A Comparative Study of Non-Linear Threshold Filtering for Image Denoising

Rimpy Garg

Deptt. of Computer Science

Patiala Institute of Engineering & Technology for Women

Patiala, India

errimpy@gmail.com

***Abstract*— Now a day's, image processing is an important task in many application and area ranging from television to tomography, from photography to publishing, from robotics to remote sensing and many more. Image processing can be done for two reasons; one is improvement of pictorial information for human interpretation and second is processing of image for storage, transmission and representation so that it can be used in meaningful way. Out of various images processing technique, denoising is an important pre-processing task before further processing of image like segmentation, feature extraction; texture analysis etc. The process in which noise signal is separated from meaningful signal to generate a noise free image is called denoising. The main objective of this article is to present a comparative analysis of the various developed and proposed non-linear threshold filtering technique in wavelet domain.**

***Keywords*— Non-Linear methods, VISU Shrink, SURE Shrink, Bayes shrink, Neighbour shrink.**

I. Introduction

Denoising is a process of removal noise from the digital image to get a denoised image. Noise is unwanted signal that is added into image during acquisition, transmission & reception and storage & retrieval processes. As a result, there is degradation in visual quality of an image. To get a denoised image, it is necessary to remove the embedded noise from the image without disturbing the edges and other fine detailed features as much as possible. Image denoising still remains a challenge for researchers because noise removal introduces artifacts and cause blurring of the images. Different types of images inherit different types of noise and different denoised models are used. Denoising method tends to be problem specific and depends upon the type of image and noise. Donoho and Johnstone [1] pioneered the work on filtering of additive Gaussian noise using wavelet thresholding. In wavelet thresholding, image data is decomposed into wavelet coefficients, comparing these coefficients with a given threshold value and shrinking these coefficient close to zero to remove the effect of noise in the data. The image is reconstructed from the modified coefficients. Denoising of image using wavelet technique is very effective because of its multiresolution and sparsity characteristics. It is good at energy compaction, the small coefficients are due to noise and large coefficients are due to important signal feature. Due to this fact noise can be effectively removed from image data. In this paper various non-linear threshold denoised method are compared and analysed.

II. Non-Linear Method

Filtering operation in wavelet domain can be subdivided into linear filtering and non-linear threshold filtering [2]. Linear filters such as wiener filter produce optimal result if image is corrupted by Gaussian noise and the accuracy criterion is mean square error (MSE). Non-linear threshold filtering exploits sparsity property of wavelet transform. The fact is that during wavelet transformation signal energy becomes more concentrated into fewer coefficients and noise energy does not, due to this noise coefficients are easily removed. Based on this criterion, thresholding can be divided into hard and soft thresholding. In hard thresholding small coefficient are removed while others are untouched. The main drawback of this technique is that it blurs the resultant image ad produces artifacts. In contrast soft thresholding is where the coefficients with greater than the threshold are shrunk towards zero after comparing them to a threshold value. It overcomes the demerits of hard thresholding. Non-linear thresholding further divided into adaptive and non-adaptive. Various techniques of both categories are compared and analysed in this paper.

A. VISU Shrink

Visual Shrink is non-adaptive universal thresholding by applying universal threshold proposed by Donoho and Johnstone [3]. Threshold T can be calculated using the formulae

$$T = \sigma\sqrt{2\log n}$$

Where σ is noise variance and n is size of image.

It yields best performance in terms of MSE when the number of pixels reaches infinity. It offers the advantage of smoothness and adaptation but it produces visual artifacts. It can remove only additive noise.

B. SURE Shrink

Due to problem in universal threshold, Donoho and john stone proposed SURE shrink [4]. It uses a hybrid of the universal threshold and the SURE (stein unbiased risk estimator) threshold. It is sub band adaptive and is derived by minimizing stein's unbiased risk estimator.

C. Bayes Shrink

BayesShrink was proposed by Chang, Yu and Vetterli [5]. The goal of this method is to minimize the Bayesian risk, and hence its name, BayesShrink. It uses soft thresholding and is subband-dependent, which means that thresholding is done at each band of resolution in the wavelet decomposition assuming a Generalized Gaussian Distribution (GGD). Like the SureShrink procedure, it is smoothness adaptive.

D. Neigh Shrink

Its stand for Neighbour shrinks. It threshold the wavelet coefficient according to the magnitude of the square sum of the entire wavelet coefficient within the neighbourhood window. It extends Cai and Silverman's idea to the image case [6]. For images, it needs to be considering a neighbourhood window around the wavelet coefficients to be thresholded. Experimental results show that by using neighbouring coefficient neigh shrink gets higher Peak Signal to Noise Ratio (PSNR) for all the denoised images. It outperforms Visushrink, Sureshrink and wiener filters.
Let d(i,j) denote the wavelet coefficients of interest and B(i,j) is a neighbourhood window around d(i,j). Also let $S^2 = \sum d^2(i,j)$ over the window B(i,j). Then the wavelet coefficient to be threshold is shrieked according to the formulae, $d(i,j) = d(i,j) * B(i,j)$ where the shrinkage factor can be defined as $B(i,j) = \left(1 - T^2/S^2(i,j)\right)+$ and the sign + at the end of the formulae means to keep the positive value while set it to zero when it is negative [7].

E. Modified Neigh Shrink

It is a modified form of Neigh shrink. During Neigh shrink, reconstructed image contained mat like aberrations [7]. These aberrations can be removed using wiener filter. Rest is same as Neigh shrink except

$$B(i,j) = \left(1 - (3/4) * T^2/S^2(i,j)\right) +$$

F. Neigh Sure Shrink

Neighshrink and sureshrink threshold is applied next as a new combination threshold to reduce a noise image in wavelet domain named neighsure shrink method [8]. In this method first noise is estimated using local statistics of the image such as local mean, second order moment and variance. The estimated images are processed by the dynamic tracking method. These methods are transformed to wavelet domain. The detail wavelet coefficients are modified according to the shrinkage algorithm. Neighsure shrink gives better result than Neighshrink and Sureshrink in terms of PSNR values.

III. RESULTS

The above mentioned methods are compared using quality measure PSNR (Peak Signal to Noise Ratio).

$$PSNR = 10 \log_{10} \frac{255^2}{MSE}$$

Where MSE is the mean squared error between the original image and reconstructed denoised image. The experiments are conducted on natural gray scale test image Lena of size 512 × 512 at different noise level σ = 10, 20, 30. Table I shows the values of PSNR obtained after applying above mentioned method respectively on Lena image [2][9].

IV. CONCLUSIONS

The purpose of this paper is to present a comparative study of non-linear threshold filtering for digital image denoising. As images are very important in each and every field so Image Denoising is an important pre-processing task. In this paper, global, level and subband adaptive thresholding techniques are compared to address the issue of image recovery from its noisy counterpart. The results obtained are compared from the PSNR point of view between input image and the reconstructed output image. After experiment, Neighsure Shrink has proved to be best thresholding technique among the applied techniques. I have seen that wavelet thresholding is an effective method of denoising noisy signals. I also found that subband adaptive thresholding performs better than a universal thresholding i.e. non adaptive where single value of threshold is applied globally.

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TABLE I
PSNR VALUES OF VARIOUS IMAGE DENOISED METHOD ON LENA IMAGE

Image	**Variance**	**Noisy**	**VISU Shrink**	**SURE Shrink**	**Bayes Shrink**	**Neigh Shrink**	**Modified Neigh Shrink**	**NeighSure Shrink**
Lena	σ=10	28.1493	28.9396	31.8001	32.8905	33.8439	33.4761	35.1977
	σ=20	22.1010	26.1311	27.4047	28.8787	30.0915	29.0227	31.6496

	σ=30	20.1629	25.1649	24.2642	27.6743	28.9310	27.6670	29.582

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