A Nobel Approach for Denoising Images Corrupted with Salt & Pepper Noise in Wavelet Domain

Atul Kumar Singh[1], Gopal Prasad[2], Prabal Pratap Singh[3]

[1]*Electronics Engineering Department, Kamla Nehru Institute of Technology, Sultanpur, UP, INDIA*

[2] *Electronics Engineering Department, K. P. Engineering College, Agra, UP, INDIA*

[3] *Electronics Engineering Department, ITM University, Gwalior, UP, INDIA*

ABSTRACT

Image denoising involves the manipulation of the image data to produce a clear and high quality image. Selection of the denoising algorithm is depends on the types of images and applications area of images. Hence, it is necessary to have knowledge about the noise present in the image so as to select the appropriate denoising algorithm. Wavelet based filtering approach is Nobel approach for denoising images corrupted with Salt & Pepper noise. This paper proposed the wavelet based filtering approach on the images corrupted with Salt & Pepper noise and performs their study by considering Average, Median and Weiner filters. A quantitative measure of comparison between original image and denoised image is provided by the PSNR (peak signal to noise ratio).

Keywords: Image denoising, Salt and Pepper Noise, Average filter, Median filter, Weiner filter, PSNR (Peak Signal to Noise Ratio).

1. INTRODUCTION

Digital images play an important role in the areas of research and technology such as geographical information systems. It is the most vital part in the field of medical science such as ultrasound imaging, X-ray imaging, CT scans, MRI etc. A very large portion of digital image processing includes image compression, denoising and retrieval. Image denoising is a process of removal or reduction of noise that is incurred during the image capturing. Noise comes from blurring as well as due to analog and digital sources. Blurring is the form of bandwidth reduction of images caused by imperfect image formation process such as relative motion between camera and original scene or by an optical system that is out of focus. Noise is in the form of unwanted signal that interferes with the original signal and degrades the visual quality of digital image. The main sources of noise in digital images are imperfect instruments, problem with data acquisition process, interference natural phenomena, transmission and compression. Image denoising forms the preprocessing step in the field of photography, research, technology and medical science, where somehow image has been degraded and needs to be restored before further processing.

Image denoising is a fundamental problem in the field of image processing. Wavelets give a superior performance in image denoising due to properties such as sparsity and multiresolution structure. With Wavelet Transform gaining popularity in the last two decades various algorithms for denoising in wavelet domain were introduced. The focus was shifted from the Spatial and Fourier domain to the Wavelet domain. Ever since Donoho's Wavelet based thresholding approach was published in [1], there was a surge in the denoising papers being published. Although Donoho's concept was not revolutionary, his methods did not require tracking or correlation of the wavelet maxima and minima across the different scales as proposed by Mallat in [2]. Thus, there was a renewed interest in wavelet based denoising techniques since Donoho demonstrated a simple approach to a difficult problem.

Researchers published different ways to compute the parameters for the thresholding of wavelet coefficients. Data adaptive thresholds [3] were introduced to achieve optimum value of threshold. Later efforts found that substantial improvements in perceptual quality could be obtained by translation invariant methods based on thresholding of an undecimated Wavelet Transform [4]. These thresholding techniques were applied to the non-orthogonal wavelet coefficients to reduce artifacts. Multi-wavelets were also used to achieve similar results. Probabilistic models using the statistical properties of the wavelet coefficient seemed to outperform the thresholding techniques and gained ground. Recently, much effort has been devoted to Bayesian denoising in Wavelet domain. Hidden Markov Models and Gaussian Scale Mixtures have also become popular and more research continues to be published.

In this paper wavelet based filtering approach for denoising of images which are corrupted by Salt and Pepper noise is presented. Denoising process is carried out by Average, Median and Weiner filters. The rest of the paper is divided in the various sections. Section 2 briefly explains Salt and Pepper noise. Section 3 presents the Wavelet theory. Section 4 gives experimental results and analysis followed by conclusions and references.

2. SALT AND PEPPER NOISE

Salt and pepper noise [5] is an impulse type of noise, which is also referred to as intensity spikes. This is caused generally due to errors in data transmission. It has only two possible values *a, b*. The probability of each is typically less than 0.1. The corrupted pixels are set alternatively to the minimum or to the maximum value, giving the image a "salt and pepper" like appearance. Unaffected pixels remain unchanged. For an 8-bit image, the typical value for pepper noise is 0 and for salt noise 255. The salt and pepper noise is generally caused by malfunctioning of pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process.

3. WAVELET THEORY

Mean Filter

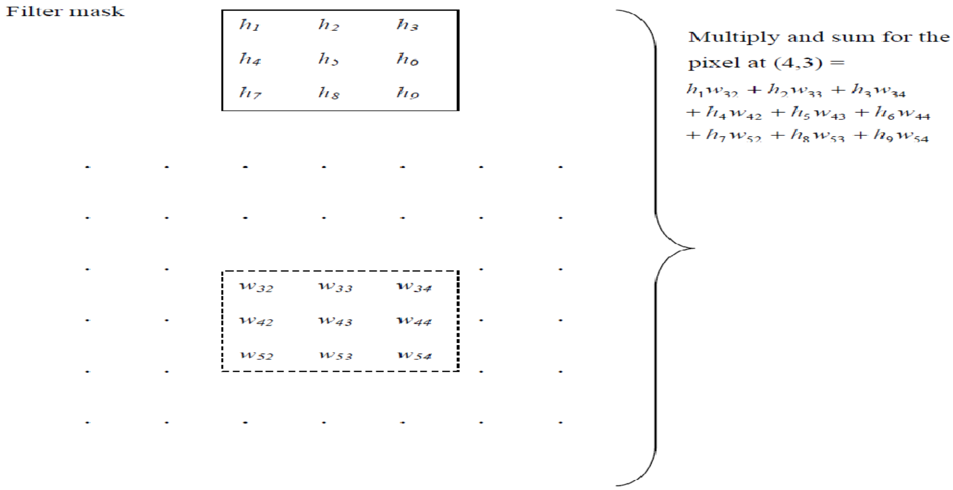


Fig. 1 Multiply and sum process

A mean filter [6] acts on an image by smoothing it; that is, it reduces the intensity variation between adjacent pixels. The mean filter is nothing but a simple sliding window spatial filter that replaces the center value in the window with the average of all the neighboring pixel values including it. By doing this, it replaces pixels that are unrepresentative of their surroundings. It is implemented with a convolution mask, which provides a result that is a weighted sum of the values of a pixel and its neighbors. It is also called a linear filter. The mask or kernel is a square. Often a 3× 3 square kernel is used. If the coefficients of the mask sum up to one, then the average brightness of the image is not changed. If the coefficients sum to zero, the average brightness is lost, and it returns a dark image. The mean or average filter works on the shift-multiply-sum principle. This principle in the two-dimensional image can be represented as shown in Figure 1.

The mask used here is a 3× 3 kernel. Note that the coefficients of this mask sum to one, so the image brightness is retained, and the coefficients are all positive, so it will tend to blur the image.

Median Filter

A median filter [7] belongs to the class of nonlinear filters unlike the mean filter. The median filter also follows the moving window principle similar to the mean filter. A 3× 3, 5× 5, or 7× 7 kernel of pixels is scanned over pixel matrix of the entire image. The median of the pixel values in the window is computed, and the center pixel of the window is replaced with the computed median. Median filtering is done by, first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. Note that the median value must be written to a separate array or buffer so that the results are not corrupted as the process is performed. Figure 2 illustrates the methodology.

Neighborhood values: 115,119,120,123,124,125,126,127,150
Median value: 124

The central pixel value of 150 in the 3×3 window shown in Figure 3.6 is rather unrepresentative of the surrounding pixels and is replaced with the median value of 124. The median is more robust compared to the mean. Thus, a single very unrepresentative pixel in a neighborhood will not affect the median value significantly. Since the median value must actually be the value of one of the pixels in the neighborhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason the median filter is much better at preserving sharp edges than the mean filter. These advantages aid median filters in denoising uniform noise as well from an image.

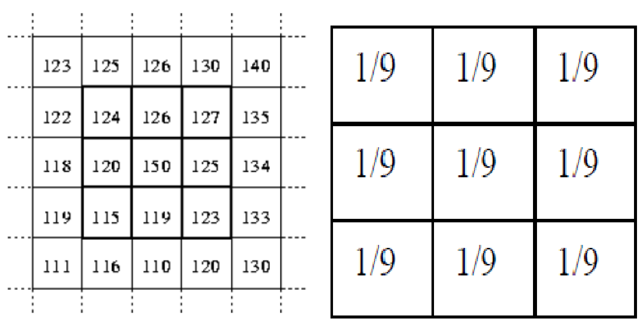


Fig. 2 Concept of median filtering

4. RESULTS AND ANALYSIS

Peak Signal to Noise Ratio (PSNR)

The experimental evaluation is performed on "Lena" image of size 512 X 512 pixels at different noise strength using different filtering approach. The objective quality [8] of the reconstructed image is measured by equation (1) as,

$$PSNR = 10\log_{10}\frac{255^2}{mse} \quad (1)$$

where *mse* is the mean square error between the original (i.e. *x*) and the de-noised image (i.e.) with size *M* x *N* can be expressed by equation (2) as,

$$mse = \frac{1}{M\times N}\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j)-\hat{x}(i,j)]^2 \quad (2)$$

Below table 1 shows PSNR of "Lena" image at different noise levels using different filtering approach.

Table 1: PSNR for Salt and Pepper Noise

Noise Strength (d)	0.01	0.05	0.1	0.3	0.6	0.8	1
Median Filter (PSNR)	35.15	34.41	33.27	23.53	12.42	8.16	5.48
Average Filter (PSNR)	30.12	26.34	23.73	18.86	15.10	13.40	12.04
Wiener Filter (PSNR)	27.55	23.98	22.55	19.62	16.55	14.85	13.44

For Median Filter d=0.05


Original Image


Noisy Image


Denoised Image

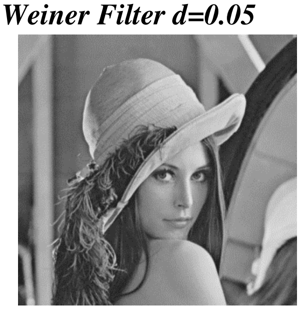
For Average Filter d=0.05


Original Image


Noisy Image


Denoised Image

For Weiner Filter d=0.05


Original Image


Noisy Image


Denoised Image

5. CONCLUSIONS

A large number of wavelet based image denoising methods have been proposed in recent years. These methods are mainly reported for image such as Lena.

From the experimental and mathematical results it can be concluded that PSNR is basically a comparison between original and de-noised image as how the de-noised image is close to original image. Tables 1 shows the peak signal to noise ratio (PSNR) of smooth image like 'Lena' by using Average, Median and Weiner filters. From the tables 1 we can conclude that the median filter is optimal compared to mean filter and weiner filter. It produces the maximum PSNR for the output image compared to the linear filters considered. The weiner filter proves to be better than the mean filter but has more time complexity. Since selection of the right denoising procedure plays a major role, it is important to experiment and compare the methods. As future research, we would like to work further on the comparison of the denoising techniques. If the features of the denoised signal are fed into a neural network pattern recognizer, then the rate of successful classification should determine the ultimate measure by which to compare various denoising procedures. Besides, the complexity of the algorithms can be measured according to the CPU computing time flops. This can produce a time complexity standard for each algorithm. These two points would be considered as an extension to the present work done.

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