Comparative Evaluation of Rician Noise Denoising Techniques for MRI Images

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***Abstract*—Image processing plays an important role in Brain tumor detection. MRI images are usually preferred for brain tumor analysis. These images are highly affected by Rician noise. Images should be noise free becausenoisy image analysis results in poor accuracy. Comparative evaluation of denoising techniques is carried out where the Median filter, Weiner filter, Hard Wavelet Transform and Soft Wavelet Transform are used. Filter performance is evaluated by Mean Square Error and Peak Signal to Noise Ratio. Hard Wavelet Transform is proved to be the best filtering technique for Rician noise removal.**

***Index Terms*— Brain Tumor, Image processing, MRI, Filtering, Rician noise.**

I.INTRODUCTION

The brain tumor is a clot of the cell which can be or non-cancerous. Early detection of tumor is essential to carry out medical treatment. Most of the doctors prefer MRI images of the brain to carry out analysis. These MRI images are highly affected by Rician noise[4]. This noise affected images if used for further processing, it might affect its accuracy. Denoising of an image hence plays a very important role in image processing.

Denoising is carried out byfiltering techniques. There are various filtering techniques available but the resultant filtered image is prone to edge blurring and over smoothing. Maintaining the image features while carrying out image filtering is of extreme importance. Image denoising can be divided into two domain spatial and frequency. In the spatial domain, the operation takes place directly on the pixel while in a frequency domain operation is carried out on Fourier transform of a respective image[10]. The spatial domain denoising techniques include the Mean filter, Median filter, Average filter, Weiner filter while frequency domain denoising includes Fourier transform and Wavelet transform [3].

In this paper, comparison is carried out between spatial domain methods which include Median filter and Weiner filter and frequency domain methods which include Hard wavelet transform and Soft wavelet transform.

The comparative study of filtering techniques is provided as follows:

Section II deals with the information of images that are used to carry out this analysis.

Section III deals with the kind of noise in MRI images.

Section IV deals with the filtering techniques.

Section V carries out the performance evaluation of the filtering techniques and determines the advantage of each.

II.IMAGES AND DATABASE

Brain tumor images can be MRI images or CT scan images. Doctors usually prefer MRI images over CT scan. This is because ionizing radiations are not used while carrying out MRI imaging besides MRI image depicts anatomy and evaluate structure in much greater details as compared to CT scan[14]. MRI images are therefore used for carrying out an evaluation of filtering techniques.

III. RICIAN NOISE

Gaussian Noise, Salt Pepper Noise, Speckle Noise, Poisson Noise, Rician noise are different noise present in images. MRI images are highly affected by Rician noise[4].

Rician noise displays varying probability distribution function depending on image SNR. Higher SNR follows Gaussian distribution while lower SNR follows Rayleigh distribution

The pdf of Rician noise is –

$$p(x) = \frac{x}{\sigma^2} \exp\left(-\frac{x^2 + A^2}{2\sigma^2}\right) I_0\left(\frac{xA}{\sigma^2}\right) \qquad (1)$$

Where A is Amplitude of the signal without noise,σ *is* a standard deviation of the Gaussian noise, Io -zeroth order Bessel function, x is the value in magnitude image.

We have used MATLAB to add rician noise to the MRI image.

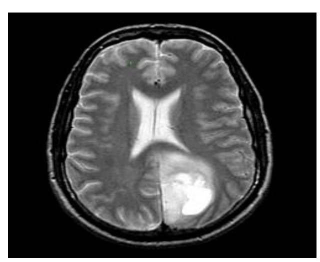

Fig 3.1 Original image

Fig 3.2: Image effected by Rician noise

Fig 3.1 is the MRI image and Fig 3.2 shows an image which is affected by 20% rician noise.

IV. FILTERING TECHNIQUES

The noise affected image is then subjected to the filtering techniques. Filtering techniques used are Median filtering, Weiner filtering which are spatial domain filtering techniques and Hard wavelet transform and Soft wavelet transform which are frequency domain filtering technique.

A Median filter is a nonlinear filter. It is also called as order statistical filter.A window is moved over the image, the pixels in the window are then sorted in the ascending order and the median value is calculated which is then used as the output pixel value. A Median filter allows high spatial frequency detail to pass. Thus they are less effective in denoising image affected by complex Gaussian noise.

Weiner filter is a linear filter. Weiner filtering is carried out by estimating the power spectra of the original image and the additive noise.Consider X(n,m) be the noisy image, Discrete Fourier Transform is used to determine X(u,v).The original image spectrum is then obtained by multiplying the X(u,v) with Weiner filter function G(u,v)[5]. The Weiner filter function G(u,v) can be given by

$$G(u,v) = \frac{H*(u,v)Ps(u,v)}{|H(u,v)|^2 Ps(u,v) + Pn(u,v)} \qquad (2)$$

Where H(u,v) is the Fourier transform of the point spread function.Ps(u,v) is the Power spectrum of the signal processobtain by taking Fourier transform of signal autocorrelation function and Pn(u,v) is the Power spectrum of the noise processobtain by taking Fourier transform of signal autocorrelation function[5].

This kind of filter optimization reduces the mean square value present in image thus reducing error.

In Frequency domain, hard wavelet transform and soft wavelet transform with two level of decomposition are used. In wavelet transform, multilevel wavelet decomposition is performed. The discrete wavelet transform splits up the signal into lowpass subband and high pass sub band. An analysis is then carried out to determine the suitable thresholding technique. The detail coefficient is then subjected to threshold and reconstruction is then carried out.

The universal thresholding technique is used for calculating the threshold.

$$\lambda_j = \delta\sqrt{2\log(N)} \Big/ \sqrt{log_2^{j+1}} \qquad (3)$$

Wavelet thresholding is divided into two categories hard and soft wavelet thresholding. In both thresholding, the coefficient less then the threshold is set to zero. The difference between hard wavelet and soft wavelet is that in hard wavelet the coefficient greater then threshold are left unchanged while in soft wavelet the coefficient greater than the threshold is reduced by the threshold value.

Hard thresholding- $y = x \quad if\ |x| > \lambda$ (3)

$y = 0 \quad if|x| < \lambda$

Soft thresholding- $y = sign(x)(|x| - \lambda)$ (4)

Where y is the output signal, x is the input and λ is the threshold value.

V. EVALUATION AND RESULTS

The following images show the filtered output.

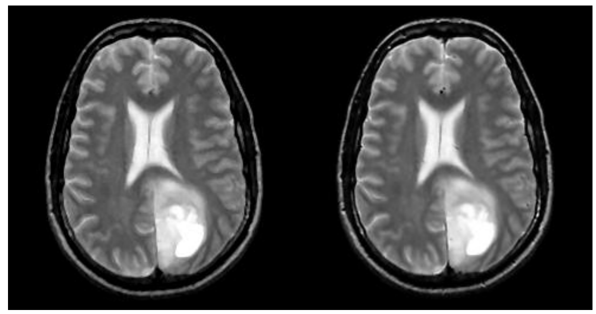

Fig 5.1Image after Median Filtering Fig 5.2Image after Weiner Filtering

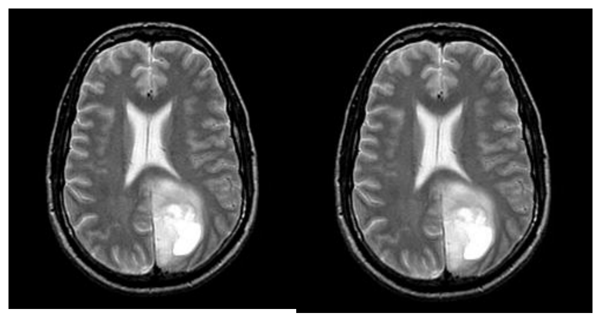

Fig 5.3 Image after Hard Wavelet T/FFig 5.4 Image after Soft Wavelet T/F

The performance of the filtering technique is carried out on basis of Mean Square Error(MSE) and Peak Signal to Noise Ratio(PSNR).

The quality of reconstruction is determined by PSNR and depends on MSE. Higher the value of PSNR better is the quality of the image.MSE should be small in this case.

MSE is given by following formula-

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2 \qquad (5)$$

Where m,n are total pixels in x and y coordinate, $f(i,j)$ is the original image while $g(i,j)$ is the denoised image.

PSNR ratio is given by formula –

$$PSNR = 20log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right) \qquad (6)$$

Where MAX_f is maximum pixel value while MSE is Mean Square Error

The following table provides the comparative analysis of the filtering technique based on PSNR and MSE.

Method	PSNR	MSE
Median Filter	32.43db	36.78db
Weiner Filter	37.02db	16.32db
Soft wavelet transform	50db	3.3db
Hard wavelet transform	64.23db	2.92db

Fig. 5.1 Comparison of filtering techniques

VI. CONCLUSION

In this paper, the main focus is on Rician noise filtering. Four different techniques from different background are selected which include a Nonlinear Median filter, Linear Weiner filter, and Wavelet Transform filtering with hard and soft thresholding.

MSE is maximum and PSNR is minimum in a Median filter. This method is not suitable for rician noise filtering. On the other hand, MSE is minimum and PSNR is maximum in Hard wavelet transform. This method thus proves to be the best technique for Rician noise filtering in MRI images.

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