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Contemplation of Thresholding in Wavelet Denoising

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Abstract: **This paper deals with basic thresholding techniques that help in denoising of the image. The image to be denoised is wavelet transformed where image first undergoes wavelet decomposition and then the denoising is applied to its coefficients. There are various methods each described highlighting their characteristics. Denoising is a vast area of research but we are dealing with wavelet denoising here. For attainment of effective image, the noise in the image should be removed without distorting or degrading the image and its quality.**

Keywords: **Wavelet Decomposition, Thresholding Techniques, Denoising, Wavelet Denoising, Image**

1. INTRODUCTION

Denoising as the word says is removing noise from the image. Noises are nothing but any disturbance or undesirable signal present in an image. Noises are of many different types and can affect the image in their own different ways for example, in high resolution data; even a speckle can degrade image quality and hide the original particulars of the image. Denoising removes the noise, enhancing its visibility and quality. Generally denoising is confused or used as a synonym for smoothing but there lies a difference between these two terms where smoothing removes high frequencies and retains low frequencies whereas denoising , regardless of the frequency content of the signal, attempts to remove whatever noise is present and retain whatever signal is present.

There are various denoising techniques and the methods that are still researched on. In this paper we will deal with wavelet denoising where image is first decomposed into its coefficients using wavelet transformation and then denoising of its coefficients are done applying thresholding methods.

Thresholding removes certain coefficient which falls below a certain value. This depends upon type of method being used.

Wavelet transforms represents a function in building blocks that are computed at various positions and scales. The building blocks are raised through mother wavelet by operations like translation and dilation. [1][2]

Discrete wavelet transform (DWT), a multiresolution analysis of image or signal representation holds a position as a standard for discrete signals and several areas of image processing industry because of its ability to provide both frequency and location details.[9][3]

2. WAVELET DENOISING

The core work on denoising is done by Donoho that is thresholding the discrete wavelet transform of the image. It emphasize on the fact that noise has a fine grained structure in an image and scale based decomposition is done by wavelet transform that helps in noise representation at finer levels. [4]

Following are the steps followed by denoising by wavelet:

1. Wavelet transform is being applied to a image that has noise present. Here the image is decomposed to few coefficients.

2. Now, the coefficients retrieved undergo further processing where denoising method is applied to them based on selected threshold method. The retrieval of coefficients and application of threshold at each level helps identify noise clearly and effectively.

3. Finally after removal of noise from the image, inverse wavelet transform is applied to get a denoised image with retained image quality.

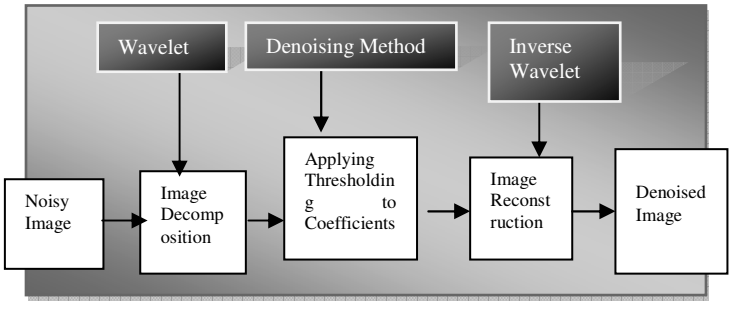

Fig.1 Framework of image denoising using Wavelet

2.1 Hard Thresholding

Hard thresholding is hard on image coefficients where it either keeps the coefficients or kills them without obtaining any average or shrinked value. In this method, the coefficients are compared to an absolute threshold value and any value lower than threshold value are set to zero. It provides an advantage of edge preservation which make it suitable in wavelet decomposition.[8][9]

Hard thresholding rule –

Let A = {x : |x| > λ}, $H\lambda(x) = x \cdot \chi A(x)$

Where χAis the characteristic set function.

2.2 Soft Thresholding

Soft thresholding is an extension of hard thresholding where it does not set the coefficients zero directly rather it shrinks the coefficients. The coefficients above the defined threshold value are shrinked rather then killed. There is a smooth transition between obtained values and deleted values. It helps in avoiding frayed edges of the image. [9]

Soft thresholding rule –

$T\lambda(x) = \text{sgn}(x) \cdot \max(|x|-\lambda, 0)$

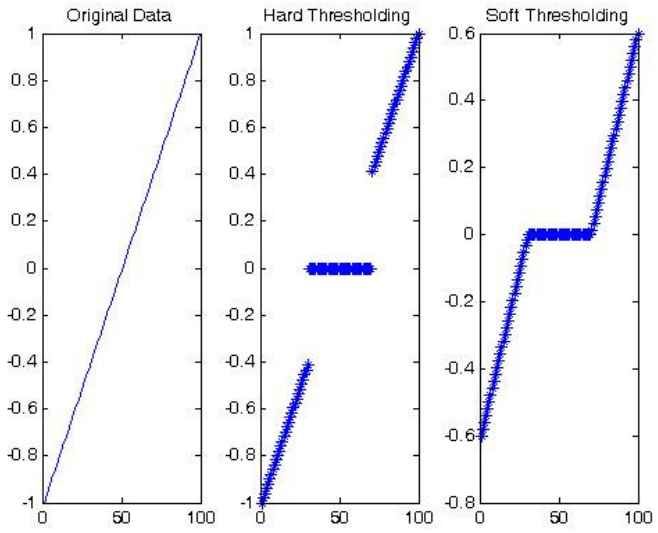

Fig2 Graph representation of hard and soft thresholding

3. THRESHOLDING ALGORITHM

Choosing a threshold is main concerned issue. Careful balance of threshold cut-off is an important aspect as one cannot discard too many coefficients leading to smoothing and neither very few coefficients leading to under smoothed estimate. [4]

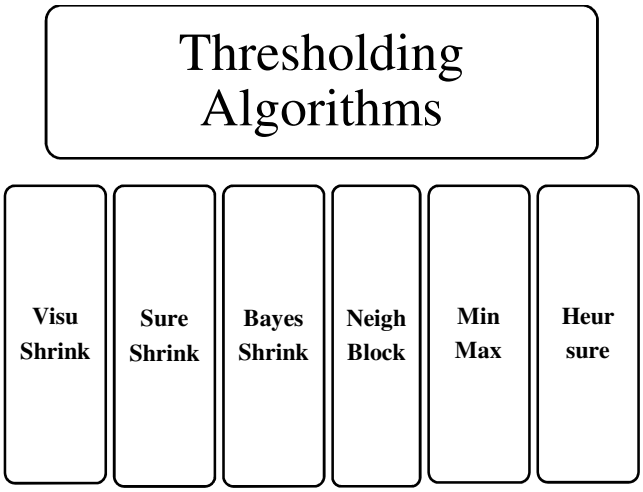

Fig.3 Different Thresholding Algorithms

3.1 Universal/ or Visushrink:

Application of universal threshold in wavelet transform for denoising an image is VisuShrink which is automatic and fast thresholding method. [13]It is quite easy where a simple threshold function is applied to obtained coefficients of the image.

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

Where, R→ noise level and N →length of the noisy signal

Then, as per soft thresholding rule, the coefficients are shrinked that estimate the noiseless signal. Finally the image is reconstructed which is noiseless in nature.

The only drawback with this method is overly smoothed images because of very high value of T. [14]

3.2 Sureshrink

This is combination of the universal threshold and the SURE threshold which is Stein's Unbiased Risk Estimator. It minimizes the mean square error by specifying a threshold value for each level of resolution. This method is a level dependent threshold. [15][16]

The threshold is derived by,

$$SURE(t;x) = d - 2.\#\{i: |x_i| \leq t\} + \sum_{i=1}^{d} (|x_i| \square t)^2$$

Where d→ number of elements in the noisy data vector and xi→ wavelet coefficients.

It takes into account soft threshold rule but thresholds are independently chosen for each sub band by minimizing SURE. SureShrink provides more detailed image, hence giving better results than Visushrink. [14]

3.3 Bayes shrink

This method is best suited for images inculcate with Gaussian noise.[17]. It is soft thresholding approach which is data driven in nature. For each detailed coefficients of wavelet transformed image, a threshold is applied that minimizes the Bayesian risk. Te generalized Gaussian distribution framework is assumed in this context. This method is better than sure shrink when compared with respect to mean square error. Sharp feature retainment is its additive advantage making it more suitable and better.[18][19]

3.4 NeighBlock

The drawback of SureShrink method that is consideration of sparcity where local neighborhood of each coefficient is neglected resulting in biased estimator hence removing many terms from derived coefficients. To overcome this and increase precision of estimation, NeighBlock approach came in the picture that utilizes information of neighboring pixels. Consideration of neighboring pixels helps in deciding the threshold value. This method is best in case of Doppler signal.

3.5 Minimax

In this method, min-max or principle of minimum value and maximum value is considered. A fixed threshold is used for estimating mean square error of coefficients. It is used in designing of estimators because of the fact that the denoised signal assimilates to regression function of estimator. Over set of maximum MSE, estimator finds the minimum value hence discovering optimal threshold. [20]

3.6 Heursure

It is a method that is made by combining SURE and global thresholding method. The drawback of SURE method when applied to signal-to noise ratio being very small resulting in more noises is overcome by heursure method that accounts for a fixed threshold selection by global thresholding method.

4. CONCLUSION

As per the study of different wavelet threshold techniques, each have their own usage and application. Some are best for certain type of images and signals and some for other. Soft thresholding retains image smoothness but do not decrease image size whereas hard threshold decrease size of image. Application area where size is not a criteria, soft thresholding is best suitable. SURE shrink is a common usage of soft thresholding used nowadays. Each threshold type has some betterment over the other. Depending upon the image and area of application, method for denoising can be chosen and applied.

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