Comparative Study of various Denoising Filters for MR Images

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Abstract— Magnitude Resonance imaging (MRI) is a priceless indicative apparatus and a basic noninvasive imaging methodology that gives an incomprehensible measure of anatomical and useful data valuable for diagnosis and patient treatment. The MRI images captured are usually corrupted from Gaussian noise, salt and pepper noise, speckle noise etc., Therefore obtaining of brain image with accuracy is very difficult. The presence of noise results in the reduction of quality in the magnetic resonance (MR) images and hence limits the visual review and impact the quantitative estimations from the information. So there is requirement for image preprocessing of the obtained image to remove unwanted noise. In this paper, various filtering algorithms in the spatial domain are discussed and their performance in removing noise is examined. The performance of these techniques was accessed with respect to two quantitative measures, Peak Signal-to-Noise Ratio (PSNR), and Mean Square Error (MSE).

Key words: Magnetic Resonance Image, PSNR, MSE Spatial Domain

I. Introduction

Magnetic resonance imaging (MRI) is a powerful and effective technique for clinical investigation and disease diagnosis since it can provide valuable information of all the structural features of a specified internal body tissue. But, MR images are affected by the noise added during acquisition process.

For an efficient denoising technique, information about the type of noise in the corrupted image plays a significant role. Mostly images are corrupted with Gaussian, speckle, rician or salt and pepper noise distribution. Speckle noise is multiplicative noise whereas Gaussian noise is an additive noise.

A plenty of various denoising strategies have been proposed in recent two decades. The important property of a good image denoising model is that it should completely eliminate noise as far as possible as well as retain edges.

Conventionally, there are two types of models i.e. linear model and non-linear model. Generally, linear models are used. The benefits of linear noise removing models is the speed and the limitations of the linear models is, the models are not able to preserve edges of the images in a efficient manner i.e the edges, which are recognized as discontinuities in the image, are smeared out. On the other hand, Non-linear models can handle edges in a much better way than linear models.

In this paper we first review the various noise models of noises present in the MRI image. Then we propose various filtering techniques to remove this noises. We cant remove all the noises using a single filter. Hence various general filters are discussed and their merits and demerits are listed out.

The performance criteria of these techniques is with respect to (i) PSNR value(ii) MSE Value. Image filtering techniques improve image quality, increase visibility of details, help in the diagnostic and accurate information in medical care.

II. Literature survey

A Review Paper of Various Filters for Noise Removal in MRI Brain Image by Mohd Tahir, Anas Iqbal, Abdul Samee Khan. In this paper various filtering algorithms are discussed and compared and was found out that the modified median is better salt and pepper highdensity removal in MRI image Study of Spatial and Transform Domain Filters for Efficient Noise Reduction-A thesis submitted by Anil Kumar Kanith. The noises considered in this thesis Additive Gaussian White Noise (AWGN), Impulsive Noise and Multiplicative (Speckle) Noise. Among the currently available medical imaging modalities, ultrasound imaging is considered. speckle noise reduction is an important prerequisite, whenever ultrasound imaging is used for tissue characterization. Among the many methods that have been proposed to perform this task, there exists a class of approaches that use a multiplicative model of speckled image formation and take advantage of the logarithmical transformation in order to convert multiplicative speckle noise into additive noise.

A brief study of various noise model and filtering techniques by Priyanka Kamboj1and Versha Rani. .In this paper several type of linear and nonlinear filtering techniques have been proposed. Different approaches for reduction of noise and image enhancement have been considered for digital images.

A review of image denoising algorithms, with a new one by A.Buades, B.Coll and J.M.Morel. The main focus of this paper is, first, to define a general mathematical and experimental methodology to compare and classify classical image denoising algorithms and, second, to propose a nonlocal means (NL-means) algorithm addressing the preservation of structure in a digital image.

Spatial domain Image enhancement and restoration techniques by Kinita B Vandara and Dr G.R.Kulkarni. This paper discusses the standard techniques of image enhancement and restoration for medical images. Experimental results of Ultrasonography (USG) modalities are presented and analysed.

Performance Evaluation of Various Denoising Filters for Medical Image by P.Deepa1and M.Suganthi. This paper presents a review of some significant work in the area of image denoising filtering techniques applied to medical image. The performance of these techniques investigated the problem of image degradation which might occur during the acquisition of the images, optical effects such as out of focus blurring, camera motion etc.

Spatial and Transform Domain Filtering Method for Image De-noising: A Review by Vandana Roy. This paper reviews significant de-noising methods (spatial and transform domain method) and their salient features and application.

A New Method to Remove Noise in Magnetic Resonance and Ultrasound Images by M. N. Nobi and M. A. Yousuf. This paper presents an efficient and simple method for noise reduction from medical images. In the proposed method median filter is modified by adding more features.

III. NOISE MODEL

The performance of picture sensor is influenced by plenty of reasons, for example, environmental condition amid picture securing or by the nature of the detecting component themselves. We can model a noisy image as follows:Where A(x ,y) is the original image pixel value and B(x ,y) is the noise in the image and C(x ,y) is the resulting noise image where C(x ,y)= A(x ,y)+ B(x ,y).

Noise modeling in images is affected by acquisition instrument, data transmission media, image quantization and discrete source of radiation. Gaussian noise (arbitrarily additive in nature) is observed in natural images where as rician noise affects magnetic resonance image (MRI). The characteristics of noise depend on its source, as does the operator which reduces its effects.

A. *Gaussian Noise*

This type of noise adds a random Gaussian distributed noise value to the original pixel value. And it has a Gaussian distribution. It has a bell shaped probability distribution function given by,

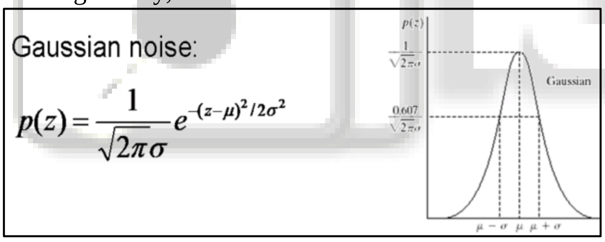

Fig. 1: PDF of Gaussain Noise

B. *Salt and Pepper noise*

Salt and pepper noise also called as an impulse noise. It is also referred to as intensity spikes. Essentially while transmitting data we will get this salt and pepper noise . It has only two possible values,0 and 1. The probability of each value is typically less than 0.1. The corrupted pixel values are set alternatively to the maximum or to the minimum value, giving the image a “salt and pepper” like appearance as salt looks like white(one)and pepper looks as black(zero) for binary ones. Pixels which are not influenced by noise remain unaffected. For an 8-bit image, the typical value for pepper noise is 0(minimum)and for salt noise 255(maximum). This noise is generally caused in digitization process during timing errors,malfunctioning of pixel elements in the camera sensors, faulty memory locations. The probability density function for Salt and pepper type of noise is shown as below

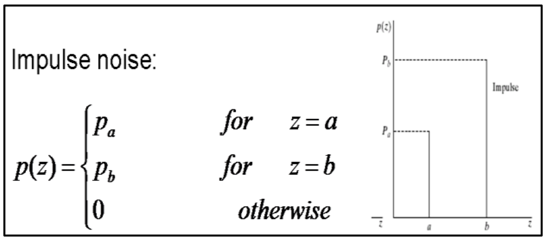

Fig. 2: PDF of Impulse noise.

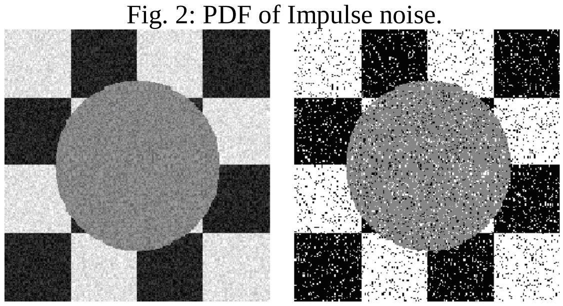

Fig. 3: Eg of Salt and pepper noise

Reasons for Salt and Pepper Noise:

a) By memory cell failure.
b) By malfunctioning of camera’s sensor cells.
c) By synchronization faults in image digitizing or transmission.

C. *Rician noise*

MR images are corrupted by Rician noise, which arises from complex Gaussian noise in the original frequency domain measurements. Rician distribution is the probability distribution of the magnitude of a circular normal random variable with potentially non-zero mean The Rician probability density function for the corrupted image intensity *x* is given by

$$f(x\mid\nu,\sigma)=\frac{x}{\sigma^2}\exp\left(\frac{-(x^2+\nu^2)}{2\sigma^2}\right)I_0\left(\frac{x\nu}{\sigma^2}\right),$$

where *v* is the underlying true intensity, σ is the standard deviation of the noise, and *I0* is the modified zeroth order Bessel function of the first kind.

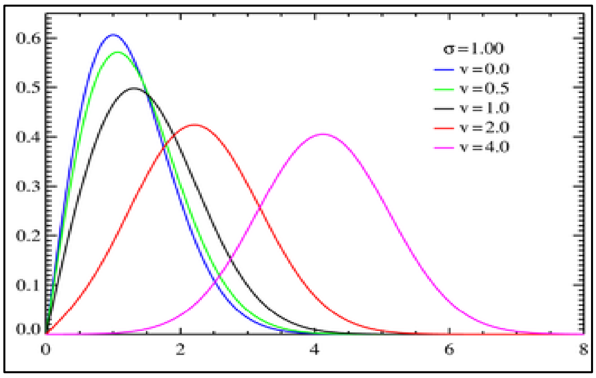

Fig. 4: PDF of Rician noise

IV. FILTERING TECHNIQUES

Filtering in an image processing is a basis function that is utilized to accomplish many tasks such as noise reduction, interpolation, and re-sampling. Filtering image data is a standard process used in almost all image processing systems. The choice of filter is determined by the nature of the task performed by filter and behavior and type of the data and noise present. Filters are used to remove noise from MR image while keeping the details of image preserved is an essential part of image processing A traditional way to remove noise from image data is to employ spatial filters. Spatial filters can be further classified into linear and non-linear filters. A. Linear Filters tend to blur sharp edges, destroy lines and other fine image details, and perform poorly in the presence of signal dependent noise. So rician noise which is a signal dependent noise is removed using non-local means of filtering.

A. Mean Filter

Mean filter is the optimal filter for removing grain noise in an image.It is also known as the average filter. Mean filtering is a simple, intuitive and easy to implement method of smoothing images, i.e , it reduces the variation in terms of intensity between adjacent pixels. The idea here is a simple moving window spatial filter, which replaces the center value in the window with the average of all the neighboring pixel values including that centre value. .It is also called a linear filter. Mean filtering is usually implemented as a convolution filter. Like other convolutions it is based around a kernel, which represents the shape and size of the neighborhood to be sampled when calculating the mean, the mask has a value of N/1, where N is the mask size. The mask or kernel is a square. Often a 3× 3 square kernel is used.This filter replaces the center value in the window. It replaces with the average mean of all the pixel values in the kernel or window. The window is usually square but it can be of any shape. Diadvantage is it does not preserve details of image.A tradeoff is to be made between the kernel size and the amount of denoising.

Unfiltered values		
2	8	3
5	2	7
4	6	8

2+8+3+2+5+7+4+6+8=45/9=5

Table 1: An Example of mean filtering of a 3x3 kernel of values is shown above

Mean filtered		
*	*	*
*	5	*
*	*	*

Table 2: In this Center value which is previously 2 in the unfiltered value is replaced by the mean of all nine values in the neighbourhood that is 5.

B. Median filter

It is so called as the median of all pixels in a local region of an image. It performs much better than arithmetic mean filter in removing salt and pepper noise from an image and in preserving the spatial details contained within the image i.e the fine details in the edges. It does not blur the image as in the case of median filtered image. It retains the sharpness of the image and gives a much better performance for MRI brain to remove noise content. Calculation of Median is done as first sorting all the pixel values from the surrounding neighborhood (either ascending or descending order) and then replacing the pixel being considered with the middle pixel value. Median filtering performance is not satisfactory in case of signal dependant noise.

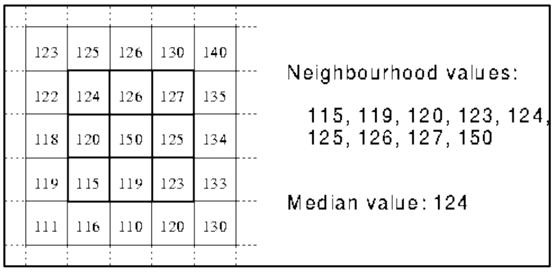

Fig. 5: The center value of 150 is replaced by the median value 124

C. Total Variance filter

The total variation (TV) of a signal measures how much the signal changes between signal values. Specifically, the total variation of an N-point signal x(n), $1 \leq n \leq N$ is defined as

$$\mathrm{TV}(\mathbf{x}) = \sum_{n=2}^{N} |x(n) - x(n-1)|.$$

The total variation of x can also be written as

$$\mathrm{TV}(\mathbf{x}) = \|\mathbf{D}\mathbf{x}\|_1$$

Where $\|.\|_1$ is the l_1 norm and

$$\mathbf{D} = \begin{bmatrix} -1 & 1 & & & \\ & -1 & 1 & & \\ & & \ddots & & \\ & & & -1 & 1 \end{bmatrix}$$

Is a matrix of size (N-1)*N

We assume we observe the signal x corrupted by additive white Gaussian noise,

$y = x + n$, $y, x, n \in R$ N.

One approach to estimate x is to find the signal x minimizing the objective function

$$J(\mathbf{x}) = \|\mathbf{y} - \mathbf{x}\|_2^2 + \lambda \|\mathbf{D}\mathbf{x}\|_1.$$

This approach is called TV denoising. The regularization parameter, λ, controls how much smoothing is performed. Larger noise levels call for larger λ.

D. Non-local means

The proposed algorithm for removing noise from images of magnetic resonance technique is non-local means (NL-means) which is based on non-local averaging of all the pixels in images. Non-local means filter for denoising takes a mean of all pixels contained in the image. The measurement is performed between the pixels and the extent of their similarity to the marked pixel. Compared to the local means algorithms, non-local means algorithm gives clearer filter results so less detail is lost in images.Non-local means filter is an efficient method for denoising magnetic resonance image, because it keeps the borders of tissue in the right way.It performs satisfactorily to suppress signal dependent noise such as rician noise.This type of filter has its limitations, because the calculation of similarity weight is exercised over the whole space in the neighborhood. The impact of noise in magnetic resonance imaging significantly affects the accuracy of similarity weight. Non-local algorithm calculates pixel similarity weight of the entire neighbourhood. The accuracy similarity weights depend on the level of the noise intensity. Non-local means algorithm is based on a process of averaging to incorporate all pixes in the image. In the filter processing, the process of averaging may be restricted to M ×M window matrix that includes only some pixels, so that the window matrix M × M is smaller than the dimensions of the entire image. Value of centered pixel of window matrix is calculated as weighted average of pixels that belong to that window. In our proposed method we used window of the size 3 × 3 biased by the empirically determined weighted mean of the larger 9 × 9 window. Non-local means algorithm is based on the definition of the concept of similarity in the local context intensity in the neighbourhood of each pixel rather than the intensity which is related only to the pixel itself. Non-local means algorithm is defined by the following equation:

$$u(p) = \frac{1}{C(p)} \int_{\Omega} v(q) f(p,q) dq$$

where Ω is the area of the image, p and q are two points within the image, u(p) is filtered value of the image at point p while v(q) is unfiltered value of the image at point q. Weighting function is f(p, q). The integral is evaluated over ∀ q ∈ Ω. C(p) presents a normalizing factor, defined by following equation:

$$C(p) = \int_{\Omega} f(p,q) dq$$

The performance when applied on a MR Image can be evaluated using performance metrics.

V. IMAGE METRICS

A. *Mean Square Error (MSE)*

The MSE represents the cumulative squared error between the compressed and the original image. The lower the value of MSE, the lower the error.
Mean Square Error (MSE) is given as

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

B. *Peak Signal to Noise Ratio (PSNR)*

Another important metric is Peak signal to noise ratio (PSNR). It is defined in logarithmic scale,in dB. It is a ratio of peak signal power to noise power. Since the MSE represents the noise power and the peak signal power, the PSNR is defined as:

This image metric is used for evaluating the quality of a filtered image and thereby the capability and efficiency of a filtering process.

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

VI. COMPARISION AND RESULTS

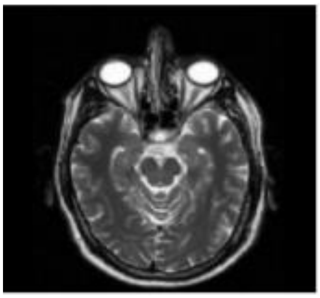

Fig. 6: Original image

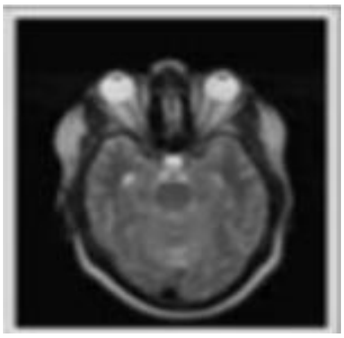

Fig. 7: Mean filtered image

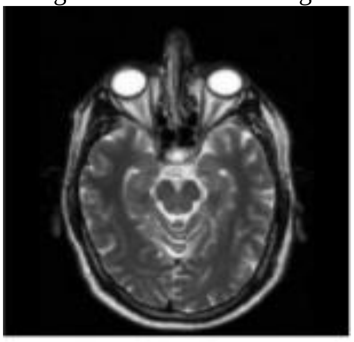

Fig. 8: Original image

Fig. 9: Median filtered image

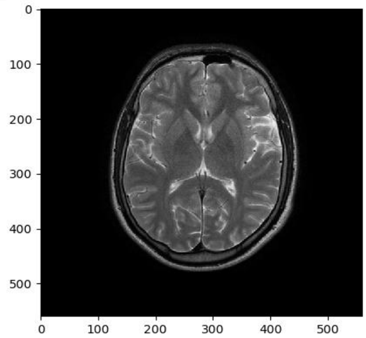

Fig. 10: Original MR Image

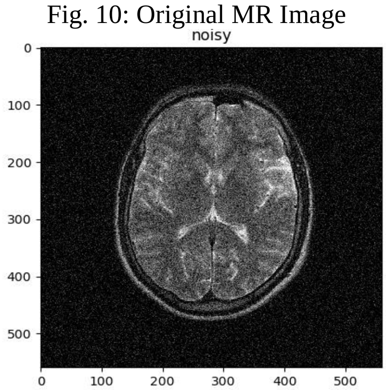

Fig. 11: MR Image with noise of variance 30 added.

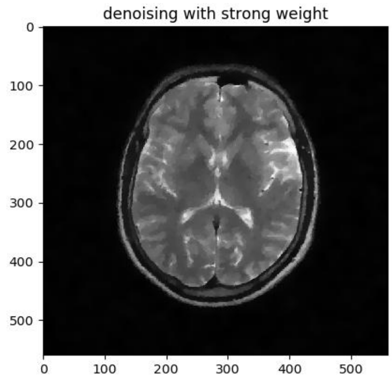

Fig. 12: Denoised image using TV method.

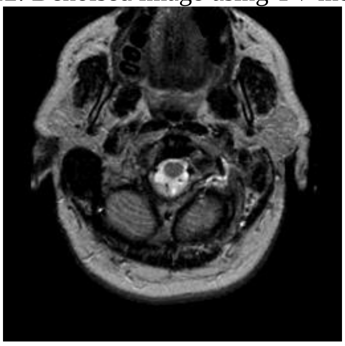

Fig. 12(a): Original MRI,

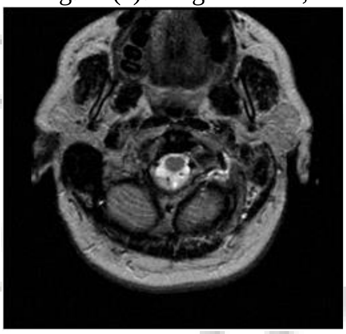

Fig. 12(b): MRI with noise,

Fig. 12(c): Denoised MRI using Non local means has MSE= 23.4604 and PSNR= 34.4275

		PSNR (db) Standard deviation(σ)		
S. No	Filter type	5	10	20
1	Mean filter[3x3]	30.24	29.12	27.74
2	Median filter[3x3]	33.76	30.44	27.22
3	Total variance filter	33.11	31.30	29.13

Table 3:

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VII. CONCLUSION

Noise is one of obstacles in automatic image understanding and noise reducing is very important to improve the results of this process In this paper, we present various simple and efficient technique to remove noise from the medical MR Images. Although smoothing filter shows better result, it suffers from blurring effect. Because in the mean filtering techniques each pixel is considered for calculating the mean and also every pixel is replaced by that calculated mean.

The decision to apply which particular filter is based on the different noise level at the different test pixel location or performance of the filter scheme on a filtering mask. Total variance filter shows better results to remove gaussian noise present in MRI images.

The filters results are tested on noisy MRI Image and their effectiveness compared using performance metrics.

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