coefficients to denoise an image degraded by an Additive White Gaussian Noise (AWGN).Jin ET. al. [6] considered the adaptive wiener filtering of noisy images and image sequences. They began by using an adaptive weighted averaging (AWA) approach to estimate the second-order statistics required by the wiener filter and extended the AWA concept to the wavelet domain and that gained 0.5 dB over traditional wavelet wiener filter. The drawback of non-redundant transform is their non-invariance in time/space; i.e., the coefficients of a delayed signal are not a time- shifted version those of the original signal. The stationary wavelet transform (SWT) was introduced in 1996 to make the wavelet decomposition time invariant [7]. This improves the power of wavelet in signal de-noising. This paper exploits the benefits of stationary wavelet transform in suppressing noise at high frequencies and wiener filter to suppress noise in low frequency bands. The proposed algorithm is divided into two steps. After taking SWT to the noisy image, soft thresholding method is applied to the details sub bands; then a transformed image is generated from approximation sub band only while the other sub bands are made equal to zero, applying inverse SWT to the generated 2-D array, then applying the adaptive wiener filter, to remove the residual noise in the low frequency band. After that the approximation band is returned by applying SWT to the denoised signal, the resulted approximation sub band is grouped with the thresholded sub bands, applying inverse SWT to obtain the denoised image. The proposed method is compared with the other two traditional denoising methods, namely SWT and Wiener filter, to validate the denoised characteristics of this method.

Tarun Kumar Sahu*, ECE Department, Gyan Ganga Institute of Technology & Sciences, Jabalpur, India, Mobile No 9425444420*
Shweta Choubey*, ECE Department, Gyan Ganga Institute of Technology & Sciences, Jabalpur, India, Mobile No 9926660634*
*.****Ritesh Beohar****, ECE Department, Gyan Ganga Institute of Technology & Sciences, Jabalpur, India, Mobile No 9424309933*

II. WAVELET THRESHOLDING

The principal work on denoising is done by Donoho, which is based on thresholding the DWT of the signal. The method relies on the fact that noise commonly manifests itself as fine-grained structure in the signal, and WT provides a scale-based decomposition. Thus, most of the noise tends to be represented by the wavelet coefficients at finer scales. Discarding these coefficients would result in a natural filtering out of noise on the basis of scale. Because the coefficients at such scale also tend to be the primary carriers of edge information, the method of Donoho thresholds the wavelet coefficients to zero if their values are below a threshold. These coefficients are mostly those corresponding to the noise. The edge related coefficients of the signal on the other hand, are usually above the threshold.

An alternative approach to hard thresholding is the soft thresholding, which leads to less severe distortion of the signal of interest. Several approaches have been suggested for setting the threshold for each band of the wavelet decomposition. A common approach is to compute the sample variance of the coefficients in a band and set the threshold to some multiple of the deviation.

Wavelet denoising has wide range of application in signal processing as well as other fields. The signals may be one-dimensional, two-dimensional and three-dimensional. They carry useful information. Denoising (noise reduction) is the first step in many applications. Other applications include data mining, medical signal/image analysis (ECG, CT etc.), radio astronomy image analysis etc. Motivation to the thresholding idea is based on the assumptions that the de-correlating property of a wavelet transform creates a sparse signal: most untouched coefficients are zero or close to zero. Also noise is spread out equally along all coefficients. The noise level is not too high so that we can distinguish the signal wavelet coefficients from the noisy ones. As it turns out, this method is indeed effective and thresholding is a simple and efficient method for noise reduction. Further, inserting zeros creates more sparsity in the wavelet domain and one can see a link between wavelet denoising and compression.

Hard and soft thresholding with threshold are defined as follows:

The hard thresholding operator is expressed in equation (1) as

$$D(U,\lambda) = U \text{ for all } |U > \lambda| \quad \text{.......... (1)}$$

=0 Otherwise

The soft thresholding operator on the other hand is expressed in equation (2) as

$$D(U,\lambda) = sgn(U)\max(0, |U| - \lambda) \quad \text{..... (2)}$$

Hard threshold is a “keep or kill” procedure and is more intuitively appealing. The alternative soft thresholding shrinks coefficients above the threshold in absolute value. While at first sight hard thresholding may seem to be natural, the continuity of soft thresholding has some advantages. It makes algorithms mathematically more tractable. Sometimes, pure noise coefficients may pass the hard threshold and appear as annoying "blips" in the output. Soft thresholding shrinks these false structures.

III. METHODOLOGY

The denoising procedure is explained in the flow chart shown in Figure 1.

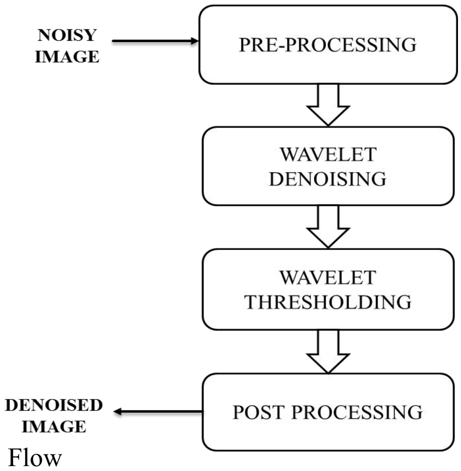

Fig1: Flow chart for Image Denoising

In the methodology the noisy image is preprocessed by spatial domain tools then after processed image is converting into the frequency domain and applied wavelet denoising & thresholding.

Type of thresholding used is soft thresholding. Denoised signals performance is compared based on mean square error computed. This is implemented using Matlab tool box, which is widely used for high performance numerical computation and visualization the wavelet used is sym20. Ingrid Daubechies invented what are called compactly supported orthonormal wavelets, thus making discrete wavelet analysis practicable. Daubechies wavelets are the most popular wavelets. They represent the foundations of wavelet signal processing and are used in numerous applications. The names of the Daubechies family wavelets are written symN, where N is the order, and sym the "surname" of the wavelets. Symlet wavelets are a family of wavelets. They are a modified version of Daubechies wavelets with increased symmetry.

IV. RESULT ANALYSIS

The experimental evolution is performed on color images of 512*512 pixels at different noise level. The objective quality of the reconstructed image is in the PSNR of the three color component X, X∈(R, G, B), which is defined as:

$$\text{PSNR} = 10\log_{10}\frac{255^2}{mse(x)} \quad \text{...... (3)}$$

Where mse(x) is the mean-square error of the original color component and the estimated one.

The overall PSNR is obtained as:

$$PSNR = 10\log_{10}\frac{255^2}{mse(R)+mes(G)+mes(B)} \quad \text{...... (4)}$$

The proposed method was implemented using MATLAB 2013a.

Table I: PSNR of proposed method

Test Image	**Noise Variance**	**Noisy Image PSNR**	**Proposed PSNR**
Lena	0.01	18.2000	34.060
	0.03	19.8840	28.8298
	0.06	18.9870	24.2175
Pepper	0.01	20.2269	31.9930
	0.03	19.8359	28.4288
	0.06	18.8409	23.9326

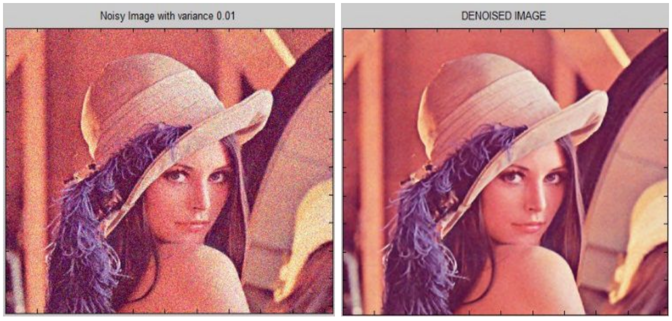

Fig 2 Image of Lena (Variance=0.01)

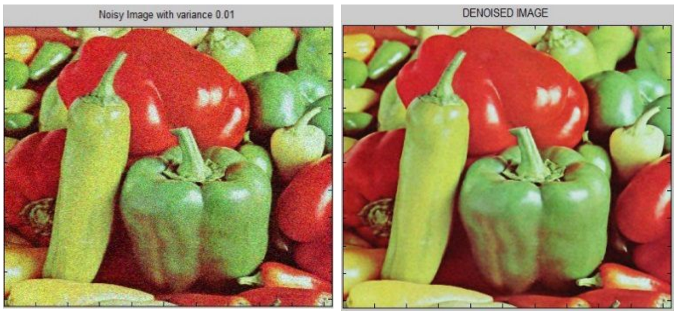

Fig 3: Image of Pepper (Variance=0.01)

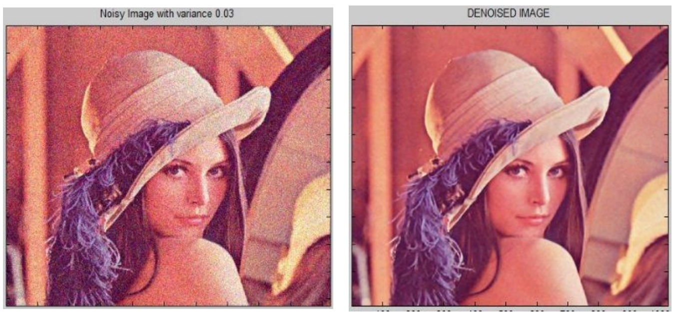

Fig 4: Image of Lena (Variance=0.03)

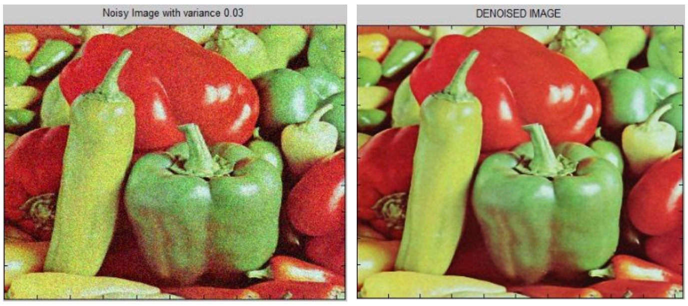

Fig 5: Image of Pepper (Variance=0.03)

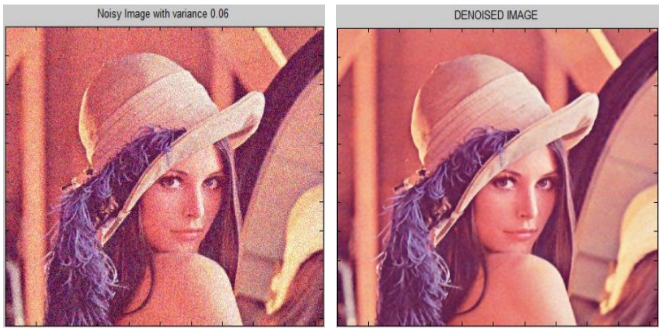

Fig 6: Image of Lena (Variance=0.06)

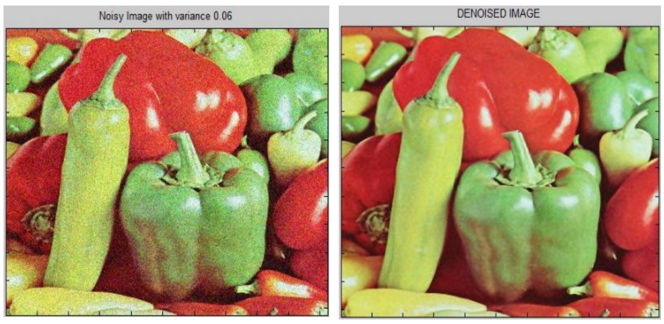

Fig 7: Image of Pepper(Variance=0.06)

V. CONCLUSION

Computational competence makes wavelet scheme attractive. The major observation from the set of experiments is wavelet gives best performance. It is observed that performance symlet Wavelet is better than the other techniques. Denoising performance varies with type of Image under considerations and wavelet chosen.

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Tarun Ku Sahu
BE, M.Tech
Asst professor GGITS Jabalpur (M.P)

Shweta Choubey
BE, M.Tech
Asst professor GGITS Jabalpur (M.P)

Ritesh Beohar
BE, M.Tech
Asst professor GGITS Jabalpur (M.P)