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Image Denoising Techniques- A Review paper

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Abstract— Removal of noise from the original signal is still a bottleneck for researchers. There are several methods and techniques published and each method has its own advantages, disadvantages and assumptions. This paper presents a review of some significant work in the field of Image Denoising.The brief introduction of some popular approaches is provided and discussed. Insights and potential future trends are also discussed

Index Terms—Denoising, Spatial Filters, Threshold, Orthogonal Transforms.

I. INTRODUCTION

Digital images plays very significant role in our daily routine like satellite television, computer resonance imaging and in area of research and technology. Image sensors collect the data sets which are contaminated by noise due to imperfect instruments, disturbed natural phenomenon can all degrade the quality of data of interest. Noise can also be introduced in images due to transmission and compression of images. Thus; image denoising is the necessary and foremost step for image analysis. So, it is necessary to depute some effective image denoising techniques to prevent this type of corruption from digital images.

Image denoising problem is still a bottleneck for the researchers because removal of noise causes the artifacts and image blurring. This paper provides different methodologies for noise reduction and gives us also the insights into the methods to determine which method will provide the reliable and approximate estimate of original image given its degraded version.

Modelling of noise is dependent on several factors such as data capturing instruments, transmission media, and quantisation of image and discrete sources of radiation. Depending on the noise model, different algorithms can be used. In ultrasound images, speckle noise [1] is observed whereas in MRI images rician noise [2] is observed.

II. EVOLUTION OF IMAGE DENOISING TECHNIQUES

Image denoising is the fundamental problem in Image processing. Wavelet gives the excellent performance in field of image denoising because of sparsity and multiresolution structure. With the popularity of Wavelet Transform for the last two decades, several algorithms have been developed in wavelet domain. The focus was shifted to Wavelet domain from spatial and Fourier domain. Ever since the Donoho's wavelet based thresholding approach was published in 2003, there was surge in the image denoising papers being published.

Although his approach was not revolutionary, it did not require tracking and correlation of the wavelet maxima and minima across the different scales as proposed by Mallat [3].Thus there was renewed interest in wavelet approach since Donoho's [4] demonstrated a simple solution to difficult problem domain. Researchers published different approaches to compute the simulation parameters for wavelet coefficients. To achieve optimum threshold, data adaptive threshold [6] were introduced. Substantial improvements in perceptual quality could be obtained by translation invariant method based on thresholding of an Undecimated Wavelet transform [7].Much effort has been devoted to Bayesian denoising in wavelet domain. Gaussian scale mixtures and hidden markov models have also become popular and more research is continued to be published. Independent component analyses (ICA) have been explored in data adaptive components. Different statistical models are focused to model the statistical properties of wavelet coefficients and its neighbours.Future trend will be to find more probabilistic model for non-orthogonal wavelet coefficients distribution.

III. CLASSIFICATION OF IMAGEDENOISING TECHNIQUES

There are two categories for image denoising:-a) Spatial filtering methods b) Transform domain filtering methods.

3.1. Spatial Filtering

This can be divided into Linear and Non-Linear filter and this is the traditional method to remove the noise from images.

A)Non-Linear Filters

In Non-Linear filters, noise can be removed without identifying it exclusively. It employs a low-pass filtering on the assumption that noise always occupies a higher region of spectrum frequency. It removes the noise to very large extent but at the cost of blurring of images. Rank conditioned selection [9], weighted median [8], relaxed median [10] have been developed over recent years to cover up some of the drawbacks.

B)Linear Filters

The optimal linear filter for gaussian noise is the mean filter in terms of mean square error. It also tends to destroy the edges which are sharp, destroy lines and other details of image. It doesn't perform well in case of signal-dependent noise. The filtering of Weiner method [11] requires the details of the spectrum of original signal and noise and it will give the good results if the underlying signal is smooth.Donoho and Johnstone proposed wavelet based denoising scheme in [12,13].

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3.2 Transform domain filtering

These methods can be subdivided according to the basis functions. This can be further classified into data adaptive and non adaptive.

i) Spatial Frequency Filtering

It refers the use of low pass filters using Fast Fourier Transform(FFT) .The removal of noise is done by adapting a frequency domain filter and deciding a cut-off frequency when the component of noise are decorrelated from the useful signal. These methods are time consuming and dependent on cut-off frequency. Furthermore, in the processed image they create artificial frequencies.

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 modelled as gaussian process, Linear filters such as Weiner filter can give the optimal result and mean square error (MSE) [14,15].is the accuracy criterion. However, if we design a filter on this assumption, this results in a filtered image which is very displeasant than the original noisy signal even though it considerably reduces the MSE.In [16] a wavelet domain spatially adaptive Weiner Filtering is proposed in which intrascale filtering is not allowed in any case.

b) NON-LINEAR THRESHOLD FILTERING

The most researched domain in denoising using wavelet transform is the non-linear coefficient thresholding based method. This exploits the fact of the sparsity 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 [5].In this process, certain blips occurred which are also known as Artifacts which shows the unsuccessful attempts to remove moderately large noise coefficients. To cover the demerits of Hard Thresholding, Wavelet transform soft thresholding was also introduced in [5].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 Garrot Thresholding [6].

i) Non-adaptive Thresholds

VISUShrink [12] is non-adaptive universal threshold which is completely dependent on number of data points. It suggests the best performance in terms of MSE, when the pixel number reached infinity. It yields the smooth images because its threshold value is quite large due to its dependency on the number of pixels in image.

ii) Adaptive Thresholds

SUREShrink performs better than VISUShrink. Cross validation [19] replaces wavelet coefficient with the average of its neighbours to minimise the component i.e. generalised Cross validation (GCV) which provides the optimum threshold for each and every coefficient.

One assumption that can be possible when we distinguish the noise and signal, the coefficients magnitudes are violated. Under these conditions, spatial configuration of neighbouring coefficients can plan a significant role in classification of signal and noise respectively. Noise coefficients can scatter randomly while signal makes the meaningful configurations.

c) NON-ORTHOGONAL WAVELET TRANSFORMS

For decomposing the signal to provide visually better solution, Undecimated Wavelet transform (UDWT) can be used. It is shift invariant and avoids the defects and artifacts.Thus, largest improvements were there in results but computations overhead makes it less usable .In [20] normal hard/soft thresholding was concentrated to Shift Invariant Discrete Wavelet Transform. To obtain the number of basis functions, in [21], 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 denoise the data.

Use of multiwavelets is further explored which enhances the performance but it increase the computational complexity. By applying more than one mother function to given dataset, multiwavelets are generated. It possesses the properties like symmetry, short support, foremost is the higher order of vanishing moments. In [22], combination of invariance and multiwavelets shows the superior results with the Lena image.

d) WAVELET COEFFICIENT MODEL

It focuses on exploring the multiresolution 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 modelled 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. It is adopted in [23].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. In [24], tree structure is tracked using wavelet local maxima .Another method is proposed by Dunoho [25] using wavelet coefficient method.

ii) Statistical Modelling

This approach explores some interesting properties of Wavelet Transform such as local correlation between neighbouring 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 [26] and [27].Two techniques are there to exploit the statistical properties of wavelet transforms which are:

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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 modelling the wavelet coefficients are Gaussian Mixture Model (GMM) [28] and Generalised Gaussian distribution (GGD) in [29].GMM is simpler to use but GGD is more accurate. Authors proposed a methodology in [30] which has the wavelet coefficients assumed to be conditionally independent zero mean. The methods presented above requires the noise estimate which is very hard to achieve practically.Chang [30] proposed the use of adaptive wavelet thresholding for denoising of the images by analysing the wavelet coefficients as generalized Gaussian random variable where parameters can be calculated locally.

ii) Joint Probabilistic Model

The efficient model for capturing interscale dependencies are Hidden Markov Model (HMM) [29] whereas random markov models are useful for capturing intrascale 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. In [30], a model is based in which Wavelet coefficient's neighbourhood i.e. called as Gaussian State Mixture(GSM) is a product of Gaussian Random Vector and an independent hidden scalar multiplier. Another approach is used by Jansen and Bulthel [25] for wavelet a coefficient that uses a Markov Random Field model. A drawback of the HMT is the computational burden of the stage of training. To overcome the drawback of HMT,a simplified approach uHMT [27], was used.

3.3 Data-adaptive transforms

Now-a-days, a new method called Independent Component Analysis (ICA) has gained the worldwide attention. In denoising non-gaussian data, the ICA method was successfully implemented [27, 28].One property of ICA is to assume the signal which is Non-gaussian which is helpful to denoise the images with Gaussian and Non-Gaussian distribution. The demerit of ICA based as compared to wavelet based method are the cost of computation because it uses the sliding window and requires the sample of noise-free data or at least some frames of the image or scene. It is very difficult to find the noise free data in some applications.

IV. DISCUSSION

Denoising algorithm's performance is measured using the quantitative performance measures such as signal-to-noise ratio (SNR) and peak signal-to-noise ratio (PSNR) as well as visual quality of images. Currently, gaussian noise model can be assumed for many techniques. This may not be always true because of source of noise and nature varied sources of noise. A priori knowledge is required in ideal denoising algorithms, whereas practical procedure do not have the information. For comparing the performance with different algorithms, most of the algorithms assume variance of the noise and noise model. To test the performance of algorithm, Gaussian noise with different values is added in the natural images.

Due to the limitations in providing sparse representation of data, use of FFT is restricted in filtering. For its properties like multiresolution, sparsity and multistage nature, wavelet transform is best suited for its performance. Issue of complexity is also to be considered. Techniques of thresholding used with Discrete Wavelet Transform is simplest to use.Multiwavelets and UDWT Non-orthogonal wavelets improve the performance at the cost of overhead in the computation.HMM seems to be complex but promising technique. While comparing different algorithms, it is very important not to delete the comparison details. Some papers did not mention the wavelet used and neither the wavelet transform decomposition level was mentioned.

Future research will focus on building the reliable statistical model of non-orthogonal wavelet coefficients based on interscale and intrascale correlations. Such models can be deputed properly to achieve the aim of Image Denoising and compression.

V. CONCLUSION

In this paper, numerous amounts of Image Denoising Techniques are discussed and it might be possible to get confused with all the methodologies, so it is important to summarize all of those to regain the full content of the paper.

The selection of Denoising technique depends on what kind of denoising is required. Further, it depends on what kind of information is required. Few examples, based on literature review done in this paper. Fuzzy model will be a good choice to represent the region boundaries ambiguity. It would be a good choice if we use neural model.

As the future perspective can be seen, the mentioned methods can be implemented that to look how it can be used on different images. With different spatial resolution, different behaviours of same image would be quite interesting. Addition of existing quantative analysis of recent denoising techniques would be quite helpful.

Properties	**Classical Logic**	**Fuzzy Logic**
Logic	Bivalent	Multivalent
Sets	Crisp	Fuzzy
Memberships	0 or 1	Between 0 or 1, verbal interpretation by linguistic variables
Numbers	Crisp	Fuzzy
Operators	Crisp	Fuzzy
Compromises	Often not possible	Always Possible

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