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Image Denoising Using Wavelet Thresholding

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Abstract*:* Removing noise from the original signal is still a challenging problem for researchers. Wavelet transforms enable us to represent signals with a high degree of scarcity. Wavelet thresholding is a signal estimation technique that exploits the capabilities of wavelet transform for signal denoising. This paper presents a comparative analysis of various image denoising techniques using wavelet transforms. Furthermore, this study is done to review various denoising algorithms using wavelet transform, those algorithms are discussed with specific details in order to understand the effect of each algorithm on the quality of the image. In this paper, we analyzed several methods of noise removal from degraded images with Gaussian noise by using adaptive wavelet threshold (Bayes Shrink, Neigh Shrink, Sure Shrink, Visu Shrink and Block Shrink) and compare the results in term of PSNR and MSE.

Keyword: Wavelet thresholding, Bayes Shrink, Neigh Shrink, Sure Shrink, Visu Shrink and Block Shrink

I. Introduction

Visual information transmitted in the form of digital images is becoming a major method of communication in the modern technology, unfortunately, the image obtained after transmission is often corrupted with different kinds of noise. Image processing is one form of signal processing for which the input is an image, these photographs or frames of video and the output of image processing can be either an image or a set of characteristics or parameters related to the image processing. De-noising plays a vital role in the field of the image pre-processing. The primary goal of noise reduction is to remove the noise without losing much detail contained in an image. The denoising of a natural image corrupted by Gaussian noise is a classic problem in signal processing. The wavelet transform has become an important tool for this problem due to its energy compaction property.

De-noising of natural images corrupted by noise using wavelet techniques is very effective because of its ability to capture the energy of a signal in few energy transform values. Wavelet denoising attempts to remove the noise present in the signal while preserving the signal characteristics, regardless of its frequency content.

II. Wavelet

Wavelets are especially well suited for studying non stationary signals and the most successful applications of wavelets have been in compression, detection and denoising A Wavelet is a waveform of efficiently limited duration that has no average value zero. A wavelet system is a set of building blocks to construct or represents a signal or function. Wavelet systems are generated from single scaling function by scaling and translation.

III. Thresholding

The most straightforward way of distinguishing information from noise in the wavelet domain consists of thresholding the wavelet coefficients. . Wavelet thresholding is a signal estimation technique that exploits the capabilities of wavelet transform for signal denoising. At the time of thresholding, a wavelet coefficient is compared to the given threshold and is set to zero if its magnitude is less than the threshold otherwise, it is then retained or modified depending on the thresholding rule.

The thresholding is classified into two categories.

1. **Hard Thresholding**

The hard-thresholding TH is given as

$$TH = \begin{cases} x \; for \; |x| \geq t \\ 0 \; in \; all \; other \; region \end{cases}$$

Where t is the threshold value. Hard thresholding may seem to be natural. Hard threshold is a "keep or kill" procedure and is more intuitively appealing. Sometimes pure noise coefficients may pass the hard threshold and appear as annoying "blips" in the output.

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2. Soft Thresholding

Soft thresholding is that where the coefficients with greater than the threshold are shrunk towards zero after comparing them to the threshold value. The false structures in hard thresholding can overcome by soft thresholding. Soft thresholding can be defined as follow:

$$T_s = \begin{cases} sign\,(x)(|x| - t)\; for\; |x| > t \\ 0 \qquad in\; all\; other\; region \end{cases}$$

The false structures in hard thresholding can overcome by soft thresholding. Also, the soft method yields a smaller MSE (minimum mean squared error) compared to hard form of thresholding.

IV. Thresholding Techniques

We used the following five thresholding techniques in our work.

A. Bayes Shrink

The goal of this method is to minimize the Bayesian risk, and hence its name. Bayes shrink is an adaptive data driven threshold for image denoising via wavelet soft thresholding. The Bayes Shrink method is effective for images including Gaussian noise. The sharp features of image are retained. But MSE is considerably lower.

B. Neigh Shrink

Neigh Shrink is an efficient image denoising algorithm based on the decimated wavelet transform (DWT). The shrinked wavelet coefficient according to the neigh shrink is given by this formula:

$w'_{ij} = w_{ij}\beta_{ij}$

The shrinkage factor β_{ij} can be defined as:

$\beta_{ij}=(1-T_{UNI}^2 / S_{ij}^2)+$

Here, the + sign at the end of the formula means tokeep the positive value while set it to zero when it is negative and T_{UNI} is the universal threshold, which is defined as:

$$T_{UNI} = \sqrt{2\sigma^2 \ln(n)}$$

Where n is the length of the signal.

C. Block Shrink

Block Shrink is a completely data-driven block thresholding approach and is also easy to implement. The block thresholding increases the estimation precision by utilizing the information about the neighbor wavelet coefficients. It utilizes the pertinence of the neighbour wavelet coefficients by using the block thresholding scheme. Block Shrink can select the optimal block size and threshold for the given subband by minimizing Stein's unbiased risk estimate. The block thresholding simultaneously keeps or kills all the coefficients in groups rather than individually, enjoys a number of advantages over the conventional term-by-term thresholding.

D. Visu Shrink

The VisuShrink technique consists of applying the soft thresholding operator using the Universal Threshold. This threshold is given by,

$$T = \sqrt{(\sigma^2 \log M)}$$

Where σ is the noise variance and M is the number of pixels in the image. The estimate should be at least as smooth as the signal. So Universal threshold (UT) tends to be high for large values of M,killing many signal coefficients along with the noise.

E. Sure Shrink

Sure shrink is a thresholding by applying sub band adaptive threshold, a separate threshold is computed for each detail sub band based upon SURE (Stein's Unbiased Risk Estimate).The goal of Sure Shrink is to minimize the mean squared error. Sure Shrink follows the soft thresholding rule. Sure Shrink suppresses noise by threshold the empirical wavelet coefficients. It is smoothness adaptive, which means that if the unknown function, contains abrupt changes or boundaries in the image, the reconstructed image.

V. Compared Output

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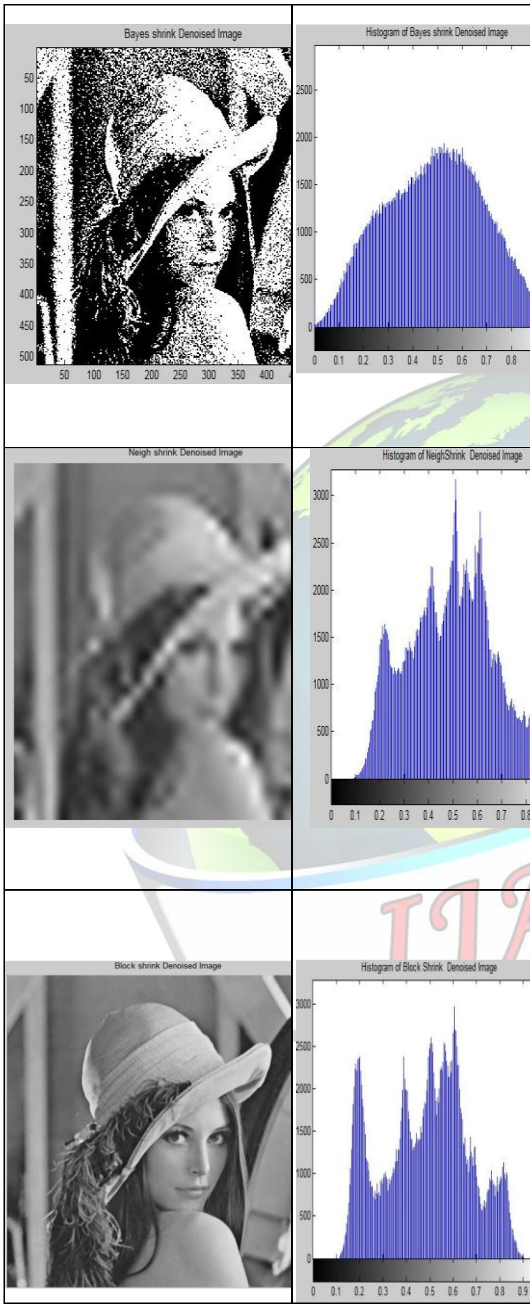

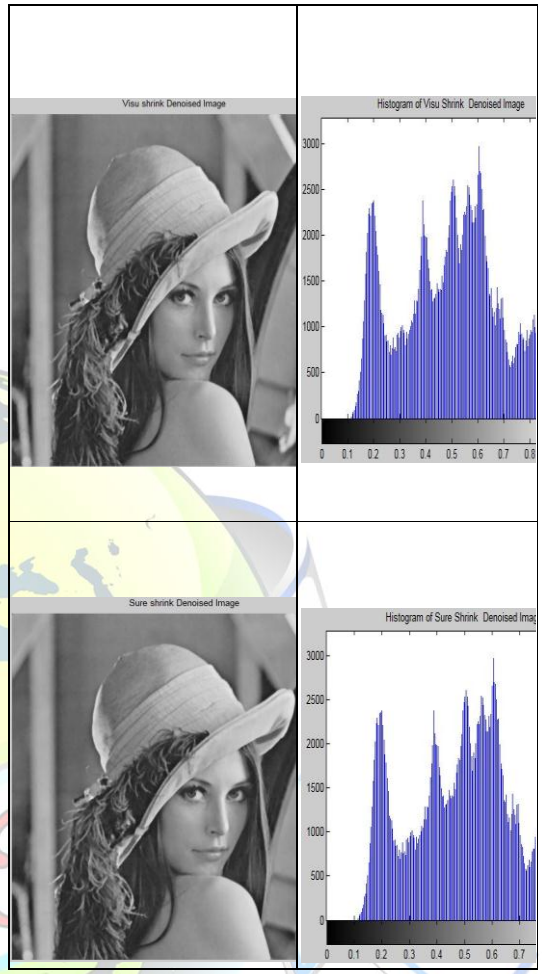

S.No	Name	MSE	PSNR
1	Noisy image	0.1052	61.4865
2	Bayes Shrink	0.0094	68.3765
3	Neigh Shrink	0.0056	70.6592
4	Block Shrink	2.8716e-04	83.5496
5	Sure shrink	2.8716e-04	83.5496
6	Visu Shrink	2.8716e-04	83.5496

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VI. CONCLUSION

Performance of denoising algorithms is measured using quantitative performance measures such as peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR) as well as in terms of visual quality of the images.

Many of the current techniques assume the noise model to be Gaussian. A lot of combinations have been applied in order to find the best method that can be followed for denoising intensity images. We then investigated many thresholding schemes such as VisuShrink, Sure Shrink, Neigh Shrink, Block Shrink and Bayes Shrink for denoising images. Among these, Sure shrink, Block Shrink, Visu Shrink gave the best results, where they produce similar outputs.

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