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RESEARCH ARTICLE

STUDY OF VARIOUS IMAGE DENOISING APPROACHES.

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Abstract

The important challenging factor in image denoising is removal of noise from an Image while preserving its details. Noise causes a barrier and it affects the performance by decreasing the resolution, image quality, image visuality and the object recognizing capability. Due to noise presence it is difficult for observer to obtain discriminate finer details and structure of image. There are various types of noise that corrupt the original signal. There are no of existing denoising methods like wavelets transform domain, spatial domain filtering and Principal Component Analysis (PCA) based etc. Each method has its own advantages, disadvantages and assumptions. The denoising methods are generally based on application. It is essentially to have information about the noise level present in the image to select the right algorithm. This paper outlines the brief introduction of noise, noise types and presents a study of some significant work in the field of Image denoising. Some popular approaches and their limitations that are identified by the survey are also discussed. Insights, potential issues and challenges are also discussed in the area of image denoising. This paper may provide a platform to the researchers for further research work in area of image denoising.

Introduction:-

Digital images are playing an important role in the area of digital image processing. Noise present in an image is a distracting artifact that degrades the quality and resolution of an image. Noise is an undesirable signal and random variation of brightness or color information [15]. There are various sources of noise in an image. Noise may be internal or external. External noise added due to external factors like environmental conditions and internal noise that is generated within system like faulty switching etc. Sources of noise that are considered mainly are given below:

- By environmental conditions that affect the image sensors during image acquisition or transmission process.
- Noise can be introduced due to dust particles on scanner screen.
- Interferences in transmission channels introduce noise in an image during transmission process.
- Due to sensor temperature or insufficient light levels.

Image denoising is vital field and plays very effective role in digital image processing like image restoration, image classification, image registration etc, computer vision and other research areas related to digital images. Image denoising is difficult delicate task. Removal of noise has always been standard problem of image processing. Denoising and deblurring are major tasks of image restoration. Image denoising lies on the objective side while image enhancement lies on the subjective side. Image denoising is a still valid challenge for researchers because presence of noise produces artifacts and causes blurring in images. There are number of existing methods to perform denoising. A good denoising method preserves the features, edges and finer details of image while removing the

noise. By using the denoising problem, X is an original image and N is any type of noise and by adding N noise into an original image gets a Y noisy image as output [15].

$$Y = X + N$$

Different Noise Types:-

There are various types of noise depending upon the disturbance that affects the image at different extents [17] [18]. Image noise can be categories as:

- Amplifier Noise (Gaussian noise)
- Salt & Pepper Noise(Impulse Noise)
- Poisson Noise.
- Speckle Noise.
- Anisotropic noise.
- Film grain.
- Quantization noise.

Related work:-

There are a number of Image denoising methods like Spatial filtering, Frequency Domain and Wavelet Domain filtering, Wavelet Thresholding, Principal component analysis etc. Each method follows its own unique technique and each method has its own pros and cons. Some methods select denoising algorithm according to type and quantity of noise that are present in the image. But some methods take account other factors like performance, edge discontinuities, computational time, computational cost while performing denoising process. Some of these denoising approaches are considered here.

Spatial Filtering Domain:-

Spatial filtering method is traditional method. It is used to remove the noise by using spatial filters. Spatial filtering operations are based on Fourier Transform and perform manipulation directly on the pixels of image. Spatial filter has two categories [25][18]:

Linear Filter:-

Linear Filter are used to remove the certain kind of noise, blurring of sharp edges and eliminate lines and other finer details of image but it performs poorly in the presence of signal dependent noise. Mean and wiener filters are linear filters [15].

Advantages:- Linear filter shows better performance if underlying signal is smooth.

Disadvantages:- Performance of Linear filter is poor in case of signal dependent noise.

Non-Linear Filter:-

Non Linear filters have been developed to overcome the limitations of linear filters. Median filter [18] is a non linear filter. There are various types of median filters used to remove the drawbacks of linear filter such as relaxed median[13],weighted median[11], rank selection and rank conditioned [12] etc. Noise is removed without identifying noise explicitly with non linear filters. Non Linear filters have good performance as compared to linear filters.

Transform Domain Filtering:-

The transform domain filtering method can be divided into two categories according to basis functions [24]. The basis function can be further subdivided into two classes as data adaptive and non adaptive. Non adaptive is more popular method [23].

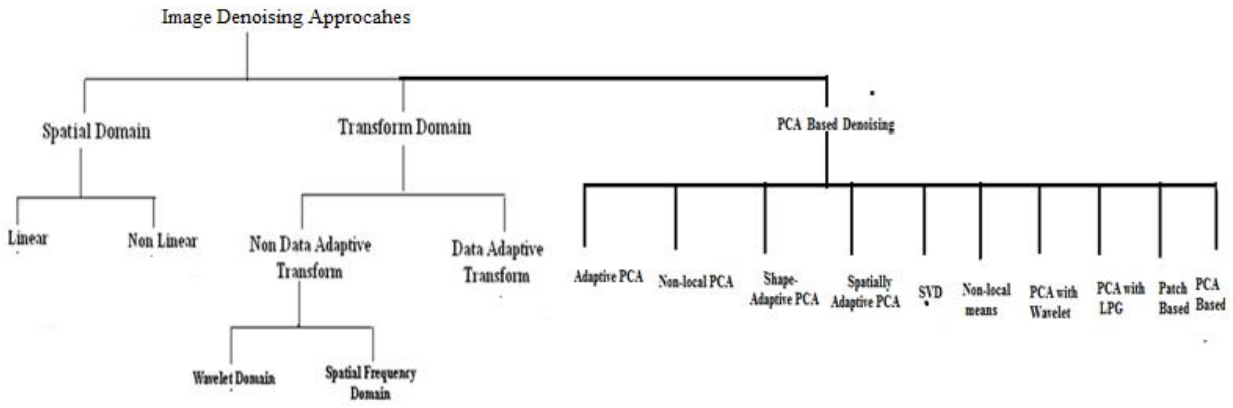

Fig 1:- Image Denoising Approaches [23]

Non-Adaptive Transforms:-
Non data adaptive transform uses the same set of parameters for dimensionality reduction regardless of the underlying data.

Spatial Frequency Filtering:-
Spatial Frequency Filtering based on Fast Fourier Transform by using low pass filters. When the components of noise are decorrelated from useful signal then decides a cut-off frequency and adapting a frequency domain filter for removal of noise [18][28].

Disadvantage:-
a. This method is Time consuming.
b. It depends on cut-off frequency and behavior of filter function. Moreover, it generates the artificial frequencies in the processed image.

Wavelet Domain Filtering:-
The Wavelet domain filtering methods has two types: linear and non linear methods [23]. Wavelet transform contains group of basic functions and these functions can be used to analyze signals in terms of both time and frequency domains simultaneously. The Wavelet transform is an important tool due to its energy compaction factor used in denoised process to solve the problem of noise. Wavelet transforms are multiresolution representation of images as well as signals.

Data Adaptive Transform:-
Data adaptive transform techniques take into account the underlying data and adjust their parameters accordingly. Data adaptive transform contains a new method known as Independent Component Analysis (ICA). ICA method performs denoising for non Gaussian data [20] [23].

Advantage:- ICA is used to denoise both non Gaussian data as well as Gaussian distribution.
Disadvantages:-
a. This Method has greater computational cost as compared to wavelet domain.
b. It demands sample of noise free data. Moreover, it is very difficult to achieve the noise free training set in some applications.

PCA Based denoising:-
In this section, discuss the different methods of denoising based on PCA. These PCA based Denoising methods are patch based PCA, adaptive PCA, Local PCA, and Non local PCA and two stage method based on PCA with local pixel grouping , PCA based spatially adaptive denoising , SVD based denoising, PCA with wavelet etc.

Image denoising with patch based PCA:-
Deledalle and salmon et al. [1] in the recent year, describes three patch based denoising algorithms. For denoising process it performs hard Thresholding on the coefficients of the patches in image-specific orthogonal dictionaries. These three algorithms use different methodology: local PCA, hierarchical PCA and global PCA. Denoising performed on the basis of block-wise rather than pixel-wise. The performance of these algorithms computed in terms of accuracy and running times, computational cost. Patch based PCA contains two steps: First step performing a Principal Component Analysis to get an orthogonal basis from the noisy image. In second step, zeroing all the small coefficients in the representation of noisy patch in the learned basis to get denoised patch.

Advantage:- This method is simple and gives better results as compared to existing methods for large images and for moderate value of signal-to-noise ratios.
Disadvantage:- Patch based PCA methods based on selection of at most three parameters by user: size of patches, threshold value and searching zone width (PLPCA) or the number of recursions (PHPCA).

PCA with local pixel grouping:-
Zhang et al**. [**2**]** presents a novel scheme for efficient image denoising by using the Principal Component Analysis (PCA) with Local Pixel Grouping (LPG). This method has two stages: The first stage evaluates image estimation by removing the noise and second stage gives further refinement of the first stage. The both stages have the same procedure except for the parameter of noise level. In the first stage the noise is significantly reduced and the second stage improved LPG accuracy due to better accuracy the final denoising result is better by visually. It also uses an algorithm BM3D for selection of training samples. In this algorithm block matching is performed and on the basis of similarity frames are grouped together according to matched blocks. The LPG-PCA method iterated more than one time to improve the denoising performance [16].

Advantage: This method preserves the local image structures and edges while performing denoising.
Disadvantage: It has low image quality due to low peak-signal noise ratio.

Denoising with shape-Adaptive principal component analysis:-
Dabov, A. Foi et al. [3] describes an efficient approach to represents non local image modeling, estimation of local shape-adaptive anisotropic and principal component analysis (PCA). To represent the Non-local modeling group similar image patches in 3-D group and then perform denoising by shrinkage of spectrum of 3D-Transform by applying on these groups. The effectiveness of shrinkage depends on the capability of the transform to represent the true-image data sparsely, to separate it from the noise. To improve the sparsity follows two aspects. Firstly, employs data-adaptive shape image patches (neighborhoods). Secondly, Perform PCA applies on adaptive-shape neighborhoods that are considered as a part of the employed 3-D transform. The PCA bases are get by empirical second-moment matrices' eigenvalue decomposition which is estimated from groups of similar adaptive-shape neighborhoods.

Advantages:-
a. This technique gives better results to preserving image details and introduces very few artifacts.
b. It act as very competitive and outperforms as compared to current best denoising methods, especially in and block-matching of square blocks is done by same procedure of BM3D algorithm to find similar neighborhoods.

PCA Based Spatially Adaptive Denoising of CFA images:-
Lei Zhang, et al. [4] introduces PCA based CFA image denoising scheme for single sensor digital camera imaging applications. It describes principal component analysis based on spatially adaptive denoising algorithm. It works on the color filtering array (CFA) images and uses a supporting window to analyze the local structure of each CFA variable block. Each CFA variable block contains color components from different channels. This scheme effectively describes the spatial and spectral correlation properties simultaneously. This scheme preserves the image finer details better than other existing method that gives smoothness.

Advantage:-
a. These methods effectively suppress noise when preserving color details and edges.
b. Exploit spatial and spectral correlation simultaneously effectively.

Poisson Noise Reduction With Non-Local PCA:-
The author Joseph salmon et al [5] presents a method to denoise the images that are corrupted by Poisson distribution .This method based on combination of Poisson PCA with patches. The blind application of standard noise removals methods gives significant artifacts due to the Poisson noise variance equal to its mean. The objective of the present work is to get better results from small dictionaries only and from the noisy image, they are learned directly. Patch based denoising algorithm means Non local methods perform an adaptation of PCA (Principal Component Analysis) for Poisson noise. The author also gives performance evaluation of this algorithm when the photon value is very small.

Advantage:- This method is simplest method and efficient in case of low count photons.
Disadvantage:- it is not efficient for additive Gaussian noise and it works well especially for Poisson noise.

Denoising based Adaptive Principal Components Analysis:-
D. D. Muresan et al. [6] presents an image denoising method using adaptive principal components. This method is used to denoise the images that are corrupted by additive white Gaussian noise. This denoising technique gives better performance in form of image visual fidelity, and outperforms in terms of PSNR values. The author also compares the currently published denoising algorithms against this new decomposition technique. PCA applies on local image patches and yields 2 D, locally adaptive basis set. This paper focuses selection of 2 D locally adaptive basis set and strengths of this new decomposition approach by applying it to image denoising.

Advantage:- This method gives better performance in terms of image visual fidelity and peak signal noise ratio.
Disadvantage:- This method is applied to only additive white Gaussian noisy images.

Non-Local Means Image Denoising:-
Tasdizen et al [7] presents an image denoising approach based on non local means image denoising with principal component analysis (PCA). In the non-local means algorithm, by using PCA firstly Image neighborhood vectors are projected onto a lower-dimensional subspace using PCA. Consequently, the distance in subspace rather than full space is considered to calculate the Neighborhood similarity weights for denoising. So that the lower dimensionality projections act as search criteria and also compute Neighborhood similarity. This approach is data driven and adaptive to statistics of a given image.

Advantage:- This approach gives better performance in terms of improved accuracy and computational cost due to non-local means algorithm.
Disadvantage:- It is based on assumption that image neighborhood vectors exist on a lower-dimensional manifold rather than full space.

Denoising with Singular Value Decomposition:-
Phillip K Poon, et al. [8] describes three image denoising techniques through Singular Value Decomposition (SVD). In the first method, a single noisy image represents as a linear combination of image components that are truncated at various terms by using SVD. To determine the effectiveness of truncating at each term compare each image approximation. The second technique expands the concept of image denoising via SVD by using a block wise analysis to perform denoising. Third technique performs denoising of images according to block-wise by using Principal Component Analysis (PCA) with SVD. The third technique is best technique for decreasing the root mean square error as Compared to the first two denoising techniques.

Advantage:- This method performs to minimize the root mean square error (RMSE) uses optimal block size at each noise level.
Disadvantage:- PCA does not completely recover the original image when noise is added, but it is possible to get an optimal number of projections.

Denoising with adaptive improved PCA with Wavelet Transform:-
Vikas Gupta et al [9] presents image denoising scheme based on PCA (principal component analysis) with wavelet transform. It combines the advantages of both approaches. Wavelet transform are performed to improve the contrast enhancement of an image. Principal component analysis applied for removing the noise. The results of combination approach of PCA with wavelet gives better performance in terms of Peak signal noise ratio and perform denoising process efficiently and better preserving the data of original image.

Advantage:-

a. It preserves the image details better than existing methods while removing noise from an image.
b. This approach gives better performance by improving the signal noise ratio.

Patch-based Denoising:-

Xiaogang Chen et al. [10] discussed a denoising method known as fast patch-based and it is based on Patch Geodesic Paths (PatchGP). PatchGPs to compute the shortest (geodesic) paths image patches act as nodes and patch differences act as edge weights. The path lengths act as weights of the smoothing kernel as well as denoising kernel. PatchGPs can be effectively approximated by minimum hop paths (MHPs). To construct the denoising kernel, perform discretize for MHP search directions and patches are used only along the search directions. In this paper, shows the comparison analysis of this technique with existing currently denoising techniques. This method is based on three parameters patch size, window size and discretized search directions.

Advantage:- This method gives better performance in terms of quality and few orders faster than existing methods.
Disadvantage:- It requires good parameters patch size, window size and discretized search directions etc.

Conclusion:-

In this paper various methods are discussed that are used for image denoising. Each method has its own advantages and disadvantages. The different parameters are used to measure the outperform of methods like wavelet based and PCA based methods. Some of these parameters are peak signal to noise ratio, structural similarity index and correlation coefficient, mean square error etc. Each method follows its own approach to denoise any noisy images. Different images are corrupted by different types of noise and some of methods work best for removing Gaussian noise like adaptive PCA while some of are used for Poisson noise like Poisson noise reduction non local . The main aim of this survey is image denoising. Insights and potential issues and challenges of various techniques are also discussed in the area of image denoising. This study also provides guidelines and platform for further research work.

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