

Performance Evaluation of Noise Reduction Algorithm in Magnetic Resonance Images

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Abstract

The objective of this paper is to do the estimation of the noise in the Magnetic Resonance images and evaluate the noise reduction algorithm present in this paper. We propose a method for reduction of Rician noise in MRI. This method shows an optimal estimation result that is more accurate in recovering the true signal from Rician noise. The method proposed specifically for Rician noise reduction, but because Rician noise can be approximated to Gaussian when SNR is high, therefore, we expect the proposed algorithm also has advantage in denoising of complex MR images.

Keywords: *Rician noise, Gaussian noise, Magnetic Resonance Images, PSNR, MAE, MSE, RMSE.*

1. Introduction

Reduction of noise in magnetic resonance (MR) images is a critical issue, peak signal-to-noise ratio (SNR), and acquisition speed, which results in images that still demonstrate significant noise levels. To understand the spatial distribution of noise in an Magnetic Resonance Image is critical to estimate the true signal. Pure noise in MR magnitude images can be modelled as a Rayleigh distribution. To overcome the problem of smoothing, spatial information can be incorporated so that spatial regularization of the noise estimation is performed rather than the simple smoothing of both signals and noise. In the image processing literature, many of the popular denoising algorithms suggested are based on wavelet thresholding. These approaches attempt to separate significant features/signals from noise in the frequency domain and simultaneously preserve them while removing noise. If the wavelet transform is applied on MR magnitude data directly, both the wavelet and the scaling coefficients of a noisy MRI image are biased estimates of their noise-free counterparts. The difficulty with wavelet or anisotropic

diffusion algorithms is again the risk of over-smoothing fine details, particularly in low SNR images. From a statistical point of view, order statistics yields optimal results. Order statistics can be used to accommodate various noise hypotheses. In this paper, we use intensities of pixels located in the neighbourhoods of a certain pixel to estimate its true noise free signal. In this method, noise is modelled as Rician and MLE is deployed within a non local neighbourhood to predict noise free signals.

2. Denoising

Denoising is the process of removing noise in the images. Noise reduction techniques are conceptually very similar regardless of the image being processed; however a prior knowledge of the characteristics of an expected signal can mean the implementations of these techniques varies, greatly depending on the type of signal. Image denoising is often used in various fields like photography, publishing, medical image processing applications, where an image was somehow degraded but needs to be improved before it can be printed or making observations. For this type of application we need to know something about the degradation process in order to develop a model. When we have a model for the degradation process, the inverse process can be applied to the image to restore it back to the original form. This type of image restoration is often used in space exploration to help eliminate artifacts generated by mechanical jitter in a spacecraft or to compensate for distortion in the optical system of a telescope. Image denoising finds applications in fields such as astronomy where the resolution limitations are severe, in medical imaging where the physical requirements for two high quality imaging are needed for doing analysis of images in unique events, and in forensic science where potentially useful photographic evidence is

sometimes of extremely bad quality .Noise can be random or white noise with no coherence or coherent noise introduced by the devices mechanism or processing algorithm In the case of photographic film and magnetic tape noise (both visible and audible) is introduced due to the grain structure of the medium. In photographic film, the size of the grains in the film determines the film's sensitivity, more sensitive film having larger sized grains. In magnetic tape, the larger the grains of the magnetic particles, the more prone the medium is to noise.

2.1 Rician Distribution

The image intensity of magnetic resonance images in the presence of noise is to be governed by a Rician distribution. Low signal intensities are therefore biased due to the noise. The noise can be estimated from the images and a simple scheme is describe to reduce the noise. The noise distributions are nearly Gaussian for SNR larger than two. "Rician noise" depends on the data itself; it is not additive, so to "add" Rician noise to data, what we really mean is make the data Rician distributed.

2.2 Ordered Statistic Filter

Order statistic filters are spatial filters whose response is based on ranking the pixels contained in the image area encompassed by the filter. The response of the filter at any point is determined by the ranking result. If x is the location of pixel and its neighborhood pixels are y and $\Omega_I(N)$ be the set of points $\{x + (i, j)\}_I$, here i, j should be in between $-N$ and $+N$, in a $(2N + 1) \times (2N + 1)$ neighborhood centered at x for positive and negative integer N .

If $N \geq 2$ then $\Omega_x^0 = \Omega_x$ represents the set of points in a 5×5 neighborhood of x . For each point y which belongs to Ω_x^0 , the absolute difference in the intensity of the pixel is defined by $d_{x,y} = |I_x - I_y|$. After taking all the differences between the neighborhood pixels with centered pixel, choose m smallest values of neighborhood pixels, and then sort these $d_{x,y}$ values in ascending order. Thus this statistic gives a measure of how close a pixel value is to its m most similar neighbors.

$$R(x) = \sum_{i=1}^m S_i \quad (1)$$

The value of $R(x)$ is very simple to introduce into existing filters. A new weighting function is incorporated into bilateral filter to implement trilateral filter. Bilateral

filters are used to remove Gaussian noise. It retains the sharpness of edges. Each pixel is replaced the weighted average of the intensities in the neighborhood. Consider x be the position of the pixel, which is under consideration. The weight of y with respect to x is the product of spatial and radiometric components. If we consider weight of spatial component is ω_i and weight of radiometric component is ω_d

$$\omega_i = e^{-\frac{1}{2} \left(\frac{|y-x|}{\sigma_i} \right)^2} \quad (2)$$

$$\omega_d = e^{-\frac{1}{2} \left(\frac{|d_{xy}|}{\sigma_d} \right)^2} \quad (3)$$

σ_i and σ_d controls the behavior of weight. They serve as rough thresholds for identifying spatially close pixels. Let Impulsive weight ω_I at point x is defined as;

$$\omega_I = e^{-\frac{1}{2} \left(\frac{R(x)}{\sigma_I} \right)^2} \quad (4)$$

3. Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is primarily a medical imaging technique most commonly used in radiology to visualize detailed internal structure and limited function of the body. MRI provides much greater contrast between the different soft tissues of the body than computed tomography (CT) does, making it especially useful in neurological (brain), musculoskeletal, cardiovascular, and ontological (cancer) imaging. Unlike CT, it uses no ionizing radiation, but uses a powerful magnetic field to align the nuclear magnetization of (usually) hydrogen atoms in water in the body. Radio frequency (RF) fields are used to systematically alter the alignment of this magnetization, causing the hydrogen nuclei to produce a rotating magnetic field detectable by the scanner. This signal can be manipulated by additional magnetic fields to build up enough information to construct an image of the body. A radio frequency transmitter is briefly turned on, producing an electromagnetic field. Unlike CT, MRI uses no ionizing radiation and is generally a very safe procedure. Nonetheless the strong magnetic fields and radio pulses can affect metal implants and cardiac pacemakers. In the case of cardiac pacemakers, the results can sometimes be lethal, so patients with such implants are generally not eligible for MRI. MRI is used to image every part of the body, and is particularly useful for tissues with many hydrogen nuclei and little density contrast, such as

the brain, muscle, connective tissue and most tumours. In clinical practice, MRI is used to distinguish pathologic tissue (such as a brain tumour) from normal tissue

4. Evaluation and Implementation

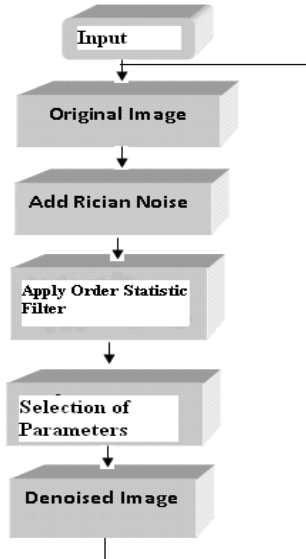


Figure 1. Flow Chart for the Implementation of Method

For the performance evaluation of the algorithm, simulated MR magnitude data is generated by adding Rician noise in noise-free images. Five criteria (SNR, PSNR, MSE, RMSE, MAE) are taken into account for the performance evaluation. Each criteria measures a specific means of the denoising method. Visual results show how well the denoised image can be visually interpreted. As shown in figure 1, Magnetic Resonance Image is taken as input image. To do the performance evolution we add noise to the original image. After the addition of noise, apply order statistic filter for the reduction of noise.

5. Testing and Performance Evaluation

The visual performance of the algorithm is shown in figure 2 to figure 6 as below.

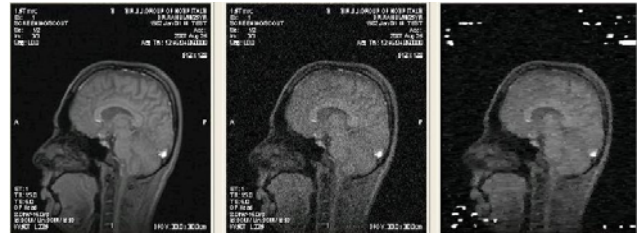


Figure 2. (a) Original image, (b) Noisy image (10%), (c) Denoised image

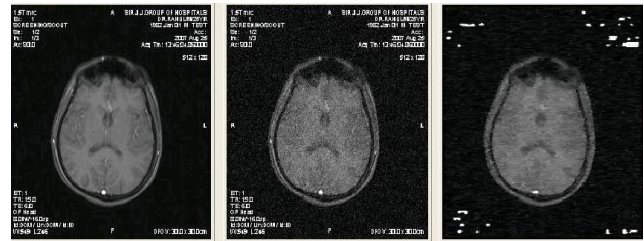


Figure 3. (a) Original image, (b) Noisy image (10%), (c) Denoised image

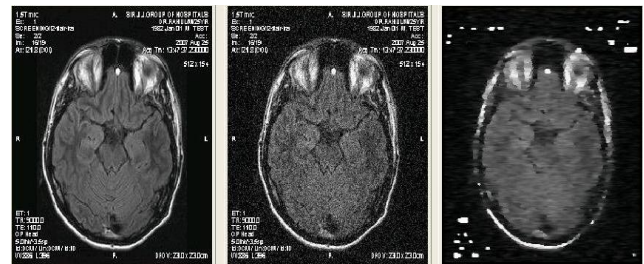


Figure 4. (a) Original image, (b) Noisy image (20%), (c) Denoised image

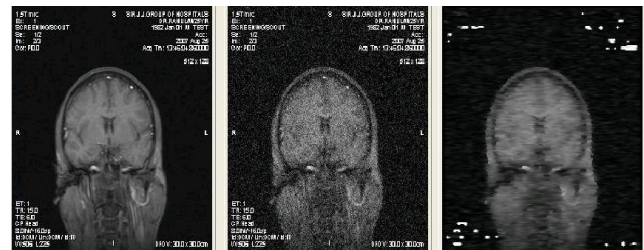


Figure 5. (a) Original image, (b) Noisy image (20%), (c) Denoised image

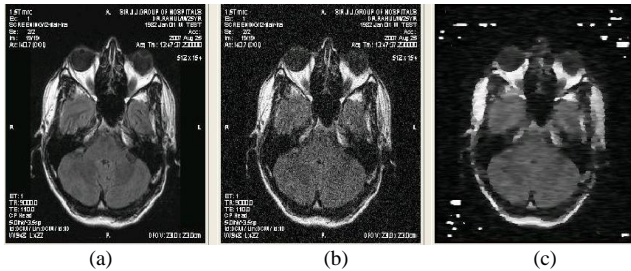


Figure 6. (a) Original image, (b) Noisy image (20%), (c) Denoised image

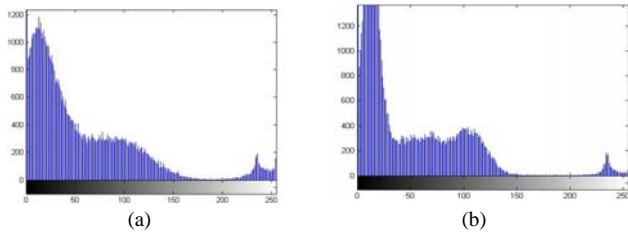


Figure 7. (a) Histogram of Noisy head image (10%) (b) Histogram of denoised head image of figure 2.

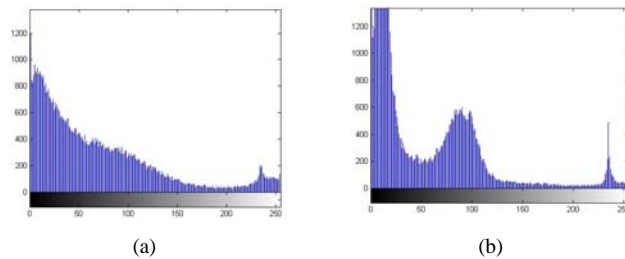


Figure 8. (a) Histogram of Noisy head image (20%) (b) Histogram of denoised image of figure 6

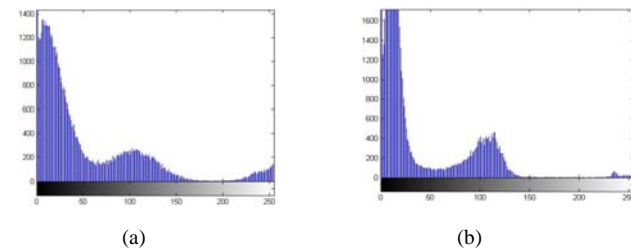


Figure 9. (a) Histogram of Noisy image (10%) (b) Histogram of denoised image of figure 3

Table 1: Results after applying the proposed method for added noise

MRI	Noise (db)	SNR	PSNR	MSE	RMSE	MAE
Figure 2	10	6.92	29.94	65.86	8.11	12.60
Figure 3	10	2.88	29.89	66.60	8.16	12.67
Figure 4	20	3.20	28.54	90.85	9.53	17.85
Figure 5	20	5.45	28.61	89.50	9.46	16.36
Figure 6	20	1.21	28.50	91.68	9.57	17.65

Table 1 shows evaluation results after adding 10% to 20% noise to the Magnetic Resonance Images. Performance evaluation is carried out in terms of Signal to noise ratio (SNR), Peak signal to Noise Ratio (PSNR), Mean Square Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE). Also the performance evaluation is to be carried by using histograms of noisy images and denoised images (figure 7 to figure 9). The Histogram shows the total tonal distribution in the image. It's a bar chart of the count of pixels of every tone of gray that occurs in the image. It helps us analyze, and more importantly, correct the contrast of the image. The average execution time require for the method is 75.83 seconds on Intel® CPU 2140 @ 1.60 GHz, 512 DDR II system.

6. Conclusions

In this experimental study, we carried out the review of the characteristics of noise in MR images. Given procedure is used for reducing Rician noise as well as Impulse noise in Magnetic Resonance Images and shows how the method performs well compared to the visual results. The performance evaluation is done by using the terms of signal to noise ratio, peak signal to noise ration MAE, MSE, sharpness, etc. We focussed on low SNR situations and demonstrated the order statistic under the visual, SNR and method error metrics. Additionally, algorithm outperformed by better preserving tissue boundaries in the visual comparisons, and also in the sharpness. This method is used here specifically for Rician noise reduction, but because Rician noise can be approximated to Gaussian when SNR is high, therefore, we expect this algorithm also has advantage in denoising raw complex MR images. Testing and evaluation section shows actual implementation results.

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