IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 18, Issue 6, Ver. III (Nov. - Dec. 2016), PP 01-04
www.iosrjournals.org

Image Denoising with Wavelet Based Thresholding

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Abstract: *Image processing is a field that continues to grow, with new applications being developed at an ever increasing pace. Image Denoising is an important part of image processing and computer vision problems. The important property of a good image denoising model is that it should completely remove noise as far as possible. One of the most powerful and perspective approaches in this area is image denoising using discrete wavelet transform (DWT). As number of levels increased, Peak Signal to Noise Ratio (PSNR) of image gets and Mean Square Error (MSE) get increased . The simulation results reveal that wavelet based method outperforms other methods.*

Keywords – *Image Demising, Discrete Wavelet Transform*

I. Introduction

Applications of digital world such as Digital cameras, Magnetic Resonance Imaging (MRI), Satellite Television and Geographical Information System (GIS) has increased the use of digital images. Generally, data sets collected by image sensors are contaminated by noise. One of the most interesting aspects of this information revolution is the ability to send and receive complex data that transcends ordinary written text. Image information, transmitted in the form of digital images, has become a main method of communication for the 21 century. 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. The majority of image processing techniques involve treating the image as a two-dimensional signal and applying standard signal processing techniques to it. Imperfect instruments, problems with data acquisition process, and interfering natural phenomena can all corrupt the data of interest [4]. Various types of noise present in image are Gaussian noise, Salt &Pepper noise and Speckle noise. Image denoising techniques are used to prevent these types of noises while retaining the important signal features [5]. Spatial filters like mean and median filter are used to remove the noise from image. But the disadvantage of spatial filters is that these filters not only smooth the data to reduce noise but also blur edges in image. Therefore, Wavelet Transform is used to preserve the edges of image [6]. It is a powerful tool of signal or image processing for its multi-resolution possibilities.

II. Wavelet Transform

The Wavelet domain is advantageous because DWT make the signal energy concentrate in a small number of coefficients, hence, the DWT of a noisy image consists of number of coefficients having high Signal to Noise Ratio(SNR) while relatively large number of coefficients is having low SNR. After removing the coefficients with low SNR, the image is reconstructed using inverse DWT [6]. Time and frequency localization is simultaneously provided by Wavelet transform. Moreover, wavelet methods represent such signals much more efficiently than either the original domain or fourier transform [7]. The DWT is same as hierarchical sub band system where the sub bands are logarithmically spaced in frequency and represent octave-band decomposition. Image is decomposed into four sub-bands and critically sampled by applying DWT as shown in Fig. 1. These sub bands are formed by separable applications of horizontal and vertical filters. Sub-bands with label LH1, HL1 and HH1 correspond to finest scale coefficient while sub-band LL1 represent coarse level coefficients [8] [6]. The LL1 sub band is further decomposed and critically sampled to find out the next coarse level of wavelet coefficients as shown in Fig. 1. It results in two level wavelet decomposition.

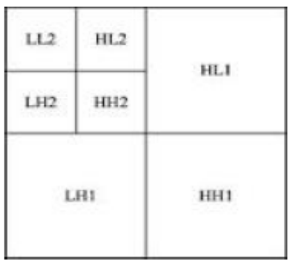

Fig 1: Wavelet Decomposition

III. Wavelet Based Thresolding

The Wavelet thresholding is a signal estimation technique that exploits the capabilities of Wavelet transform for signal denoising. It removes noise by killing coefficients that are irrelevant relative to some threshold [9] .Several studies are there on thresholding the Wavelet coefficients. The process, commonly called Wavelet Shrinkage, consists of following main stages:

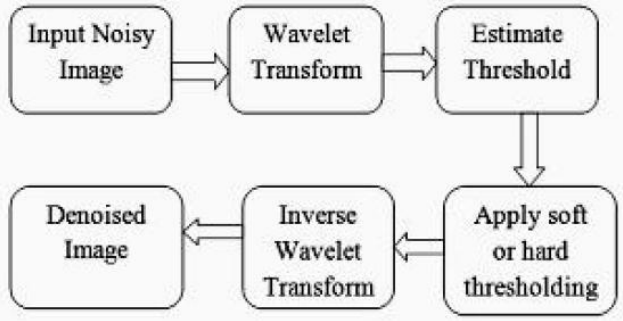

Fig 2: Proposed wavelet based Thresholding

Hard Thresholding:

- The hard thresholding operator is defined as
- Hard threshold is a "keep or kill" procedure and is more intuitively appealing.

The transfer function of the same is shown here.

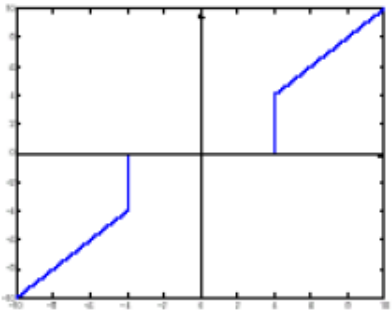

Fig 3: Hard thresholding

Soft Thresholding:

- The soft thresholding operator is defined as
- Soft thresholding shrinks coefficients above the threshold in absolute value.
- The transfer function of the same is shown here.

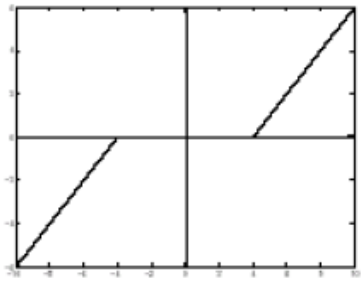

Fig 4: Soft thresholding

IV. Proposed Method

Wavelet thresholding (first proposed by Donoho) is a signal estimation technique that exploits the capabilities of wavelet transform for signal denoising. It removes noise by killing coefficients that are insignificant relative to some threshold. Researchers have developed various techniques for choosing denoising parameters and so far there is no "best" universal threshold determination technique.

Universal or Global Thresholding
- Hard
- Soft

To The steps involved in image denoising using wavelet transform are
- Read the noisy image as input.
- Perform DWT of noisy image and obtain Wavelet coefficients.
- Estimate noise variance from noisy image.

$$D(U, \lambda) = U \text{ for all } |U| > \lambda \quad (1)$$
$$D(U, \lambda) = \text{sgn}(U)\max(0, |U| - \lambda) \quad (2)$$

- Calculate threshold value using various threshold selection rules or shrinkage rules.
- Apply soft or hard thresholding function to noisy coefficients.
- Perform the inverse DWT to reconstruct the denoised image.

The experimental results of an image are shown in the following figure. The figure consists of noisy image and denoisy image using proposed method. The results are computed using MATLAB software. Nearly 20 images are compared with the proposed technique.

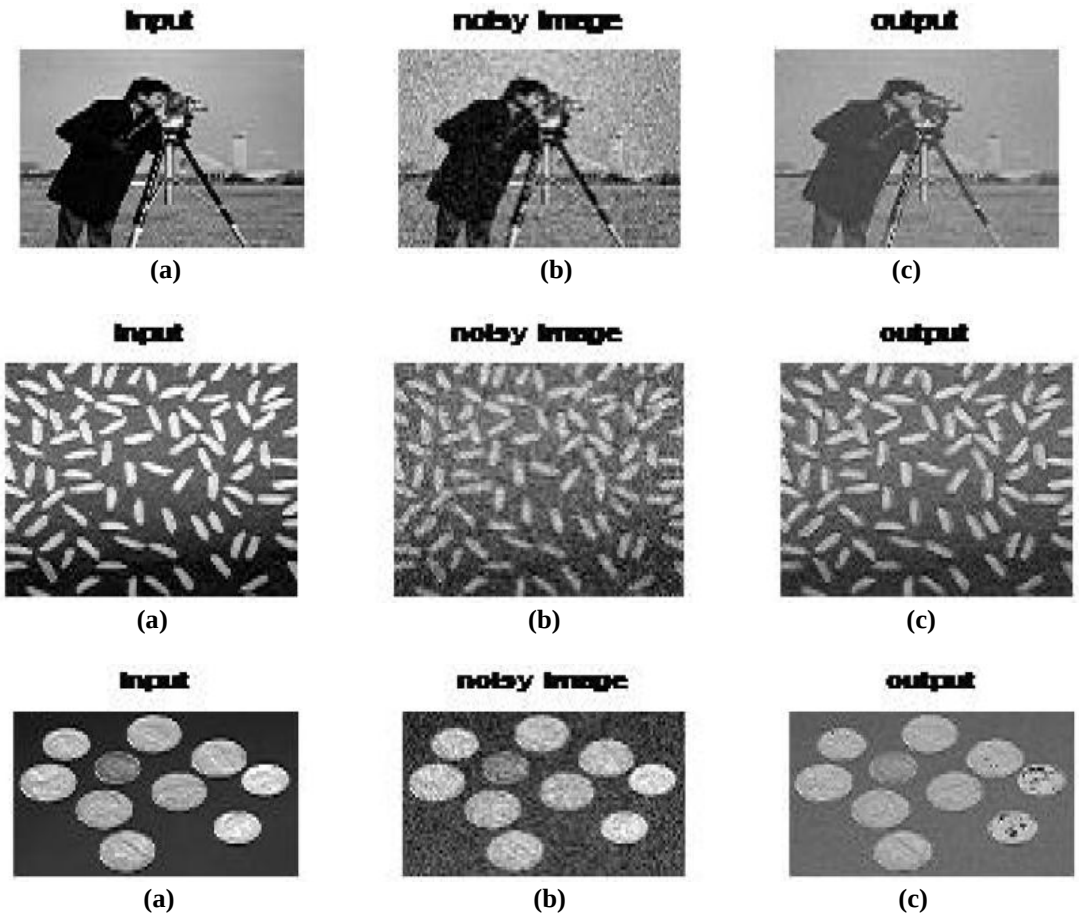

Fig 5 : (a) Input Image (b) Noisy Image (c) Denoised Output

V. Conclusion

This work presents image denoising techniques using wavelet transforms. Filtering is done by hard and soft threhsolding Filter. Experiments are conducted on standard images different noise levels to access the performance of proposed method in comparison to conventional methods for 22 different wavelets. It is verified that our method performs better in denoising of corrupted images by possessing higher PSNR. Currently, most of the images were being analyzed using the same wavelet. This approaches although attractive in its simplicity, but may not fit appropriate to use the same wavelet for all the images. Thus an effort has been made to find the optimal wavelet for denoising the Lena image. It has been found that coif-5 wavelet gives higher PSNR.

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