Soft Thresholding based Image Denoising algorithm

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Abstract— A threshold estimation method for image denoising in the wavelet transform domain is being developed. Eradication of noise plays a crucial role in the reconstruction process of an image. The proposed algorithm is based upon the discrete wavelet transform analysis, being adaptive in nature which is based on sub band data to calculate the value of threshold. Experimental results on several test images are compared with popular denoise technique from three aspects PSNR, RMSE..

Index Terms—Wavelet Thresholding, Image Denoising, Discrete Wavelet Transform.PSNR,RMSE,Noise Variance,

1 Introduction

Image Images are contaminated with noise during the acquisition process or because of naturally occurring phenomenon. One classical task of image processing is to discriminate between noise and signal, and to remove the unwanted noise from the signal. The different types of noise present in the image like Gaussian noise, salt and pepper noise, speckle noise, shot noise, white noise [2].Especially for the case of additive white Gaussian noise a number of techniques using wavelet-based thresholding have been proposed. Donoho and Johnston proposed hard and soft thresholding methods for Denoising.[4] This scheme analyzes many wavelet coefficients that might contain useful image information. The definition of coefficient independent threshold given by Donoho and Johnston depends on the noise power and the size of the image. In the recent years there has been afair amount of research on wavelet thresholding and threshold section for image denoising [3], because wavelet provides an appropriate basis for separating noisy signal from the image signal. Wavelet transform is good at energy compaction, the small frequency coefficients appearing due to noise and large frequency coefficient represent the important signal features[8]. These small coefficients can be thresholded without affecting the significant features of the image.

The wavelet coefficient represents a measure of similarity in the frequency content between a signal and a chosen wavelet function [2]. These coefficient are computed as a convolution of the signal and the scaled wavelet function,which can be interpreted as a dilated band pass filter because of its band pass like spectrum [5]. Thresholding is a simple non-linear technique, which operates on one wavelet coefficient at a time. In its most basic form, each coefficient is thresholded by comparing against threshold value. If the coefficient is smaller than threshold then it set to be zero; otherwise it is kept or modified. We replace the small noisy coefficient by zero and apply inverse wavelet transform on the result leading to signal reconstruction with less noise.

2 IMAGE DENOISING

Wavelets play an important role in edges detection, watermarking, texture detection, compression, denoising, and coding of interesting features for subsequent classification. Image denosing based on the wavelet transform is mainly completed by wavelet thresholding in wavelet domain [12]. The reconstruction of image in wavelet domain can considered as an optimal estimation to the input image with noise data using the threshold. The wavelet thresholding for image denoising involves the following steps :.

1.The wavelet coefficients can be obtained by using the wavelet decomposition on the input image with noise.

$$w = W(X + N) \quad \ldots 1$$

Where w are the wavelet coefficients; W is the wavelet transform; X is the ideal input data; N is the noise data.

2. The optimal estimations are acquired by modifying the wavelet coefficients based on a rule of wavelet threshold.

$$W' = \delta\lambda(w) \quad \ldots 2$$

Where *W'* is the optimal estimation of the wavelet coefficients, δλ(w) is a wavelet threshold function and λ is the threshold.

3. Applying inverse wavelet transform on the modified wavelet coefficients results in the denoised image

$$X' = W^{-1}w \quad \ldots 3$$

Based on the above analysis, obviously, there are two problems existing in this research of the wavelet thresholding denoising on image:
a: The choice of the wavelet thresholding function
b: The choice of the wavelet threshold

Our research revolves around the above two main questions, To compute the two-dimensional DWT of an image, we decompose the approximations at level j to obtain four matrixes of coefficients at level j +1.

3 Soft and Hard Thresholding

Signal denoising using the DWT follows, signal decomposition, thresholding and signal reconstruction. wavelet analysis of a noisy signal is done to determine the level *N*. followed by thresholding of the detail coefficients from level 1 to N, and synthesize the signal using the altered detail coefficients from level 1 to N and approximation of coefficients of level N [2]. However, it is generally impossible to remove all the noise without corrupting the signal. According to D.Donoho's method, the threshold estimate δ for denoising with an orthonormal basis is given by

$$\delta = \sigma^2 \log N \ldots 4$$

where the noise is Gaussian with standard deviation σ of the DWT coefficients and L is the number of samples or pixels of the processed signal or image. thresholding can be either soft or hard. Hard thresholding zeroes out all the signal values smaller than δ. Soft thresholding zeros all the signals values smaller than δ followed by, subtracts δ from the values larger than δ. Incontrast to hard thresholding, soft thresholding causes no discontinuities in the resulting signal.

4 Wavelet Threshold

The traditional Donoho's wavelet threshold is represented in equation 5

$$\lambda = \sqrt{2\sigma^2 logN} \ldots 5$$

Where σ^2 is the estimate variance, and N is the number of the wavelet coefficients. However, this wavelet threshold has a fatal shortcoming. The threshold value is proportional with the signal size logarithm's square root, therefore, when N is big, the threshold value tends to reset, as a result, the wavelet filter will degenerate as the degradation of low-pass filter. Due to the above deficiency of Donoho's threshold, the more effective Bayes wavelet threshold is used to optimize the performance of the wavelet threshold denoising algorithm inthis study with assumption of the wavelet coefficients obeying a distribution. The threshold According to the Bayes Rule is shown formula:-

$$\lambda_s = \frac{\sigma_D^2}{\sigma} \ldots 6$$

where λ_s represent the thresholds in various sub bands. σ_D is the noise variance estimation, σ is the wavelet coefficients variance estimations in various sub-bands. the noise variance estimation of the noisy images concentration on the wavelet high frequency i.e. low-scale sub band is calculated using equation 7

$$\sigma_D = \frac{median(w)}{0.6745} \ldots 7$$

where w are the wavelet high-frequency diagonal coefficients. The wavelet coefficients variance estimations in varioussub-bands can be calculated as formula:-

$$\sum \sigma = \sqrt{\max\left(\sigma_n^2 - \sigma_D^2,\ 0\right)} \ldots 8$$

$$\sigma_n^2 = \frac{1}{m \times n} \sum_{j=1}^{m,n} W_n^2 \ldots 9$$

where σ_n are the variance estimations of the coefficients in various sub-bands. m x n is the number of the corresponding coefficient W_n in different sub bands. The wavelet bayes threshold considers the distribution characteristics of the wavelet coefficients, hence the properties of this threshold is more excellent than the traditional wavelet threshold. Based on the above section the improved method based on the wavelet thresholding function has many advantages and can obtain the great result.

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5 Image Denoise Algorithm

This section describes the image denoising algorithm, which achieves near optimal semi soft thresholding in the wavelet domain for recovering original signal from the noisy one. The algorithm is very simple to implement and computationally more efficient. It has following steps:

1. Perform multi scale decomposition of the image corrupted by Gaussian noise using wavelet transform.
2. Estimate the noise variance σ2
3. For each level, compute the scale parameter
4. Compute the standard deviation
5. Compute threshold λ
6. Apply soft thresholding to the noisy coefficients.
7. denoise high frequency coefficient
8. merge low frequency coefficient with denoise high frequency coefficient
9. Invert the multi scale decomposition to reconstruct the denoised image .

6 Experimental Results And Discussions

In this section we present some results to demonstrate the performance of our algorithm. The experiments are conducted on Lena image of size 512x512 which is corrupted by Gaussian white noise of standard deviation 0.05. threshold noise filter, and wavelet soft threshold noise filter eliminate image noise, and the results which are shown in fig.1, show that the proposed filter is significantly effectivethan the other in quality.also shown that psnr rmse and coc value. Gaussian noise with mean = 0.005 and variance =0.005.

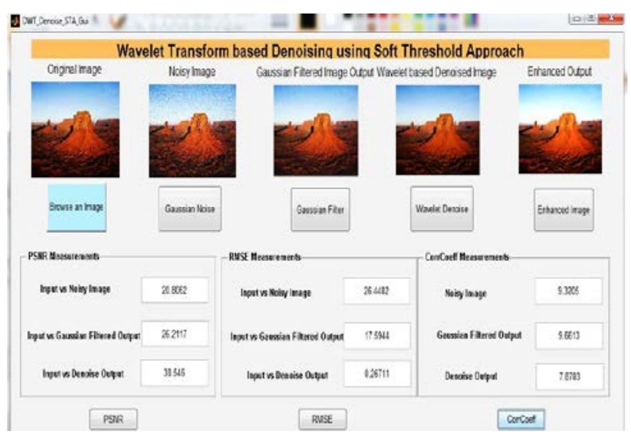

Figure 1: Wavelet Transform based Image Denoising using Soft Threshold Approach

The experiment shows that the traditional image denoisemethods are difficult to preserves the details of the imageeffectively while removing the noise. So, compared with theabove several methods, the proposed methods in this papercan preserves most satisfying image details.

7 CONCLUSION

This paper is based on the discrete wavelet transform and Gaussian distribution modelling of sub band coefficients. The image denoise algorithm uses soft thresholding to provide smoothness and better image details preservation.The wavelet soft thresholding denoise algorithm produce overall better PSNR RMSE and COC result compared with other traditional denoise approaches.

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