International Journal For Technological Research In Engineering
Volume 2, Issue 8, April-2015 *ISSN (Online): 2347 - 4718*

IMAGE DE-NOISING TECHNIQUES: A REVIEW PAPER

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Abstract: A critical issue in the image restoration is the problem of de-noising images while keeping the integrity of relevant image information. A large number of image de-noising techniques are proposed to remove noise. Mainly these techniques are depends upon the type of noise present in images. So image de-noising still remains a important challenge for researchers because de-noising techniques remove noise from images but also introduce some artifacts and cause blurring. In this paper we discuss about various image de-noising and their features. Some of these techniques provide satisfactory results in noise removal and also preserving edges with fine details present in images.

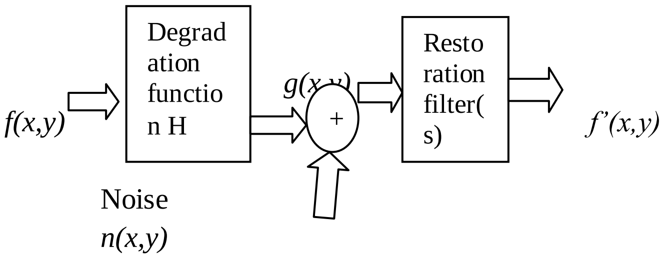
I. INTRODUCTION

Images are corrupted with various type of noises. So it is very difficult to get useful information from noisy images. That is why de-noising techniques are very important subject nowadays, For example, medical images obtained by X-ray or computed tomography CT in adverse conditions, or a mammographic image which may be contaminated with noise that can affect the detection of diseases or the object of interest. The aim of this work is to provide the overview of various de-noising techniques. Some of these techniques provide satisfactory results in removing noise from images and also preserve edges with other fine details present in images. Different methods have been proposed for image restoration depending on the type of noise present in image. Some of these algorithms provide better result for smoothing flat Regions like spatial domain approaches. One of the biggest advantages of these techniques is a Speed but these techniques do not preserve the fine details in the image. On other hand wavelet domain techniques has great advantage of preserving edges and fine details in images. This paper is organized as follow: Section II gives the overview of various types of noises. Section III gives an overview of performance measures line MSE, MAE, PSNR, SNR. Section IV gives de-noising techniques. Finally discussion and future directions are drawn in section IV.

II. IMAGE NOISE MODEL

Image noise is a random variation of brightness or color information in images. It can be produced by sensor or circuitry of a scanner or digital camera. Noise in digital images arises during image acquisition and/ or transmission.

Image noise model: in image noise model image degradation and image restoration process are used. In image degradation an degradation function His applied on input image f(x,y) with some additive noise n(x,y) and produce degraded image g(x,y). after that image restored with specific techniques and produce an estimated image of original image.



Types of noise: There are various types of noises present in images . Table 1(a) gives description of various types of noise with their probability density function is as below. In this z represents intensity,µ represent mean value of z etc.

S. NO.	TYPES OF NOISE	PROBABILITY DENSITY FUNCTION	EFFECTS
1.	Gaussian Noise	??H?H= 1/H2??? ?? (?- ?)²H2?²	In sensors or in low lightening conditions
2.	Rayleigh Noise	??H?H = H 2/? H?- ??H? H- ??f H?? ???? ? = ? H 0 ??h????????	In range imaging
3.	Exponential Noise	??H?H= H ??? ??? ???? ? = 0 H 0 ???? ?< 0	In laser Imaging
4.	Uniform Noise	??H?H= H 1/?- ? ?????? = ??= ?? H 0 ??h??????	occurs uniformly on pics
5.	Erlang Noise	??H?H= H ???? ³/(? - 1)! ? ??? ???? ? = 0 H 0 ??????< 0	In image acquisition
6.	Impulse Noise	??H?H= H ?? ???? ? = ? ?? ?????= ??H 0 ??h??????	In quick Transformation situations
7.	Speckle Noise		In Radar images
8.	Shot Noise		In electronic circuit

III. IMAGE QUALITY EVALUATION METRICS

To quantify the performance the noise reduction method, various measures may be used. The commonly preferred measures are mean squared error (MSE), mean absolute error(MAE), peak signal to noise ratio(PSNR), signal to noise ratio(SNR).These measures of two images u and I of size M × N.[3]

Mean square error(MSE)

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\|I(i,j) - u(i,j\|^2$$

Mean absolute error(MAE)

$$MAE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\|I(i,j) - u(i,j)\|$$

Peak signal to noise ratio

$$PSNR = 10\log_{10}\left(\frac{MAX_1^2}{MSE}\right)$$

Signal to noise ratio(SNR)

$$SNR = 10\log_{10}\frac{\sum_{i=0}^{M-1}\sum_{i=0}^{N-1}\left(I_{(i,j)}^2 - u_{(i,j)}^2\right)}{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(I(i,j) - u(i,j))^2}$$

IV. IMAGE DE-NOISING TECNIQUES

There are large numbers of techniques present for removing noise from images. These techniques are mainly classified into two categories 1) spatial domain 2) Transform domain. These categories have further subcategories of image de-noising techniques. These techniques are discussed as follow:

1.Spatial domain

This approach of image de-noising directly operates on pixels. one of the biggest advantages of spatial domain is its speed but this technique is unable to preserve edges and fine details in image[1][2].This approach is further divided into two categories: I)Linear filters II) Non linear filters

I) Linear filters: Linear filters are also known as average filters. These filters remove noise from images but blur sharp edges, destroy lines and other fine details in image. Performance of this filter is not used in case of signal dependent noise. Linear filters further divided into two types: a) Mean filters b) wiener filters.

a) Mean filters: Mean filtering is a simple and easy to implement method of smoothing images i.e. The idea of mean filtering is simply to replace each pixel in an image with the mean value of its neighbors, including itself.[4] These types of filters don't preserve filters and fine details in image. Mean filters include 1) arithmetic mean filters, 2) geometric mean filters, 3) harmonic filters. Arithmetic mean filtering process computes the average value of image in the area covered by filter. Then restore value at the place of corrupted pixel. In Geometric filtering each restored pixel is given by the product of the pixels in the sub image window, raised to the power 1/mn. [3]A geometric mean filter achieves smoothing comparable to the arithmetic mean filters but tends to loss less image details in the process. Harmonic mean filters well for salt noise but fails for pepper noise. It does well also with other types of noise like Gaussian noise. Means filters further improved by A. baude et al by taking non local mean[6] of pixels i.e. non local means filters that removes noise and also preserve edges.

b) Wiener filters: wiener filters is a class of optimum linear filter which involves estimation of desired signal sequence from another related sequence. This type of filtering is optimal in terms of mean square error i.e.[1] It minimizes overall mean square error in the process of inverse filtering and noise smoothing. To implements this we estimate the power of original image and additive noise.[2][3]

II) Non Linear filters: In non linear filters noise can be removed without identifying it exclusively. These filtering techniques apply low pass filtering on images on assumption that noise signals always have high frequencies.[7] This approach is classified into a)Median filter b) Spatial median filter

a)Median Filtering This filter is a simple nonlinear operator that replace the middle pixel in the window with the median value of its neighbors. These filters mostly used to remove Gaussian noise and impulse noise..[9] It is influenced by the size of filtering window to a great degree, has the conflicts between noise reduction and detail protection: when the filtering window is downsized it maintains the details better while reducing less noise; when the window size is enlarged, it reduces noise in a better way while diminishing the protection of details.[3].This filter is further improved byZienab A.mustaf et al. by introducing modified hybrid median filters[4]

Hybrid Median filtering: This proposed filter is the modified version of the median filter explained above. It works on the sub windows similar to hybrid median filter. The mean value of the 45^0neighbors forming an "X" and the 90^0neighbors forming a "+" [4] The median value of 45^0neighbors are compared with the Central pixel and the median value of that set are then saved as the new pixel value. As on its comparative study with other methods like means filtering, median, TV filter, wavelet threshold [4] it provides higher SNR, PSNR and low MSE as compare to other methods.

Adaptive median filtering: It is improvement over the median filters. One advantage of adaptive median filter is that it can protect the details of the images from losing while reducing the noise. Different with other types of median filters, adaptive median filter should change the size of the window during filtering operation. This filter introduced by H. Hwang, R.A. Haddad et al. [10]

Block based median filter:

In adaptive median filter, the threshold value is fixed artificially. However, in an MRI image, signal distribution has different characteristics in different region; therefore it is not suitable to adopt the same threshold to determine noise point during filtering process. So block-based adaptive median filter divide the MRI image into several sub-images first, and then calculate the standard deviation of each sub-image since it is closely associated with the degree of signal distribution, and the threshold of each filtering window lies on the standard deviation of corresponding sub-image.[5] This method is used for salt and pepper noise.

b) Spatial median filter: In spatial median filter the spatial median is calculated by calculating the spatial depth between a point and a set of point. This spatial depth is defined by

$$S_{depth} = 1 - \frac{1}{N-1}\left\|\sum_{i=1}^{N}\frac{X - x_i}{\|X - x_i\|}\right\|$$

In this filter after finding out the spatial depth of each point lying within the filtering mask, this information is used to decide whether the central pixel of window is corrupted or not, If central pixel is uncorrupted then it will not be changed. We then find out the spatial depth of each pixel within the mask and then sort these spatial depths in descending order .The point with largest spatial depth represent the spatial median of the set. If central pixel is corrupted with noise then it is replaced by calculated spatial median as in [2].

2) Transform domain: Transform domain filtering method includes spatial frequency filtering and wavelet domain. These techniques subdivided on the basis of functions as data adaptive and non data adaptive transforms.

I) Spatial Frequency Filtering This technique refers the use of low pass filters using Fast Fourier Transform(FFT) .This approach removes noise by adapting a frequency domain filter and deciding a cut-off frequency. These methods are time consuming and dependent on cut-off frequency. These methods create artificial frequencies in the processed images.

II) Wavelet Domain In wavelet domain filtering methods are divided into linear and non-linear methods.

a) LINEAR FILTER If the signal corruption can be modeled as Gaussian process, Linear filters such as Weiner filter can provide the optimal result and mean square error (MSE) [12].is the accuracy criterion. However, if we design a filter on this assumption, this results in a filtered image which is very displeasing than the original noisy signal even though it considerably reduces the MSE. In [11] a wavelet domain spatially adaptive Weiner Filtering is proposed in which intractable filtering is not allowed in any case.

b) NON-LINEAR THRESHOLD FILTERING The most researched domain in de-noising using wavelet transform is the non-linear coefficient thresholding based method. This exploits the fact of problem of wavelet transform and maps white noise in the signal domain to white noise in the transform domain. Thus, white signal energy is more concentrated into transform domain, noise energy cannot be accumulated. So, this is the very effective method of noise removal from signal. The method which removes the small coefficients while others are untouched, is known as Hard Thresholding [14]. To cover the demerits of Hard Thresholding, Wavelet transform soft thresholding was also introduced in [13]by Donoho .In this, the coefficients greater than threshold are limited by the absolute value of threshold itself. Techniques other than soft thresholding are semi-soft thresholding and Garrote Thresholding .

i) Non-adaptive Thresholds: Non-Adaptive thresholds generally used are VISU Shrink. When the number of pixels reaches infinity it shows best performance in terms of MSE. This approach generally yields smoothed images[3].

ii) Adaptive Thresholds Adaptive Threshold technique involves SURE Shrink, Visu Shrink and Bayes Shrink methods. The Performance of SURE Shrink improved in comparison to the VISU Shrink because SURE Shrink uses a mixture of the universal threshold and the SURE [Stein's Unbiased Risk Estimator] threshold.[14] When noise levels are higher than signal magnitudes the assumption that one can distinguish noise from the signal . Bayes-Shrink outperforms SURE-Shrink most of the times. Bayes-Shrink minimizes the Bayes' Risk Estimator purpose assuming Generalized Gaussian prior and thus yielding data adaptive threshold

c)NON-ORTHOGONAL WAVELET TRANSFORMS Undecimated Wavelet transform (UDWT) can be used for decomposing the signal to provide visually better solution. It is shift invariant and avoids the defects and artifacts. Thus, largest improvements were there in results but there are computations overhead that makes it less usable .In [14] normal hard/soft thresholding was concentrated to Shift Invariant Discrete Wavelet Transform. To obtain the number of basis functions, in [15], Shift Invariant Wavelet Packet Decomposition (SIWPD) is exploited. Using the principle of Minimum description length, finds the basis function which yields the smallest length. Then, thresholding is used to de-noise the data. Use of multi-wavelets is further explored which enhances the performance but it increase the computational complexity. By applying more than one mother function to given dataset, multi-wavelets are generated. It possesses the properties like symmetry, short support, foremost is the higher order of vanishing moments.

d) WAVELET COEFFICIENT MODEL: It focuses on exploring the multi resolution properties of wavelet transform. By observing the signal across multiple resolutions, this technique identifies the close correlation of signal at different resolutions. This method gives the excellent results but is computationally less feasible due to cost and complexity. The Wavelet coefficients can be modeled either in the statistical or deterministic way. i) Deterministic It involves making of tree structure of wavelet coefficients with each level in the tree representing scale of transformation and nodes representing the wavelet coefficients. At particular node, if the wavelet coefficient has the strong presence than the signal, its presence is more pronounced at the parent nodes itself. If there is noisy coefficient, then its consistent presence is missing.Another method is proposed by Dunoho [13] using wavelet coefficient method.

ii) Statistical Modeling This approach explores some interesting properties of Wavelet Transform such as local correlation between neighboring wavelets and multiple and global correlation between the wavelet coefficients etc .It has the inherent goal of perfecting the data of image by using Wavelet Transforms. A review of statistical properties can be found in [15] and [16].Two techniques are there to exploit the statistical properties of wavelet transforms which are:

i) Marginal probabilistic model

Many homogeneous local probability models have been developed by researchers in the field of image processing based on wavelet domain. The Wavelet coefficient distributions are highly disturbed and marked peak of zero at heavy tails. The commonly used models for modeling the wavelet coefficients are Gaussian Mixture Model (GMM) [17] and Generalized Gaussian distribution (GGD) .GMM is simpler to use but GGD is more accurateThis methods requires the noise estimate which is very hard to achieve practically.

ii) Joint Probabilistic Model The efficient model for capturing inter scale dependencies are Hidden Markov Model (HMM) [17] whereas random markov models are useful for capturing intra scale dependencies [24].Local structure complexity is not well defined by Random Markov model whereas Hidden markov model are able to capture higher order statistics in much better way. a model is based in which Wavelet coefficient's neighborhood i.e. called as Gaussian State Mixture(GSM) is a product of Gaussian Random Vector and an independent hidden scalar multiplier. A drawback of the HMT is the computational burden of the stage of training. To overcome the drawback of HMT,a simplified approach uHMT was used.

OTHER IMAGE DE-NOISING TECHNIQUES

I.PGFND(peer group fuzzy non linear diffusion) method: This technique is the combination of PGFM and NDF method. The sequence of application of the methods is as follows: first PGFM and then NDF. The peer group with fuzzy metric approach removes the impulsive noise and the Gaussian noise is eliminated by NDF and both methods to eliminate speckle noise. The performance of this method is evaluated by sanchez, vidal,verdu and mayo in [20]. After evaluation, it have been observed that PGFND method provides much better results in terms of PSNR, SNR, MSE, MAE for impulse noise(salt and pepper noise),Gaussian noise and speckle noise as compare to PGNF which provide better results only for one type of noise not for these three.

II. Non Local mean algorithm: NL means algorithm was discovered by buades[6] and takes into account the redundancy of information in the image. Non-local means is an algorithm in image processing for image de-noising which takes a mean of all pixels in the image, weighted by how similar these pixels are to the target pixel.[18] This result in much greater post-filtering clarity and less loss of detail in the image compared with local mean algorithms. If compared with other well-known de-noising techniques, such as the Gaussian smoothing model, the anisotropic diffusion model, the total variation de-noising, the neighborhood filters and an elegant variant, the wavelet thresholding this filter provides better result in noise removing and maintaining fine detail in images. Nl means approaches provides satisfactory results for speckle noise, rician noise, passion noise(shot) , Gaussian noise. Nl method preserve edges, lines and other fine detail in structure.

III.Total variation Method: Total variation which goes back to Rudin and osher takes into account the minimization of energy function.[19] Total variation de-noising, also known as total variation regularization is a process, most often used in digital image processing, that has applications in noise removal. It is based on the principle that signals with excessive and possibly spurious detail have high total variation, that is, the integral of the absolute gradient of the signal is high. According to this principle, reducing the total variation of the signal subject to it being a close match to the original signal, removes unwanted detail whilst preserving important details such as edges. Indeed it has proved that it conserve straight edges however the finer details in images can be lost after de-noising process. It is mostly used for speckle noise.

V. ADAPTIVE APPROACH OF TOTAL VARIATION AND LOCAL NOISE ESTIMATION FOR RICIAN NOISE

This is an adaptive approach proposed by verghees,mank\ikandean and gini[19]. The regularization parameter of the TV based de-noising method is adapted based on the standard deviation of noise in MRI. using standard deviation of noise in a MR image. The noise standard deviation is computed using local statistics. Effectiveness of the adaptively tuned regularization parameter has been validated using a set of MR images with noise level ranging from 2 to 30. The proposed method is compared with other denoising methods based on the nonlocal filter, bilateral filter and multi-scale linear minimum mean square-error estimation (LMMSE) approach.[19] Both subjective visual quality and objective quality tests show that the proposed automated adaptive total variation denoising method sufficiently removes Rician noise while simultaneously preserving edges and fine structures in a given noisy MR image.

VI. NEUTROSOPHIC APPROACH

This approach is used for removing rician noise from MRI images. This technique is discovered by J.mohan,v.krishnaveni,Yanhui guo.[21] Neutrosophic Set (NS) approach of Magnetic Resonance Image (MRI) de-noising based on structural similarity such as Structural Similarity Index (SSIM) and Quality Index based on Local Variance (QILV). The Neutrosophic Set approach of median filter is used to reduce the Rician noise in MR image. This filtering method tends to produce good de-noised image not only in terms of visual perception but also in terms of the quality measures such as PSNR, SSIM and QILV. [21]This filter performs better than Median filtering method for reducing the Rician noise with different noise levels. Further, and also it outperforms the Non Local Mean approach when the noise level is high (low SNR).

Bilateral Filter: A bilateral filter is a non-linear, edge-preserving and noise-reducing smoothing filter for images. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution.[21]Crucially, the weights depend not only on Euclidean distance of pixels, but also on the radiometric differences (e.g. range differences, such as color intensity, depth distance, etc.). This preserves sharp edges by systematically looping through each pixel and adjusting weights to the adjacent pixels accordingly.

VII. CONCLUSION

After studying a number of techniques, it is conclude that some of the techniques are designed for a particular type of noise in image for which they provide good results but for other type of noises their results are not good. These are also some other techniques that can be apply to more than one type of noise but not all like NL means algorithm, TV, PGFND. so from this it is concluded that there is no such a method that can be apply to all types of noises.

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