Survey on Image Denoising using Filters and Transforms

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Abstract— *Image Denoising is the fundamental and a preprocessing procedure in the digital image processing. Images are often corrupted by noise during image acquisition. So, it is necessary to remove the noise for better perception. This paper discusses some reviews of filtering and transforms domain techniques of image denoising. The selection of suitable denoising algorithm is application dependent and is necessary to know about the noise present in the image to employ suitable algorithm. In this paper some types of denoising algorithms are discussed with their features to help in finding.*

Keywords— Denoising, Filtering, Transform

I. INTRODUCTION

Images especially digital images will play a major role in our day today life.Usually images are corrupted or degraded by means of noise. There are many types of noises like Gaussian noise, Rician noise, Speckle noise, Thermal noise, Salt and Pepper noise which will degrade the image.

In order to remove the noise in the digital images, denoising is employed. For medical imaging, denoising will provide better clearance in the image for easy diagnostics of diseases. The good diagnostic method must able to retrieve as much details of image even though the image is highly noise affected. There are several types of denoising techniques. Each one has its own advantages and disadvantages. Some methods are discussed in this paper.

II. FILTERING

Filtering in image processing is a function that is mainly used as the preprocessing step. The filter is employed by the nature of the task, type and behavior of the data. There are two types namely linear and non-linear filtering. In image processing, linear filters are known for its speed whereas the nonlinear filters are mainly used for edge preservation, whereas Non-linear filters can do this effectively. There are many types of linear and nonlinear filters. Based on application, filters are considered for efficient denoising.

A. Mean Filter:

Mean filtering is mainly considered for image smoothing. It uses the sliding window concept in which it replaces the centre value of the window by considering the average of all neighbouring pixels including the centre pixel. It is implemented using convolution mask. The mask is a square; usually 3*3 mask is employed.

Arithmetic mean filter [6] is the simplest of the mean filters. Let S(x,y) represents the set of coordinates in a rectangular subimage window of size m×n centered at point (x,y). It computes the average value of the corrupted image.

$$f(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t)$$

This operation can be implemented using a convolution mask in which all coefficients have value 1/m*n. A mean filter simply smoothes local variations in an image. PSNR [6] values are calculated for the images with various noise densities. The value of PSNR gets decreased with increase in the noise density of the image. The research results shows that the mean filter is best suited for commercial images compared to the medical images since it gives better PSNR value.

B. Median Filter:

Median filter is very efficient compared to mean filter but it is nonlinear in manner. Here the centre pixel is replaced by the median value. The median filter is much better at preserving sharp edges than mean filter. The best known order-statistics filter [6] is the median filter, which replaces the value of the pixel by the median of the gray levels in the neighborhood of that pixel-

$$f(x,y) = median_{(s,t)\in S_{xy}}\{g(s,t)\}$$

PSNR [6] values are calculated for the images with different noise densities. The value of PSNR gets decreased with increase in the noise density of the image. Compared to the mean filter, the PSNR is high for median filter for the image with same noise density. The edge preservation is good in the median filter compared to the mean filter. The PSNR value obtained using this filter clearly shows that median filter is well suited for the images corrupted by salt and pepper noise compared to mean and wiener filter [4].

C. Bilateral Filter:

Bilateral filter [12] is a nonlinear filter to preserve edges and for better smoothing. It works by replacing the current value of a focal pixel with the bilaterally weighted sum of pixels in its immediate area. The weights are calculated such that pixels on the same side of an edge contribute to the new focal pixel value, while those on opposing side effectively do not contribute, helps in maintaining the edges.

The MRI image is usually reconstructed by means of the inverse DFT .For the enhancement of the noisy MRI, bilateral filter is employed. Here it is considered for the undecimated wavelet coefficients. For the transform technique third level decomposition is considered because increase in the decomposition level provides a global average for the low pass coefficients to provide better smoothing. The approximation obtained in third level is passed through bilateral filter. The resultant is a denoised form of the approximation coefficient. The detailed coefficients obtained at each level are denoised by soft Thresholding.

Finally the reconstructed image provide high PSNR compared to the common wavelet domain technique. This method can produce good denoised images not only in terms of performance metric but also in terms of visual perception. Optimization can be done by employing adaptive bilateral filtering.

D. Wiener Filter:

The wiener filter [1] is known for its simplicity and speed. It is a system of linear equations which calculates a set of weights that denoised the input image. In order to calculate weight, cross correlation and covariance matrices of the input image is taken. This method is optimal if the input image is Gaussian noise distribution. It also minimizes the overall mean square error in image denoising and image smoothing.

The Rician noise is one which will affect the MRI images highly. In order to remove the noise, a new filtering technique is employed. This filtering is based on the Neutrosophic set approach [13] of the weiner filtering. First the entropy of the NS set image is defined, then wiener filter is used. The performance of this filtering method is high compared to the anisotropic diffusion and non-local means filtering method in terms of the signal to noise ratio and structural similarity index. This filter will remove noise in the images corrupted by poisson and speckle noise compared to mean and median filtering.

E. Anisotropic Diffusion:

In order to remove noise in the images several classical filtering techniques are employed. A recent technique where it can be effectively used in medical diagnostics is anisotropic diffusion. We can employ this to remove noise in 2D MRI images which also supports 3D and multiecho MRI images.

Anisotropic diffusion [11] is an iterative procedure based on smoothing that can be used for image denoising. The main requirements: Object boundaries are preserved, and noise should be efficiently removed in homogeneous regions. Images can be considered to consist of many regions, in which case the goal of anisotropic diffusion is to preferentially perform smoothing within regions rather than between regions. It preserves the edges and provides better PSNR compared to the filtering techniques. This method is used for MRI and ultrasound images compared to the commercial images since it gives better performance in case of PSNR.

F. Fourth Order PDE:

There are many types of filtering techniques but the fourth order PDE is used to avoid the blocky effects in the image which is not done in filtering methods. It is also used to optimize the tradeoff between noise removal and edge preservation. Compared to the second order, higher order PDE (fourth order) results in much cleaner images.

Fourth order PDE [9] preserves the step edges by using the original image and piecewise harmonic image. Second order PDE will have a limitation of staircase alleviation which can be overcome by using fourth order PDE. Fourth order PDE is derived by minimize energy functional of second derivatives of an image. It damps high frequency components of the image much faster than the 2nd order PDE. It can also be used as iterative procedure by fixing the threshold value.

III. WAVELET TECHNIQUES

Wavelet method is the highly preferred method for image denoising as it preserves noise, without affecting the signal characteristics. It operates in the frequency domain. It is nothing but the multiresolution representation of the image in two dependent domains. There is different wavelet used for the image denoising. Here some wavelets are discussed as follows:

A. Discrete Wavelet Transform:

Here the wavelet technique is analyzed using the orthogonal basis wavelet. DWT [8] will produce a better noise free image compared to other multi scale representation. The DWT is calculated and the resultant wavelet coefficients are compared to some thresholds. Since it has good energy compaction, the small coefficients are likely due to noise that has its energy spread over a large number of coefficients. These small coefficients can be threshold without affecting the significant features of the signal.

In wavelet denoising, the whole process is carried out in frequency domain. The DWT is calculated and the coefficients are compared to certain thresholds. Thresholding is the technique where one wavelet coefficient is used at a time. There are two types of Thresholding namely hard and soft [8]. During hard thresholding process, it keeps the image coefficient to determine the optimum threshold, but during soft thresholding, the image coefficient shrinks above the threshold in absolute value. During hard thresholding process, it keeps or kills the image coefficient to determine the Optimum threshold, but during soft thresholding, the image coefficient shrinks above the threshold in absolute value.

Here we use Haar, Daubechies and symmlet wavelet [8] for image denoising. It will provide better PSNR and less visual artifact. Among all the Daubenchies wavelet gave better result than others, so we use this wavelet as the reference to analyze the image. Compared to the spatial filtering technique, wavelet technique will provide better Denoising results.

B. Curvelet Transform:

In order to remove the noise in the digital images, a [1] 2D FDCT is used. Digital curvelet transform can be implemented in two ways, using USFFT (Unequally Spaced Fast Fourier Transform) and wrapping. Wrapping is considered here because it is simpler, faster and less redundant. Bayes shrink soft Thresholding tracks better curve so it provides better denoising. First curvelet coefficients are obtained by using FDCT and threshold the coefficients. By using inverse 2D FDCT, the denoised image is reconstructed.

The performance metrics like PSNR and MSE are used for the analysis. These values are improved in case of the curvelet transform than the wavelet transform. When compared to the Db4 wavelet [10].It provides better edge preservation and improves smoothness.

C. Fast Wavelet Transform:

Mallat's algorithm [3] is a computationally efficient method of implementing the wavelet transform. It calculates DWT coefficients for the input data, which is a power of two called down sampling. In certain applications, some form of processing is done to the wavelet coefficients obtained after the DWT. Once the processing is done, the data vector is built back from the coefficients. This process is known as the inverse Mallat algorithm. In the reconstruction procedure, quadrature mirror filters Equation are supplied with the coarse coefficients and the accumulated detail coefficients. The so obtained outputs of the two filters are summed and are treated as the coarse coefficients for the next stage of reconstruction. This procedure is continued until the data vector is obtained.

In this paper, denoising of medical MRI images is performed using daubechies and fast wavelet transform at both soft and hard threshold levels and PSNR and MSE are calculated for both techniques. From the results, the fast wavelet transform shows better results as compared to daubechies wavelet transform with lesser processing time. It enhances the visual quality of the medical images by achieving high PSNR value and minimum MSE. One of the key advantages of fast wavelet transform is that it reduces both memory requirements and complexity. It also increases the flexibility.

D. Contourlet Transform:

It is mainly employed for the images with salt and pepper noise in order to remove noise in the image. Denoising problem is commonly removed by using the transform techniques especially wavelet transforms. The directionality and anisotropy properties will effectively handles the 2D singularities. The Bayesian Least Square Gaussian Scale mixture (BLS-GSM)[14] is a recently developed image Denoising method. It is based on modeling of coefficients of multiscale oriented frame of the steerable wavelet transform. Other wavelet transforms can also be employed, whereas here contourlet transform is employed. While comparing with the BPDN techniques (Basis-Pursuit denoising) It provide higher PSNR values whereas the visual quality remains similar in all the cases.

IV. Conclusion

Denoising has been a promising research area till now, as there is not a particular technique for wide range of images. From these discussion, it is clear that based on the application and the noise model we can employ denoising method .The filtering technique will work best if the image is affected by salt and pepper noise and the transform domain technique will be best suitable for the images affected by Gaussian noise. Based on the amount of noise present in the image, we can also use fourth order PDE technique. When filtering techniques are employed in wavelet domain, efficient results can be obtained. For example before employing a wavelet for denoising, filtering can be employed as a preprocessing step.

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