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Implementation and Comparison of Various Filters for the Removal of Fractional Brownian Motion Noise in Brain MRI Images

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Abstract: Recently in all medical imaging systems, noise plays a dominant role in suppressing the useful information needed for diagnosis and hence, doctors are finding a great difficulty in analyzing the progression of the disease. This paper deals with removal of one such noise, namely fractional Brownian motion noise by using various filters such as mean filter, alpha trimmed mean filter, contra harmonic mean filter, wiener filter and homomorphic filter. The performance of all these filters are compared using evaluation metrics such as PSNR (Peak Signal to Noise Ratio), MSE (Mean Square Error), NAE (Normalized Absolute Error) and the time elapsed to filter the noisy image. Among all the filters, homomorphic filter proves to be better in terms of PSNR, MSE, NAE and time elapsed.

Key Words: Alpha trimmed mean filter**,** contra harmonic mean filter, exponential, homomorphic filter, logarithmic transform, mean filter, wiener filter.

1 INTRODUCTION

Image processing is the field of science, which deals with the processing of raw images into a form which is suitable for us to process the image further. Generally, image processing can be categorized into image segmentation, image enhancement, image compression and image restoration. Of this, image restoration forms a major part in the image processing. Image restoration is the removal of noise from the noise affected image and this gives a clean image, which is free from noise.

Generally, noise is a form of unwanted signal or an interruption, which makes the image appear blurred and noisy. Noisy image tends to reduce the details of the image which are very much needed to diagnose the image. Noise comes as an external disturbance or an internal disturbance. Noise mainly arises during transmission of the image from the transmitter to the receiver or it may arise during the acquisition of the image by the intended receiver. Various other sources are also available in the literature [1], [2], [3]. Noise may be a form of bandwidth reduction of an image which leaves a blurred image.

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There are various types of noises such as salt and pepper noise, Gaussian noise, Poisson noise, speckle noise and Brownian noise. Each noise has its own effects and results on the original image and each noise has its own source of origin. There are two types of noise models, namely the additive noise model and the multiplicative noise model. The rule for additive noise is given by,

$$F(u,v) = S(u,v) + N(u,v) \quad (1)$$

And the rule for the multiplicative noise model is given by,

$$F(u,v) = S(u,v) \times N(u,v) \quad (2)$$

Where F (u,v) is the original noisy image, S(u,v) is the original noise free image and N(u,v) is the noise present in the image S(u,v). All the image restoration techniques aim at removing the noise N (u,v) and restoring the original image S(u,v) as such, preserving all features and to make the image more suitable for further analysis.

Filters are used for removing noises in image and in general they can be classified as linear filters and nonlinear filters. Examples of linear filters include averaging filter and the filters for removing Gaussian noise. They tend to blur the image as much as possible. The nonlinear filtering technique includes mean filter, median filter and so on. Mean filter simply replaces the center pixel value with the mean value of the surrounding pixels. And the median filter replaces the center pixel value with the median value of all the pixels. Various other filters are also available such as homomorphic filter, max-min filter, box filter and so on. Various noises and filters are discussed in [4], [5], [6]. This paper implements five filters namely, mean filter, alpha trimmed mean filter, contra harmonic mean filter, wiener filter and homomorphic filter. All these filters are implemented to remove fractional Brownian motion noise which occurs in brain MRI (Magnetic Resonance Imaging) images and is a low density noise and it cannot be visually seen.

This paper is organized as follows. Chapter 2 deals with the background work of this paper. Chapter 3 deals with the implemented filters such as mean filter, alpha trimmed mean filter, contra harmonic mean filter, wiener filter and homomorphic filter. Chapter 4 deals with the experimental results. Performance comparison of all these filters are given in chapter 5 and Conclusion and future works are given in the chapter 6.

2 BACKGROUND STUDY

In [7], image denoising produces visually high quality images and larger part of image processing involves image denoising or image restoration. Noise degrades the visual quality and blurring decreases the bandwidth of the image. Sources of noise are due to imperfect instruments, due to data acquisition process and interference due to transmission and compression. Here two types of noise models, namely additive noise model and the multiplicative models. There are various types of noises such as Gaussian, salt & pepper, speckle and Brownian noise. Among all, Brownian noise comes under fractal or 1/f noise and its mathematical model is called fractional Brownian motion (fBm). Various types of filters are proposed for the above mentioned noises. They are broadly classified into the spatial domain filtering and transform domain filtering. The mean and median filter comes under spatial filters while adaptive and non-adaptive filters come under transform filters. Among all, wavelet domain filtering proves to be the best in removing all kinds of noises.

In [8], noise reduction is necessary to retain image in its best quality. Noise reduction is applicable in various fields such as astronomy, medical images and forensic sciences. In this paper four noises are mentioned such as Gaussian noise, salt & pepper noise, speckle noise and brownian noise. Brownian noise comes under non-stochastic process and it follows the normal distribution. Brownian noise is obtained by integrating white noise and hence it is evident that Brownian noise is additive since white noise is also additive in nature. Different filters are proposed and among that, AWMF (Adaptive Weighted Median Filter) is the enhanced form of median filter. Butterworth filter has maximal frequency response whereas, the ideal filter allows the specified frequency range to pass through. Homomorphic filtering is used to remove the multiplicative noise. Wavelet transform expresses the function in the form of wavelet and here the analysis is done in both frequency and time scales and it is found to remove the noise better.

3 IMPLEMENTED FILTERS

Recently in all medical imaging systems, noise plays a dominant role in suppressing the useful information needed for diagnosis and hence, doctors are finding a great difficulty in analyzing the progression of the disease. This paper deals with removal of one such noise, namely fractional Brownian motion noise by using various filters such as mean filter, alpha trimmed mean filter, contra harmonic mean filter, wiener filter and homomorphic filter. The performance of all these filters is compared using evaluation metrics such as PSNR (Peak Signal to Noise Ratio), MSE (Mean Square Error), NAE (Normalized Absolute Error) and the time elapsed to filter the noisy image. Among all the filters, homomorphic filter proves to be better in terms of PSNR, MSE, NAE and time elapsed.

3.1 Proposed Approach

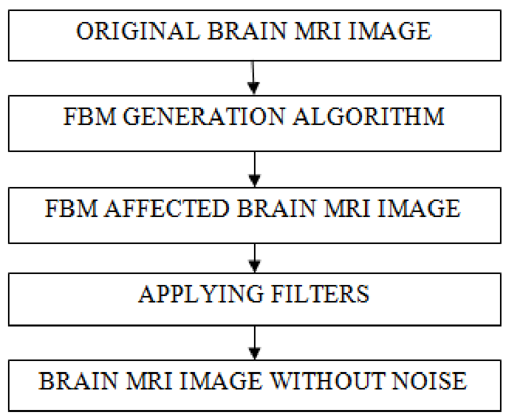

Figure1. Flow Diagram for the Proposed Approach

The flow diagram for the proposed approach is given in the figure 1. Initially the original brain MRI image is given to the noise generation algorithm. This gives us an fBm affected image and this is passed onto the intended filters. Finally fBm is removed after passing the noisy image on to the filters.

3.2 Filters Used

Mean filter is a simple filter and it replaces the center value of the pixel with the mean value of the surrounding pixels including the center pixel value. Generally the kernel in a mean filter is in square shape and it can be designed to be in any shape. This helps to smooth the pixels and it reduces noise in an image. It also reduces the intensity values between a given pixel in the image and its neighboring pixel. This works similar to convolution. The main drawback with mean filter is that, it tends to over smooth the image when removing noises present in the image. Alpha trimmed mean filter is a nonlinear filter and it is the combination of mean and median filter. It will discard the typical values of the image and filters the image with the remaining values. The window is placed over the elements, and the elements are ordered and filtering is carried out. The contra harmonic mean filter uses a complementary function of the harmonic filter. Wiener filter is a linear time invariant filter. It assumes a known stationary signal and a noise.

In homomorphic filter, all the components can be filtered individually and hence this filters the noisy image better when compared to other filters. Initially noisy image is subjected to logarithmic transform followed by FFT (Fast Fourier Transform). Then, homomorphic filter is applied, which is followed by inverse FFT and exponential operation. Finally filtered image is obtained. This filter has optimum values for all the performance evaluation metrics.

4 EXPERIMENTAL RESULTS

The fBm affected image is passed into the filters mentioned above and the simulation is done through MATLAB R2013a. The simulation results for the implemented filters are shown in the Figure 2. Figure 2a shows the original brain MRI image. Figure 2b shows the fbm affected image. Figure 2c shows the filtered image using mean filter. Figure 2d shows the filtered image using alpha trimmed mean filter. Figure 2e shows the filtered image using contra harmonic mean filter. Figure 2f shows the filtered image using wiener filter. Figure 2g shows the filtered image using homomorphic filter.

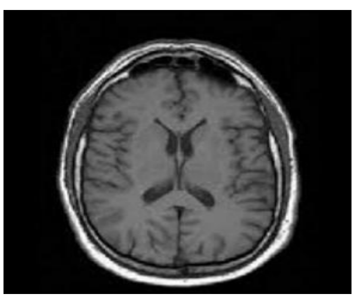

Figure 2a. Original Brain MRI Image

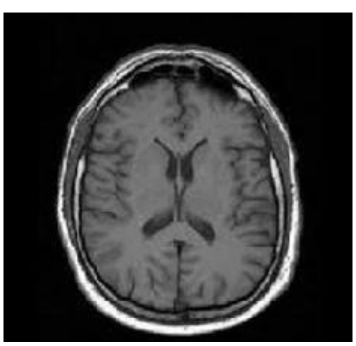

Figure 2b. Noisy Image Added with fBm

Figure 2c. Mean Filtered Image

Figure 2d. Alpha Trimmed Mean Filtered Image

Figure 2e. Contra Harmonic Mean Filtered Image

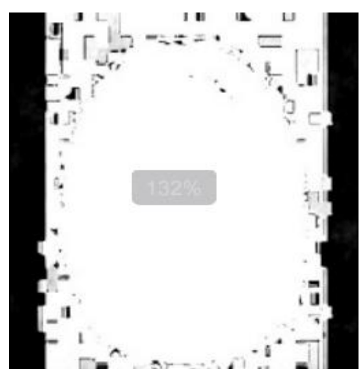

Figure 2f. Wiener Filtered Image

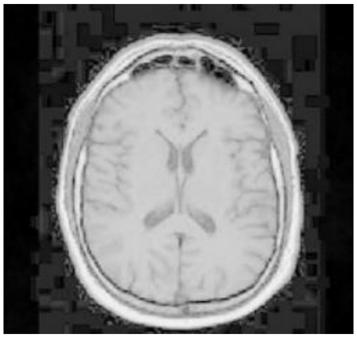

Figure 2g. Homomorphic filtered Image

Figure2. Simulation Results for the Implemented Filters

5 PERFORMANCE COMPARISION

The performances of all the implemented filters are compared using the following evaluation metrics

- PSNR (Peak Signal to Noise Ratio)
- MSE (Mean Square Error)
- NAE (Normalized Absolute Error)
- Time Elapsed

The equations for all the metrics are given below,

For MSE the equation is given by,

$$MSE = \frac{1}{MN}\sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k} - x'_{j,k})^2 \quad (3)$$

Where $x_{j,k}$ is the original image and $x'_{j,k}$ is the filtered image.

For PSNR the equation is given by,

$$PSNR = 10log\frac{(255)^\wedge 2}{MSE} \quad (4)$$

Where $x_{j,k}$ is the original image and $x'_{j,k}$ is the filtered image.

For NAE the equation is given by,

$$NAE = \sum_{j=1}^{M}\sum_{k=1}^{N}\left|x_{j,k} - x'_{j,k}\right| / \sum_{j=1}^{M}\sum_{k=1}^{N}\left|x_{j,k}\right| \quad (5)$$

Where $x_{j,k}$ is the original image and $x'_{j,k}$ is the filtered image.

The Table 1 shows the comparison of all the filters. From the table it is evident that, homomorphic filter filters the fBm affected image better when compared to all other filters. It has high PSNR value, low MSE, low NAE and minimum time to produce the filtered image. Figure 3 shows the comparison chart of the PSNR, MSE and NAE values of all the implemented filters.

S. No	Filters	PSNR (in dB)	MSE (no units)	NAE (no units)	Time Elapsed (Sec)
1	Mean Filter	5.0472	2.03e+04	0.8168	2.3422
2	Alpha Trimmed Mean Filter	5.4249	1.86e+04	0.7809	38.4384
3	Contra-Harmonic Mean Filter	4.7119	2.19e+04	0.8263	10.9736
4	Wiener Filter	5.0780	2.01e+04	0.8155	3.0989
5	Homomorphic Filter	12.8685	0.33e+04	0.3151	2.2642

Table 1. Performance Comparison

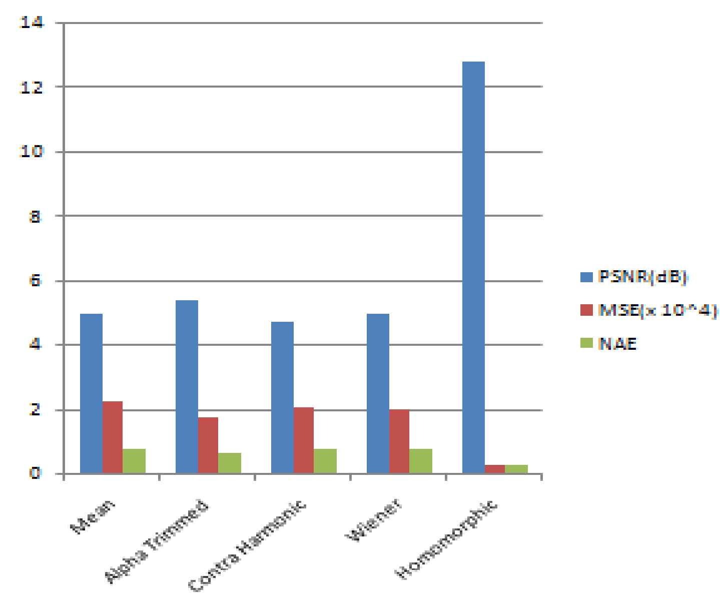

Figure3. Comparison Chart

6 CONCLUSION

Thus image filtering plays a major role in removing the noise and the filters discussed here removes the fbm noise. When comparing all the filters, homomorphic filter proves to be the best. All other filters remove noise at the compensation of over smoothing the noisy image and hence the performance of the remaining filters is not worthwhile. The future scope of this work includes implementing these filters for all other types of noises such as Gaussian noise, speckle noise, Poisson noise and salt and pepper noise. Also the future work aims at implementing various other filters proposed in the literature for removing fractional Brownian motion noise.

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