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DWT Thresholding Techniques for Denoising of Images: A Review

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Abstract

The search for an efficient techniques for denoising of images is a valid challenge in the field of image and signal processing. The most important requirement for an effective image denoising model is the complete removal of the noise along with the preservation of edges. Denoising of images is basically done to obtain an estimate of the original image by suppression of noises present in a noise-infected image. Noise in images is produced due to intrinsic and extrinsic conditions that are unavoidable in practical situations. A noise cleaned image is required for a wide range of applications like restoration of images, visual tracking, image segmentation, image registration and classification of image, etc. thus, making denoising of images a very important aspect.
Here, a review on the use of wavelet thresholding techniques for denoising of the images distorted due to noise is presented. These techniques although, prevent the loss of image details but still leaving a scope for development for improvement of the quality of the recovered image. Denoising of images henceforth needs fundamental researches to be carried on for further enhancement of the quality of the noise cleaned image.

Keywords- Image denoising, Image restoration, DWT.

Introduction

The removal of noise from a signal is known as denoising. All recording devices, either analog or digital have characteristics which make them susceptible to noise. The requirement for effective methods for restoration of images has increased with massive production of the digital images and all kinds of movies, often taken in poor condition. Despite of however good the cameras may be, still it is always desirable to improve an image in order to extend their range of action.

The two major obstructions in the accuracy of an image are categorized as noise and blur. Blur is intrinsic (sensors) to the acquisition systems for images [1], as infinite number of samples exist in digital images and they must satisfy the Shannon's Nyquist sampling condition. The other kind of image disruption is due to the presence of noise.

Digital medical images are more prone to noises as these images are captured using measurement and recording techniques, such as electroencephalography (EEG), electrocardiography (ECG), magneto-encephalography (MEG) etc which involve the use of beam of rays like X-Rays, RF pulses and others to pass through body which is opaque and leads to disruption of image details.

The noises that degrade the quality of images are:

1. *Salt & Pepper Noise* (also known as Impulsive Noise) has scattered bright & dark disruptions and the pixels of an image have different intensities of color in comparison with their neighboring pixels. The noisy pixel in the case of salt and pepper noise has no relation with the color of the neighboring pixels. This affects only small number of pixels. The contaminated image looks like it contains light and dark dots which led its name to be salt & pepper noise.
2. *Gaussian Noise* makes every pixel of the image to change from its real value by tiny amount (generally). This noise type has a Gaussian distribution which has the probability distribution function of bell-shape.
3. *Speckle Noise* is a granular noise that is multiplicative in nature. It degrades the images obtained using active image devices like active radar and SAR (Synthetic Aperture Radar) images. It elevates the mean grey level of local area.
4. *Shot Noise* exists in brighter areas of an image. It is produced from an image sensor and is caused due to statistical quantum fluctuations (number of photons vary at a certain given exposure level). It is also known as photon shot noise. It has its root-mean-square value proportional to the square-root of intensity of image and different pixels have noises independent of one another. It follows Poisson distribution which led its name to be Poisson noise.

Wavelet Transform

For denoising of signals, Fourier transform is a well-known method in the field of signal processing which converts the signal to a sine wave. Wavelets also expand a signal but despite using a smooth sine or cosine waves, they apply some basis functions known as wavelets. The wavelet functions are irregular, asymmetrical and finite, the wavelet analysis can depict the local features, sharp edged signals and better features in comparison with the Fourier transform [2].

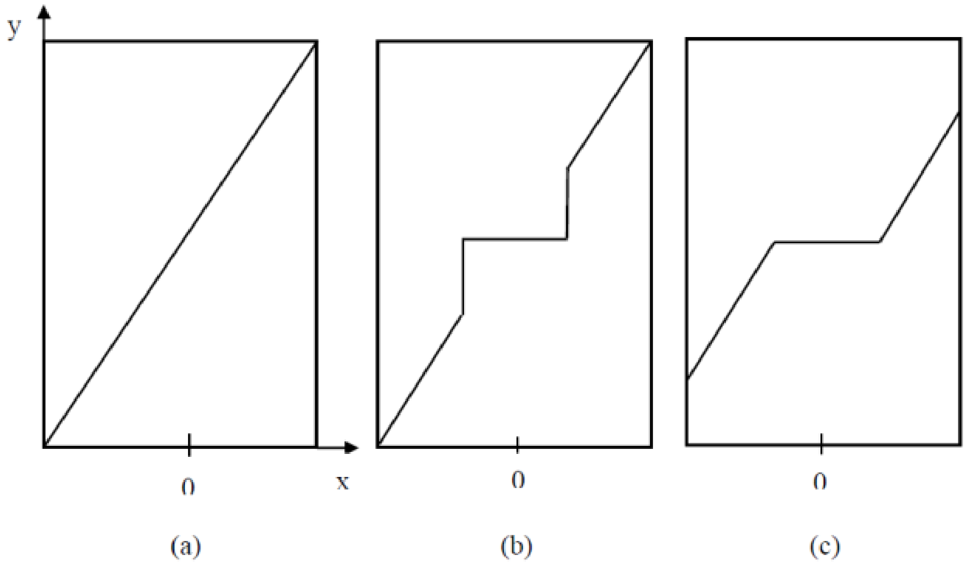

Fig1: (a) Original Signal (b) Hard Thresholded Signal (c) Soft Thresholded Signal

The wavelet thresholding for denoising of images separates each coefficient from the detailed sub-bands with the help of threshold function in order to obtain modified coefficients. Here, the threshold has a major role in the process of removal of noises.

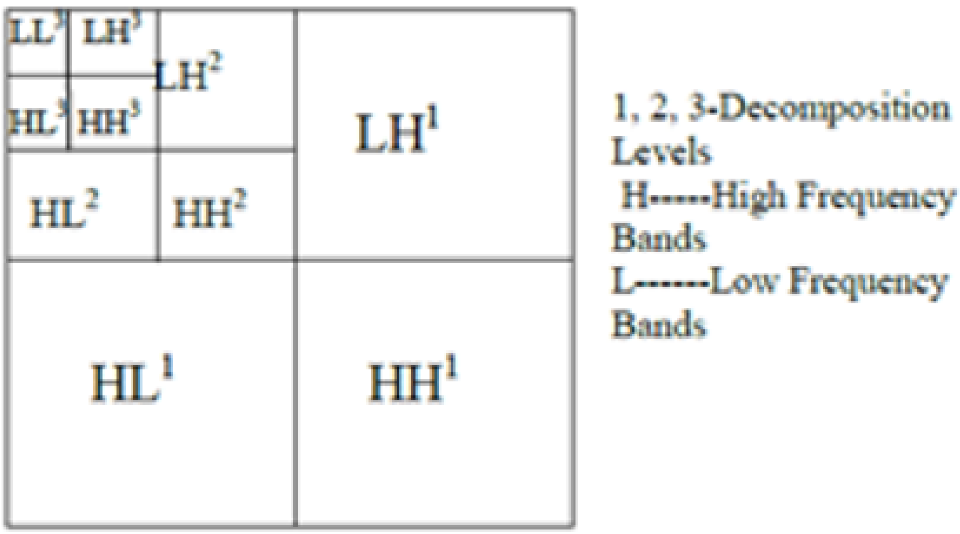

Fig 2: Sub-bands of 2-D orthogonal wavelet transform

Frequently used thresholding methods are basically divided into two categories, namely, Soft Thresholding and Hard Thresholding. The Soft thresholding shrinks the coefficients over the threshold to an absolute value while Hard thresholdng follows keep or kill rule according to which input is kept if it is larger than threshold, else it sets it to zero. The division of sub-bands could be done as shown in the figure 2 [3].

Different methods are used for selection of thresholds used in denoising of images that are based on wavelet transform.

Method 1: Bayes Shrink

According to this method, instead of replacing all the components with coefficients with values under the threshold level with zeros, different thresholds for the sub-bands are set. The difference in the level and direction of the bands exist in the case of sub-bands.

Consider an image degenerated due to the presence of additive noise. The observation model may be expressed as

$$Y = X + V \tag{1}$$

Where Y is the wavelet transform of the noisy image, X is original image's wavelet transform and V being the noise component's wavelet transform. Considering the noise components follow Gaussian distribution N (0, σv^2). Since X and V are mutually independent, σx^2, σy^2 and σv^2 of X, Y, V are variances, and can be given by

$$\sigma y^2 = \sigma x^2 + \sigma v^2 \tag{2}$$

Bayes shrink thresholding technique performs soft thresholding, along-with adaptive data driven, sub-band as well as level dependent near optimal threshold given by

$$TBS = \sigma v^2 / \sigma x \text{ if } \sigma y^2 > \sigma v^2 \tag{3}$$

and max{|AM|} otherwise

here AM are the wavelet coefficients of sub-band being considered and total number of wavelet coefficients in that sub-band being M.

Method 2: Normal Shrink

Using this method the threshold values are calculated using

$$T\ NS = \lambda \sigma v^2 / \sigma y^2 \tag{4}$$

$$\lambda = (\log(LK/J))^{1/2} \tag{5}$$

where length of the sub-band at K^{th} scale is LK and the total number of decompositions is J, σv represents the estimated noise variance and σy is the standard deviation of sub-band of noisy image.

Method 3: Neigh Shrink

This scheme incorporates the use of neighboring coefficients. According to this method, the threshold is obtained in accordance to the magnitude of squared sum of all the wavelet coefficients, which is the local energy of the neighborhood window. The window sizes for neighborhood window may be 3X3, 5X5, 7X7, 9X9, etc. among which 3X3 is the best [4]. The shrinkage function for Neigh shrink of any arbitrary

3X3 window centered at (i,j) is expressed as:

$$\Gamma ij = (1- (\Gamma^2 ij / S^2 ij)) \quad (6)$$

Where UT is the universal threshold and S^2ij is the squared sum of all wavelet coefficients in the respective 3X3 window.

Method 4: Sure Shrink
This method is based upon Stain's Unbiased Risk Estimator proposed by Donoho and Johnstone [5]. Soft thresholding rule is followed and the thresholding used is smoothness adaptive which means that if unknown function contains abrupt changes or boundaries in image, the reconstructed image also does.

Method 4: Visu Shrink
According to this method, Soft thresholding using universal threshold is done which yields an image with overly smoothed estimate. This method guarantees that the reconstructed noisy image will be highly smooth although it often compromises many important characteristics of image due to the threshold being set high.

Current Status Of Knowledge

Vikas Gupta, Rajesh Mahle, Raviprakash S Shriwas [4] explained some significant work in the area of image denoising of images using several thresholding methods such as SureShrink, VisuShrink and BayesShrink. The results are based upon the various noise types like Gaussian, Salt & Pepper noise, Poisson's and Speckle noise. SNR & MSE have been used for the measurement of the quality of the denoised signal.

Mohideen, S. Kother, S. Arumuga Perumal, and M. Mohamed Sathik [6] proposed to investigate the suitability of different wavelet bases and the size of different neighborhood on the performance of image de-noising algorithms in terms of PSNR.

Rohit Sihag, Rakesh Sharma and Varun Setia [7] worked on the wavelet denoising scheme that thresholds the wavelet coefficients arising from the standard discrete wavelet transform. In this paper, several methods are analyzed for noise removal from images degraded with Gaussian noise by use of adaptive wavelet threshold (Bayes Shrink, Normal Shrink and Neigh Shrink) and compared the results in term of PSNR.

Iman Elyasi, and Sadegh Zarmehi [8] proposed several methods of noise removal from degraded images with Gaussian noise by using adaptive wavelet threshold (Normal Shrink, Bayes Shrink, and Modified Bayes Shrink). The thresholds proposed were simple and adaptive to each sub-band because the parameters required for estimating the threshold depend on sub-band data. Experimental results showed that the proposed thresholds remove noise significantly and preserve the edges in the scene.

Conclusion

Various advances have been made in the field but there exists a vital scope for the improvement of the techniques used for the denoising of the distorted images. Varieties of methods are being used for the removal of noise from image. Thresholding techniques are way better in comparison to the filter based techniques. But there does not exist any generalized method for de-noising of images. A highly efficient cleaned image could be obtained by enhancing these wavelet transforms. We must, therefore, encourage fundamental research to resolve these challenges in order to recover an efficient image output.

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