International Journal of Engineering Research and General Science Volume 4, Issue 2, March- April, 2016
ISSN 2091-2730

De-noising Techniques for Biomedical Images

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Abstract—In Medical imaging system, biomedical images reveal internal structures hidden inside human body. It is also used for diagnosis of diseases. Database of such images used for research work.These images mayget corrupted by noise during acquisition and transmission due to patient movement, inaccurate instrumental setup, surrounding noise, etc.Thesenoisy effects decrease the performance of visual and computerizedanalysis. As biomedical images contains many important details, such noises are unwanted and hence to be removed while processing. Many approaches have been proposed to removesuch noises. Mainly two approaches are used for de-noising of biomedical images:isfilter based and second is Wavelet based.This paper surveys these techniques and provides comparative analysis depending on different parameters. Filter based techniques are conventional like averaging filter,median filter, Wiener filter, adaptive filter, etc. while Wavelet-based technique is anadvanced technique used in de-noising of biomedical images.

Keywords—Image de-noising, Median filter, Wiener filter, Wavelet Thresholding, PSNR, Discrete Wavelet Transform, Hard Thresholding, Soft thresholding

I. INTRODUCTION

An image plays an important role in the area of research and technology like Bio-medical images in Medical imaging system. But during Acquisition, Processing and Transmission, an image will inevitably be mixed with a certain amount of noise which deteriorates the quality[7].In the diverse fields, scientists are faced with the problem of recovering original images from such noisy images. So, it is necessary to deal with image noise in order to deal with a high level processing which required in bio-medical applications like PET scan, CT scan, MRI scan, etc. The removing of noise from any affected image is called asde-noising which remove the noise and retain the important image features as much as possible[12]. According to actual image characteristic, noise statistical property and frequency spectrum distribution rule, Researchers have developed many methods of eliminating noises. Traditionally, we can find many noise reduction methods, many of them are in spatial or frequency domain by filtering. Spatial Low-pass filters smooth away noise but also blur edges in images while the high-pass filters can make edges even sharper and improve the spatial resolution but also amplify the noisy background[2].In the recent years there has been a fair amount of research on wavelet thresholding and threshold selection for image de-noising. Wavelet analysis is a time-frequency analysis method used on the concept of wavelet transform with good time-frequency localization, so it has been widely applied in the field of image de-noising [8].There are different wavelet thresholding approaches out of which hard and soft thresholding are well-known. This paper makes comparative study between such thresholding techniques and different several standard filters that are largely used for noise suppression.

II. TYPES OF NOISE

Noise produces undesirable effects such as unseen lines, corners, blurred objects and disturbs background scenes etc There are the four types of noise categories in an image: 1.Gaussian noise; 2.Salt and pepper noise; 3.Poisson noise; 4.Speckle noise[1].

1. Gaussian noise : Gaussian noise is also called as electronic noise as it arises in amplifiers or detectors. This noise is additive in nature which is caused by thermal noise. Gaussian noise is independent at each pixel and signal intensity. Gaussian noise equally affects each and every pixel of an image [5].

2. Salt and pepper noise: It is also called as impulsive noise generated during data transmission. Image pixel values are replaced by corrupted pixel values either maximum 'or' minimum pixel value. The maximum or minimum values are dependent upon the number of bits used. Here, corresponding value for black pixels is 0 while for white pixels it is 1.
The salt and pepper noise is generally caused by faulty of pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process[5].

3. Poisson Noise: It is also called as quantum (photon) noise or shot noise. The poisson noise is appeared due to the statistical nature of electromagnetic waves such as x-rays, visible lights and gamma rays.

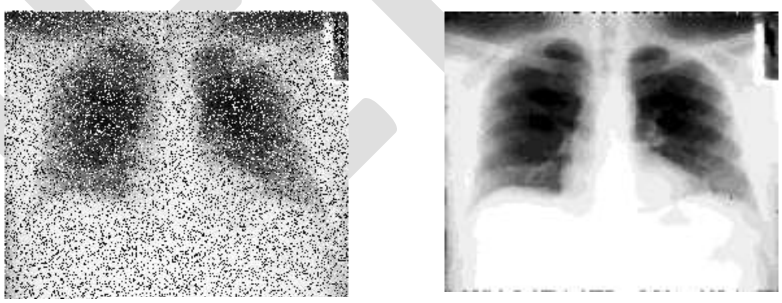
4. Speckle noise: Speckle is a granular 'noise' that inherently exists in and degrades the quality of the medical ultrasound and optical coherence tomography images. Speckle noise results from the patterns of constructive and destructive interference shown as bright and dark dots in the image

III. DE-NOISING TECHNIQUES

Different types of Filtering techniques and Wavelet thresholding techniques are used for image de-noising.
Wavelet transform has been used as a good image representation and analysis tool mainly due to multi-resolution analysis, data separability, compaction and sparsity features in addition to statistical properties. Image de-noising based on the wavelet transform is mainly completed by wavelet thresholding in wavelet domain. There are two types of wavelet thresholding: 1. Soft thresholding 2. Hard thresholding.

A. FILTER BASED IMAGE DE-NOISING

- **Median Filter**: The median filter is a nonlinear digital filtering technique, used to remove noise in image. Median filtering is very widely used in digital image processing because; it preserves edges while removing noise able to remove noise. Hence, there is no reduction in the sharpness of the image.But when noise density exceeds 50% in an image, the edge details of the original image cannot be preserved by standard median filter.Comparatively, its performance is not that much better than Gaussian blur for high levels of noise, whereas, for speckle noise and salt and pepper noise (impulsive noise), it is particularly effective.



(a) (b)

Figure 1: a) Biomedical Image with Salt and pepper noise b) Median filtered image

- **Wiener Filter**: Wiener filter is a linear filter. It is used to deblur an image. It preserves the edges and other frequency parts of an image. It uses pixel wise adaption; hence this technique is also called as adaptive filtering technique [5].It minimizes the mean square error (MSE) between the estimated random process and the desired process. Wiener de-convolution can be useful when the point-spread function (PSF) and noise level are known or can be estimated.

- **Gaussian Filter:** It is a low pass filter whose impulse response is a Gaussian function. Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time. It filters the input signal using a Gaussian FIR filter. It smoothes the image in order to remove the noise in prior to apply canny edge detection algorithm.

B. Wavelet based image de-noising

The simpler way to remove noise or to reconstruct the original image using the wavelet coefficients used the result of decomposition in wavelet transform, is to eliminate the small coefficient associated to the noise[1].

Wavelet threshold de-noising has three steps as follows:

1) An image is decomposed into multi-scale wavelet transform.
2) Setting a certain threshold, thus the wavelet coefficients are processed to remove noise as much as possible, eliminate the smaller wavelet coefficient, and larger wavelet coefficients retained.
3) Taking inverse wavelet transform.

There are two methods of processing of wavelet coefficients has hard threshold and soft threshold.

i. Soft Threshold: Soft threshold is the absolute value of the signal compared with the threshold value, if the absolute value is greater than the threshold becomes the product, the sign function of the absolute value multiplied with the difference of the threshold and the absolute value i.e. Soft threshold shrinks coefficients above the threshold in absolute value. The false structures in hard thresholding can overcome by soft thresholding[1].

$$\hat{W}_{j,k} = \begin{cases} \operatorname{sgn}(W_{j,k})(|W_{j,k}| - \lambda), & \text{if } |W_{j,k}| \geq \lambda \\ 0, & \text{otherwise} \end{cases} \qquad \text{...................(1)}$$

ii. Hard Threshold: Hard threshold is a "keep or kill" procedure. Hard threshold is the absolute value of the signal compared with the threshold. It is less than or equal to the threshold point becomes zero, and the point is greater than the threshold unchanged [8].

$$\text{..................(2)} \qquad \hat{W}_{j,k} = \begin{cases} W_{j,k}, & \text{if } |W_{j,k}| \geq \lambda \\ 0, & \text{otherwise} \end{cases}$$

The Bayes Shrink method is one of the wavelet based approach to remove noise from biomedical image. It has been attracting attention recently as an algorithm for setting different thresholds for every sub band. Bayes Shrink uses soft thresholding. The purpose of this method is to estimate a threshold value that minimizes the Bayesian risk assuming Generalized Gaussian Distribution (GGD) prior [13].

$$t_B = \sigma^2 / \sigma_S \qquad \text{...................(3)}$$

Where σ^2 is the noise variance and σ_S is signal variance without noise.

From the definition of additive noise we have,

$$w(x, y) = s(x, y) + n(x, y) \text{.............(4)}$$

Since the noise and the signal are independent of each other, it can be stated that,

$$\sigma_w^{\ 2} = \sigma_S^{\ 2} + \sigma^2 \text{ ....(5)}$$

$\sigma_w^{\ 2}$ can be computed as shown below:

$$\sigma_w^{\ 2} = \frac{1}{n^2} \sum_{x,y=1}^{n} w^2(x,y) \qquad \text{.........(6)}$$

The variance of the signal, $\sigma_S^{\ 2}$ is computed as,

$$\sigma_s = \sqrt{\max(\sigma_w^{\ 2} - \sigma^2, 0)} \qquad \text{..........(7)}$$

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{255^2}{MSE}\right)\ \mathrm{db} \qquad \text{..........(8)}$$

$$\mathrm{MSE} = \frac{1}{MN}\sum_{i=1}^{M}(\mathrm{x,y})\sum_{j=1}^{N}\left(\mathrm{X(i,j)} - P(i,j)\right)^2 \qquad \text{.........(9)}$$

V. COMPARISON OF WAVELET THRESHOLDING & FILTER BASED DENOISING TECHNIQUES:

PSNR (PEAK SIGNAL TO NOISE RATIO)				
NOISE	NOISE VARIANCE	MEAN FILTER	MEDIAN FILTER	BAYES SHRINK
GAUSSIAN NOISE	0.001	24.0598	25.4934	33.7031
	0.002	23.2251	24.3480	29.9001
	0.003	22.5261	23.4147	27.7650
	0.004	21.9796	22.6049	26.0865
	0.005	21.4536	22.0205	25.1235
	0.01	19.5569	19.7703	22.0446
SPECKLE NOISE	0.001	24.8274	26.6157	44.0220
	0.002	24.5114	26.1260	40.0535
	0.003	24.2207	25.6708	38.3935
	0.004	23.9316	25.2771	35.6827
	0.005	23.7015	24.8599	34.3460
	0.01	22.6357	23.4053	30.9207

Table 1: Comparison of Filtering and Wavelet based approaches based on PSNR values [13]

VI. CONCLUSION

This paper surveys different techniques of image denoising based on filter based and Wavelet based approach. Each method has its merits and demerits based on different parameters like PSNR, MSE, etc. After comparing these methods as shown in table 1, it is observed that Bayes shrink method is more suitable for biomedical image denoising as it has better PSNR values for particular noise variance than other filter based methods. But it is more complex than filter based approach. Hence, to achieve good performance, it is necessary to combine Bayes shrink approach and Filter based techniques.

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