International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 06 | June -2017 www.irjet.net p-ISSN: 2395-0072

A Comparative Study of Image Denoising Techniques for Medical Images

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Abstract – *In the modern age, medical images plays the most important role. It is used in the diagnosis of the diseases like cancer, diabetic retinopathy, fractures in bones, skin diseases etc. The processes of the medical imaging are different for different type of diseases. The capturing process introduced the noise in the medical image. To proper diagnosis of the diseases, the captured images need to be noise free. Hence in this paper, we discuss various noises which affect to the medical image along with the denoising algorithms.*

Key Words: Image denoising, Noise types, spatial domain filtering, transform domain, wavelet domain filtering.

1. INTRODUCTION

Digital images played the vital role in the day to day life of the human. It provides useful information like weather forecasting through satellite cameras, traffic monitoring, medical imaging like X-rays, medical resonance imaging (MRI), Computed Tomography (CT), ultrasound imaging etc. The techniques used to acquire the image are different for different images. The image acquisition process introduces the different type of noises in the images which may destroy the important information in the image. There is another source of sources of noises like instrumental defects, improper data acquisition, natural phenomenon, transmission medium, and compression.

Image denoising is the process of suppressing the introduce noise in the image with the help of image processing and computer vision algorithms. It is the significant task in the in the image processing applications. Removing the random noise from the image and preserve the image details is the primary task of the denoising process. The noisy image has the undesirable quality and contrast. Hence the noise removal is the essential and important step in image applications to enhance the quality and contrast of the image.

In most of the cases, the additive noise is found in the images. The noise having additive nature along with uniform power with Gaussian probability distribution is referred to as Additive White Gaussian Noise (AWGN) which is very difficult to remove from the image [1], [2]. The image denoising and preserving the actual information are in inverse proportional.

The denoising techniques are divided into the different domain like spatial domain and frequency domain.

The paper is organized is as follow: Section 2 explain different type of noise which is introduced into the image through various media. Section 3 explains the noise removal algorithms, Section 4 discuss the whole paper and section 5 conclude the paper.

2. TYPE OF NOISES

The noise which affects the image quality is explained below. The noises are classified into their respective type according to their nature.

2.1 Gaussian Noise

Gaussian noise is spread all over the image hence the pixel value is representing by the summation of the true pixel value and Gaussian distribution. It is a bell shaped and it is expressed as:

$$F(g) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(g-m)^2/2\sigma^2} \quad (1)$$

Where, g is the gray level of the pixel
m is the mean value
σ is the standard deviation of the noisy image

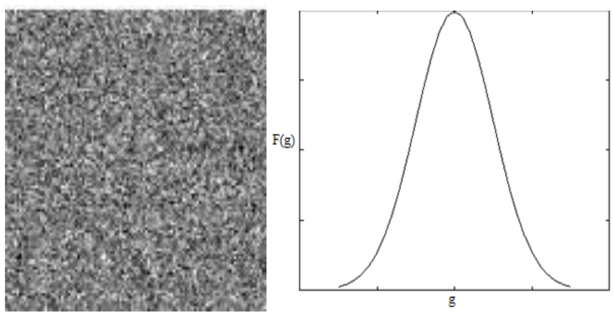


Fig -1: (a) Gaussian noise image (b) Gaussian noise distribution

The image with the Gaussian noise of zero mean and 0.05 variance is as shown in Fig. 1 (a) and respective Gaussian distribution is shown in Fig 1 (b).

2.2 Salt and Pepper Noise [3]

It is impulse type of noise also called as intensity spikes noise. It is generated in the transmission channel. It is the combination of small black (minimum intensity pixel value) and white (maximum intensity pixel value) dots hence it is called as salt and pepper noise. For grayscale image (8 bit) the value of salt and pepper noise is 255 and 0 respectively. It is produced mainly due to defect in the sensors of the camera, improper pixel elements, faulty memory location.. The appearance of the salt and pepper noise is shown in Fig. 2.

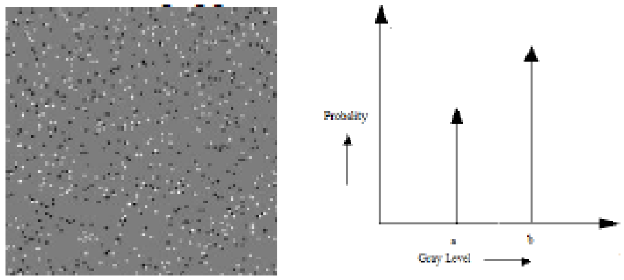


Fig -2: salt and pepper noise

2.3 Speckle Noise

Speckle noise occurs in the LASER, SAR and acoustic images. It is multiplicative noise [4], [5].

Speckle noise [4] [5] is multiplicative noise. This type of noise occurs in almost all coherent imaging. It is given by

$$F(g) = \frac{g^{\alpha-1}}{(\alpha-1)!a^{\alpha}} e^{\frac{-g}{a}} \qquad ()$$

Where, a2α is the variance
g is the gray level of the image

The image noise is shown in Fig. 3(a) and respective gamma distribution plot is shown in Fig 3 (b).

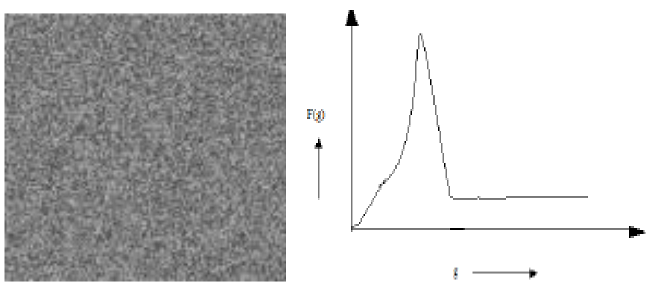
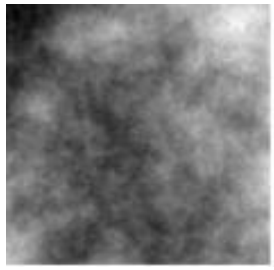


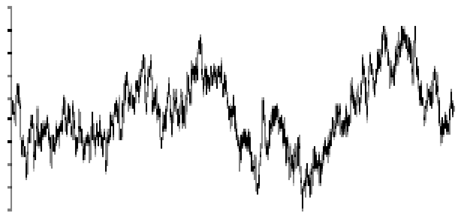
Fig -3: (a) Speckle noise (b) Gamma distribution

2.4 Brownian Noise

This is the fractal type of noise. It is also called as 1/f noise. The mathematical model is given by the Brownian movement. It is the non-stationary stochastic process. This noise is graphically represented as shown in Fig. 4



(a)



(b)

Fig -4: (a) Brownian noise (b) Brownian noise distribution Image

3. NOISE REMOVAL TECHNIQUES

The denoising techniques are categorized according to the applications. Broadly the noise removal techniques are divided into:

- Spatial domain filtering
- Transform-domain filtering

3.1. Spatial Domain Filtering

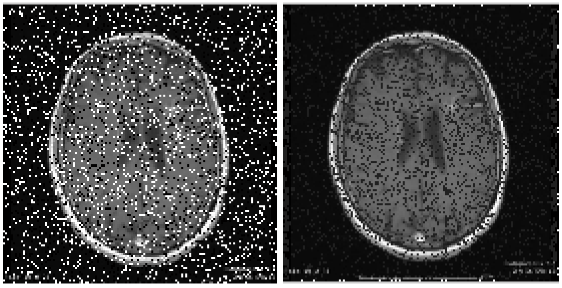
Spatial domain filtering is the traditional method of denoising. It is divided into linear and nonlinear filtering. [6]

3.1.1. Linear filtering

A. Mean Filter[6]

Mean filter is optimal linear smoothing filter. The window of 3x3, 5x5 is used as a kernel for calculating weighted sum of the pixel and it applies over the image. The window is selected such as the sum of all element of the window is equal to 1. Hence the brightness of the window remains unchanged. The kernel window is applied over the image; the middle pixel of the mask is replaced by the mean value of the neighborhood pixel.

This filter helps to remove the impulse noise in the image but it makes the edges blurred. It is failed for signal-dependent noise. Therefore it is used only for some region of the image.



(a) (b)

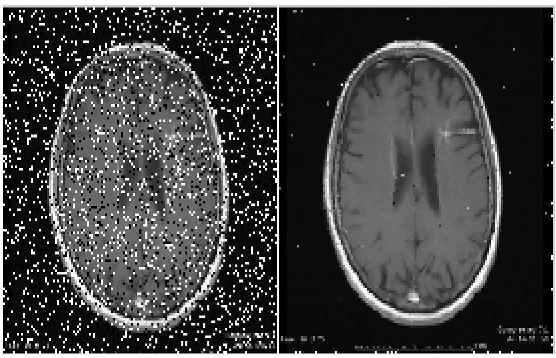
Fig -5: mean filter (a) Noisy image (b) mean filter output

1.2. Non- Linear

Nonlinear filters removed the noise without any prior information about the noise. It performs the low-pass filter on the image by considering the higher region of a frequency spectrum. Different nonlinear spatial filters are explained below.

A. Median Filter

It is a nonlinear spatial type of filters uses low pass filtering [7]. It uses a mask of the square shape of size 3x3 or 5x5. The middle pixel of the mask is replaced by the median of all the neighborhood pixels. This filter preserves the edges of an image. The main pro is it helps to compensate the uniform noise from the image.



(a) [b]

Fig -6: Median filter (a) Noisy image (b) Median filter output

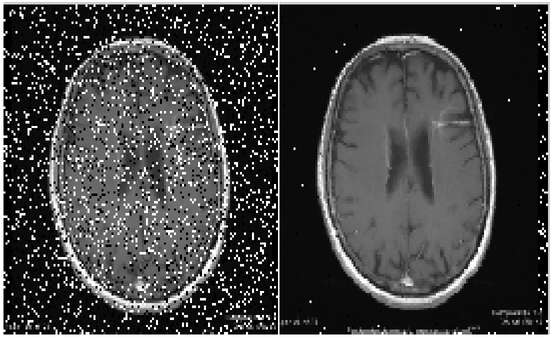


Fig -7: Adaptive median filter (a) Noisy image (b) adaptive median filter output

B. Adaptive median filter

Zhao et al. [8] proposed the technique called adaptive median filter. It uses the adaptive mask to filter the image. The algorithm first calculates the minimum and maximum value of the median of the noisy image. If the value of median is in between the range then the pixels does not contain the impulse noise otherwise median filter is applied to remove the noise. The size of the mask is adaptable such as the size of the window is increasing the impulse noise is not obtained. If the impulse noise is obtained it is removed else pixel value remain unchanged.

3.1.2. Transform-domain filtering

Transform-domain filtering is operated in the frequency domain. The various type of filter in the transform domain is as explained below.

A. Linear Filters

It is the linear type of filter. The Wiener filter used in wavelet domain gives good results when it is modeled to remove corrupted signal using Gaussian process [9]. It is assumed that the noisy signal is more differ visually than the original signal.

Another approach is proposed by the [8] used wavelet-domain spatially adaptive FIR Wiener filtering. It uses the spatial winner filtering within the scale.

B. Non-Linear Threshold Filtering

The principal for the use of the non linear filter is that the wavelet transform is used to map the white noise in the spatial domain with the white noise in the transform domain. Hence the original signals energy is concentrated into coefficient in transform domain but noise energy does not concentrated. Therefore it is easy to separate out the noise from the original signal effectively.

The research published by the researchers is based on the adaptive and nonadaptive thresholding basis which is explained below.

a. Non-Adaptive thresholds

The nonadaptive thresholding approach VISUshrink is explained in [14] which is depend on the number of data points. When a number of pixels reach to infinity, then it produces best performance and it is express in terms of MSE.

b. Adaptive Thresholds

Cross-validation replaces the existing wavelet coefficient by the weighted average of the nearest neighbors in the mask to minimize the GCV function which provides the optimal thresholding value for the wavelet coefficients. The noise is removed from the signal by considering solely coefficient of the noisy image. If the noise level is higher than the signal value, neighborhood pixels of wavelet coefficients plays the vital role.

C. Wavelet Coefficient Model

Wavelet coefficient model is the technique to find out the nearest relationship using the correlation of different signal of different resolution. This method gives the better results but it more expensive and complex. The modeling of the wavelet coefficients can either be deterministic or statistical.

- **Deterministic**

In the deterministic model, the tree structures of the wavelet coefficient at each level are presented where each node is representing the wavelet coefficient and tree represents the scale of the transformation. The whole tree is representing by hierarchical levels of the wavelet decomposition. If the wavelet coefficient has strong presence then it is considered as a parent node, if it is noisy, then consistency presence will be missed.

- **Statistical**

The statistical approach consists of different type of properties like multiscale correlations, local correlations etc. This approach has a primary aim to modeling the image data using wavelet transform. These model are again classified as Marginal Probabilistic Model and Joint Probabilistic Model.

4. Performance measurement

The performance of the noise removal techniques are performed based on the following parameters PSNR and MSE and mathematically it is given by

$$MSE = \frac{1}{MN}\sum\sum(X-Y)^2 \quad (4)$$

$$PSNR = log_{10}(255^2/MSE) \quad (5)$$

Where, X is the noisy image

Y is denoised image

5. CONCLUSION

In this paper, different noise and denoising algorithm has been explained. The linear spatial filter smoothing the image when using the fixed window but this method blurred the image and smoothen the sharpen image so important information may lose. To remove the disadvantage of the mean filter, the median filter is developed which remove the uniform noise while preserving the edges. The transform domains filter mostly to improve the PSNR value.

The wavelet transform is performed well because of the properties of sparsity, multi-resolution, and multi-scale nature.

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