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Reviews on Multiscale Transform Domain Image Denoising Methods

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ABSTRACT

The noise may arise due to the random variation of brightness, discontinuities at edges, and processing through digital hardware etc. Shot noise due to sensor, circuitry of a scanner or digital camera and photon detector can add spurious and extraneous information. The noise removal techniques are divided into two categories one is the spatial domain filtering method and other is the transform domain filtering method. There have been several work has been done regarding the noise suppression process and each approach in the previous literature has its own advantages, limitations and assumptions. This paper presents a review on transform domain noise suppression techniques in the area of image de-noising.

Keywords: Fourier transform, wavelet transform, Contourlet transform, discrete cosine transform, non-sub sampled Contourlet transform.

I. INTRODUCTION

Over a last decade, it is seen that visual information has been the important concern and witness in the area of safety, security. Even in the medical field, so many treatments are directly depending on the proper visual inspection of affected organ of the body. There is a large inflow of digital medical images and the concerned clinical data has been witnessed by the hospital. Often, so many important decisions on the basis images is restricted when an image gets often corrupted by the certain type of noise in its acquisition, processing, transmission and reception. The main aim of the noise removal algorithm is to recover the best estimate of the original image from its corrupted image[1].

Furthermore, if one looks on the type of noise, the Gaussian noise can be caused by poor image acquisition. It may also arise during the transmission of image data in noisy communication channels. The Gaussian noise can be effectively reduced using the linear filtering methods.

Other types of noises such as impulse and speckle can be caused by malfunctioning pixels of pixels in digital hardware, camera sensor and in faulty memory allocations in hardware. The salt and pepper noise changes the pixels value at certain location by taking the maximum and minimum brightness value. In case of random value noise, corrupted pixels can take any random value in the dynamic range.

Speckle noise is a random in nature; therefore, the corrupted image and the texture of the observed speckle pattern do not meet to any underlying structure. The local brightness due to the speckle pattern has a negative impact on ultrasound imaging.

It is necessary to apply an efficient noisy pixels detection technique to het correct estimate for such data corruption. Image denoising introduces artifacts and causes blurring of the images when the estimation is carried out in order to get the original form of image. Therefore, it has been a great area of research and the goal is set to preserve the integrity of edge and detail information.

There are mainly two effective approaches to image denoising, one is the spatial filtering methods and the other is transform domain filtering methods[2]. Spatial filtering techniques are a traditional way to remove noise by employing some statistical standard and thresholding on individual pixel or group of pixels. Mostly in the spatial domain, a low pass filtering is applied on homogeneous region by keeping the assumption that the noise occupies the higher frequency spectrum. However these filters reduce the noise, also causes the blurring of edges in signals and images. The edges may be preserved and the spatial resolution can be removed by employing the while the high-pass filters can make edges even sharper and improve the spatial resolution. The negative impact of the use of high pass filter is observed that it also amplifies the noisy background[3,9,10].

Spatial filters are broadly classified into non-linear and linear filters. So many non-filtering techniques is applied in the image without any attempts to identify the corrupted pixels due to noise. The non-linear filters basically depend on the satirical nature of neighborhood data. Median filter is an example of non-linear filtering method that sorts a set of pixels in ascending order and uses the median value to estimate the correct pixel at noise location. This is basically employed by examining the set of pixels under a mask which estimate the underlying image brightness using the correlation with the neighbor pixels[11,12]. The median filter is efficiently used to reduce the impact due to the impulse noise. However, with the increase noise level in the system, the non-linear filter smears out edges and cause blurring effect over he image.

On the other hand, the mean or average filter falls in the category of optimal linear filter that is helpful in reducing the Gaussian noise removal.

It utilizes the statistical parameter to estimate the noisy pixels in the image. Linear filters too tend poor response to blur sharp edge[4,5]. It may destroy lines and other significant image details. It does not perform well in the presence of signal-dependent noise.

In order to achieve a good performance, the de-noising algorithms should also cover he aspect of determining the image discontinuities[6,7]. The image discontinuities can easily be localized using the multi resolution analysis. In the transform domain image restoration process, it is seen that the image can be efficiently approximated by a linear combination of few basis elements[13,14]. In transform domain, the image is sparsely represented using the main coefficient of the signal. The main work in transform domain is emphasized on the selection of high magnitude transform coefficient. Since, it is seen that the high magnitude coefficient preserve the important information about the image and mostly original image property while the other coefficients are discarded because those are mainly due to noise.

The sparse representation depends on both the transform and its inverse property. In the recent years, there has been a lot of work is carried out on various denoising methods such as Fourier transform, DCT (Discrete cosine transform) wavelet, curvelet, Contourlet, ridgelet, non-sub sampled Contourlet and various other multi resolution analysis tools. In this work, few transform domain techniques have been reviewed in image denoising process[15]. Remaining of the work in this paper is as summarized. Section II reviews some transform domain techniques. Section III gives the comparative analysis of these transform domain image denoising process. Section IV concludes our work.

II. IMAGE DE-NOISING TECHNIQUES IN TRANSFORM DOMAIN

In transform domain techniques, the image is first transformed in frequency domain. The image is decomposed in to its frequency component and the efficient magnitude coefficient is persevered. Mainly discontinuities at the edges or anywhere due to high frequency component can be well localized in transform domain. Spurious noisy coefficient, noise detection and noise removal is done in frequency domain transformed. Latter the image estimation is carried out through inverse transform. The correct estimation of original image depends on the selection of basis function. In this section, the transform methods and its basis function is described which frequently used in image denoising process.

A. Fourier transform based image filter

The Fourier transform converts the time domain representation of signal into frequency domain representation[8]. The de-noising process includes three fundamental tasks in Fourier transform method to de-noise the image. First process computes the frequency component present in the image using FFT (Fast Fourier transform algorithm). Since the additive Gaussian noise corrupts almost all the frequency component and its coefficient. Based on the assumption that the coefficient having smaller in magnitude is greatly affected due to noise than the higher magnitude coefficient, a threshold value is calculated to differentiate the higher value and lower value coefficient. Using of adaptive threshold technique at different resolution gives better synthesis of image at the time of reconstruction. During the de noising process, use of low pass filter leaves low frequency unchanged and attenuates high frequency. These low filters also called smoothing filter. The use of high pass filter preserves the data at edges and boundary. These filters also called the sharpening filter. Though the Fourier domain for image de-noising is efficient, but sometime they suffer from ringing effect at the sharp transition region. The Gaussian and Butterworth filter both suffers from this ringing effect. The above effect can be eliminated when the FFT is combined with other transform by selecting the proper basis function.

B. Discrete cosine transform based image noise filter

DCT domain image filter efficiently removes the Gaussian noise from the digital image[6]. The DCT works also on the selection of proper coefficient, which represents significant component in the image. As it is seen that, low frequency components lies most of the energy while the existing of noise lies in the high frequency component. In DCT matrix, the left upper corner belongs to the higher energy that consists of the relevant information about an image. The lower right corner coefficient does not contain any significant information. Therefore, by choosing some suitable threshold, the unwanted components can be removed and noised can be suppressed. The threshold is chosen adaptively to remove the spurious content that is based on the percentage of edge pixels under a size of mask or window. If the percentage of edges is low then the region is flat and contains significant information. If the percentage of edges is high then it contains the information about noise, the edges and fine details of the image. Two type of thresholding approach has been applied to the DCT domain, one is soft thresholding method, and other is hard thresholding method. In hard thresholding, a fixed threshold is defined for the entire mask used during the processing of an image. However, in case of soft thresholding scheme, the threshold may vary from mask to mask which can be estimated using the statistical property of the windowed data samples. Adaptive DCT filter has superior performance than moving average filter, ranked order mean filter and simple DCT filters.

C. Wavelet transform based image noise filter

The multi resolution and sparse structure makes the wavelet transform superior denoising techniques than other transform and spatial techniques[7].

Wavelet based image relies on the assumption that noise commonly localized itself as fine-grained structure in the image. The discrete wavelet transform decomposes any signal using a certain scale. The wavelet coefficients at the finer scale represent the edges, noise, and vey fine details. Selecting a proper threshold and on the basis of scale, a natural filtering can be done.

However, the selection of proper threshold value is a matter of great concern, because the finer scale also localizes the edge feature. Therefore the threshold value is selected so as the edges are retained without much damage. Suppressing too much coefficient may lead t smooth signal and cause the blur.

In order to suppress the insignificant coefficient too many thresholding techniques such as SURE SHRINK, VISU SHRINK and BAYES SHRINK. Has been proposed in he literature. As seen that majority of wavelet coefficient is very small and they can be set to zero using a proper threshold value. In some method, few low frequency wavelet sub band is untouched that brings smoothness in the signal or in an image after filtering. A translation invariant method is proposed in the literature in order to reduce the ringing effect existing in traditional wavelet transform. Some methods used the neighborhood coefficients in order to calculate the threshold to suppress the insignificant coefficients in an image.

D. Ridgelet transform based image noise filter

Discrete ridgelet transform provides the better visualization of denoised image by keeping the both smooth object with edges. It is very optimal techniques to reduce the Gaussian noise. It localizes the energy in the image in to smaller number of ridge coefficient.

It requires fewer ridgelet coefficients to represent the edges feature of an image than the traditional wavelet transform[4].

The ordinary ridgelet transform goes through the following steps. The first stage starts with the calculation of FFT to convert in the image into the frequency domain. The sampled value of the Fourier transform is mapped with the sampled value on the polar lattice. In the next stage, the I D inverse FFT is calculated for each sampled point on the polar lattice. Now, in order to calculate the ridgelet coefficient, 1D wavelet transform is performed on each angular line. In order to achieve the shift invariant property, a complex wavelet transform is applied to obtain the good ridgelet coefficient. Complex ridgelets achieves better performance in image denoising than Visu Shrink, wiener 2, and the ordinary ridgelets. The demerit of ridgelet transform is that it cannot handle curves in the images perfectly because this transform enhances the idea f point to line mapping of the singularities. As seen, the ridgelet transform makes rapid reconstruction of image using first few coefficients but after that the process became slow. This requires large number of ridgelet coefficients to correct the initial reconstructed image.

Unlike wavelet transforms, the ridgelet transform computes the integrals over different orientations and point on the polar coordinates. Using the approximates shift property of dual tree complex wavelet transform, the ridgelet transform can efficiently reconstruct the image.

E. Contourlet transform based image noise filter

Contourlet transform is efficient to handle Gaussian white noise and random value noise in an image[1]. The noisy image is decomposed into frequency sub bands using the Contourlet transform. Later a threshold is selected to select the significant coefficient and remove the noisy coefficients. Then the synthesizing operation is applied to reconstruct the original image.

The Contourlet transform consists of double filter bank structure. In the first stage, a Laplacian pyramidal filter is applied to capture the point discontinuities. Then, a directional filter bank links all the point discontinuities into linear structures. Contourlet decomposes an image into different scales which is similar to wavelet transform but the size of scale in later stage is decomposed into arbitrarily power of two's number of directions.

The threshold selection method is required to remove the unwanted coefficients from the transformed image to reduce the impact of noise. This Contourlet technique is computationally faster than the traditional wavelet technique. It is more efficient in preserving the edge features, background information. The Contourlet is more suitable for the images which consist of a lot of curves type texture in it. The Contourlet transform lacks of the property of shift invariant due to filter bank structure.

The periodicity of 2D frequency spectra and imperfect sampling by the filter bank leads to aliasing. This effect is reduced by using the Laplacian pyramid of multiscale pyramid with both high pass and low pass filter. Though this method was also not shift invariant.

F. Non-sub sampled Contourlet transform based noise filter

Higher dimension representation is required to represent the curve and smoothness of the images[5]. The limitation of the Contourlet transform is that the filter bank do not inherits the property of shift invariant.

This Non-sub sampled Contourlet transform first passes the image through non-sub sampled Laplacian pyramid, which decomposes the images in to multiscale. It calculates the noise variance for each sub-band. Using the local statistics of the image, one can decide whether the pixel is either noisy or non-noisy. On the basis of threshold selection, the strong edges are retained and the weak edges are discarded.

The NSCT is computationally efficient and fast. It is fully shift-invariant, and uses multiscale pyramid. In the literature, the better frequency selectivity is used to estimation the better sub band decomposition. In the later research, the NSCT is combined with the soft thresholding method to get the better estimate the original image.

In comparison with the Contourlet transform, the sub band of NSCT has same size that helps to find relationship among the sub-bands. Second the NSCT gives better resolution at fewer coefficients, while a complex technique would be required to remove the noise from the corrupted image.

III. RESULTS AND DISCUSSION

As seen in Fig (1) and Fig(2), the Fourier transform performs well in terms of both visual quality and SNR. After some medication in thresholding technique, the SNR can be improved. The effects of oversampling and using tapered windows may cause ringing effect at the transition point of sub band. Choosing some significant coefficient, the noise can also be removed using DCT method. However, the blurring effect can be seen if the proper threshold is not selected. Wavelet transform is an effective method of image denoising but it is not sift invariant. Also, it is seen that, the traditional wavelet has limited direction to examine the high frequency component.

Fig.1. Images for visual performances comparison: (a) The original Lena face image; (b) Noisy Lena face with Gaussian noise (σ^2=.02); (c) DCT, (d)Wavelet transform, (e) Ridgelet Transform (f) Contourlet transform (g) Non subsample Contourlet transform (NSCT)

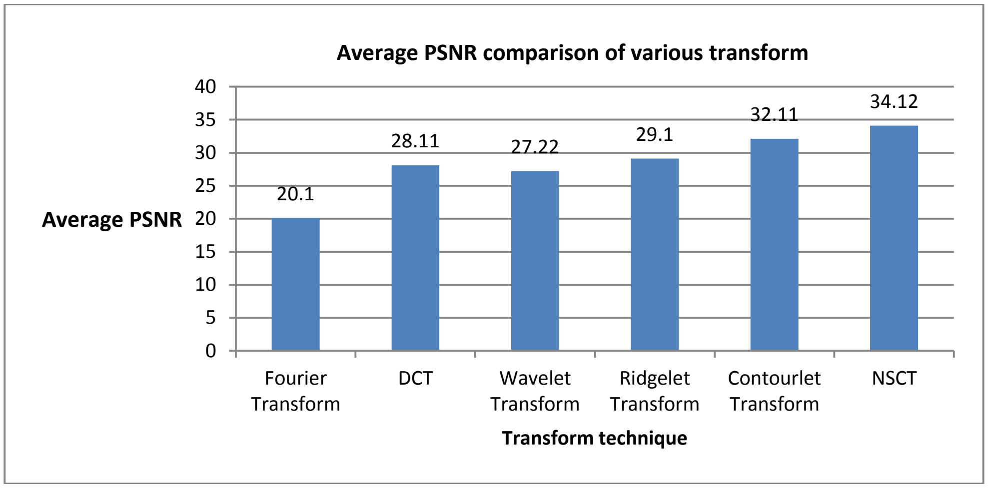

Figure 2: Average PSNR comparison of various transform techniques

Therefore wavelet is not suitable to find the curve and contour in the images. The Contourlet is more where the images consist of a lot of curves type texture in it. However, the Contourlet transform lacks of the property of shift invariant that makes it incapable in handling the curve and contour in the images. The NSCT uses multiscale pyramid and multidirectional filter with soft thresholding method to estimate the better true image from the noise.

IV. CONCLUSION

The most important concerns in digital image processing is the suppression of noise content, which is related to the detection of noisy pixel and the estimation of pixels at the proper place. There are so many varieties of noise that can exist in the images in which the Impulsive noise is one of them that can degrade the images during their acquisition or transmission or storage etc. Noise removal is the fundamental task that can be executed in such a way that important information of image should be kept preserved while estimating the true image. However, removal of noise under sophisticated condition is one of the challenging problems in digital image processing. Removing noise from the original signal is still a challenging condition. Some methods remove the noise effectively but do not maintain the regularity in the estimated images. Some of the methods do not handle the curve and contour in the image during the denoising process. Using multiscale decomposition and multidirectional filter bank, the performance can be removed during the estimation of correct images.

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