

Comparative Analysis of Image Denoising Techniques

Khushboo Saxena, Akash Saxena, Bhavana Gupta

kskhushboosaxena26@gmail.com, akash27saxena@gmail.com, bhavana.nishi@gmail.com

^{1,3} Asst. Professor, computer Science & Engg, Corporate Institute of Science and Technology, Bhopal
Associate Professor, computer Science & Engg, Compucom Institute of IT & Management Jaipur

Abstract: The search for efficient Image Denoising methods is still a challenge at the crossing of functional analysis and statistics. Image Denoising plays an important role in the image pre-processing. Visual information transmitted in the form of digital images which is becoming a major method of communication in the modern age, but image obtained after the transmission is often distorted with noise. The received image needs processing before it can be used in applications. Image Denoising involves the manipulation of the image data to develop a visually rich quality image.

There are many methods to resolve the problems of Image Denoising. There are many Image Denoising algorithms exists, such as Wavelet Transform based approach, Haar Wavelet Transform approach, and Fractal-Wavelet approach. Image Denoising methods hierarchical structure is shown via diagram. In this research survey, It is studied the fundamental performance limits of Image Denoising methods/ algorithms where the aim of all the algorithms is to recover the original image from its noisy observation.

Keywords: Image Denoising; Fractal Wavelet; Wavelet Transform;

I. INTRODUCTION

It is now possible for anyone to capture images of considerably high resolution with devices like cell phones, webcams, digital cameras, etc [1]. The attention of researchers gradually turned from frequency-based analysis to scale-based analysis when it started to become clear that an approach measuring average fluctuations at different scales might prove less sensitive to noise [2].

Noise removal is important for the reliability of subsequent image analysis, and is often one major focus during the preprocessing stage in image processing. However, most existing Image Denoising methods are for analyzing 2D images. Some of them can be extended to 3D cases, but their direct extensions may not be able to handle 3D images efficiently because the structure of a typical 3D image is often substantially more complicated than that of a typical 2D image [3].

The purpose of Image Denoising is as much as possible to maintain the main features of the original image and remove noise from the image. Due to the simple and effective algorithm, Wavelet denoising methods based on hard-threshold and soft-threshold are widely used [4].

The main goal of Image Denoising is to preserve the image features while reducing the noise. Denoising is an important historical and current problem in image processing.

Frequency domain methods transform the noisy signal into the frequency domain and manipulate the frequency coefficients to suppress the signal noise before transforming the signal back into the spatial domain.

Wavelet-based techniques are the most commonly used ones in Frequency domain methods. The classical method in time domain processing techniques is Wiener Filtering which is optimal in the least MSE sense [5]. Besides the noisy image produces undesirable visual quality, it also lowers the visibility of low contrast objects. Hence noise removal is essential in medical imaging applications in order to enhance and recover fine details which are hidden in the data. In many occasions, noise in digital images is found to be additive in nature with uniform power in the whole bandwidth and with Gaussian probability distribution [6].

II. CLASSIFICATION OF DENOISING ALGORITHMS

As shown in Fig.1, there are two basic approaches to Image Denoising, spatial filtering methods and transform domain filtering methods.

1. Image Denoising Method Using Wavelet Transform

Wavelet Image Denoising has been widely used in the field of image noise. Firstly, this method decomposes the noisy image in order to get different sub-band image. Secondly, it remains the low-frequency wavelet coefficients unchanged, and after taking into account the relation of horizontal, vertical and diagonal high-frequency wavelet coefficients and comparing them with Donoho threshold and make them enlarge and narrow relatively. Thirdly, it uses soft-threshold denoising method to achieve Image Denoising. Finally, denoising image by inverse wavelet transform is achieved.

This technique has enlarged part of the wavelet coefficients, then used traditional soft-threshold to denoise image. Denoising effects is better than traditional wavelet soft-threshold Image Denoising, especially in the edge and details of the image. This method compared to soft-threshold denoising method has a higher PSNR and visual effects.

Advantage: Denoising effects is better than traditional wavelet soft-threshold Image Denoising, especially in the edge and details of the image.

Disadvantage: In the case of natural images, there is a rich amount of pixel elements which cannot be represented using fixed wavelet basis. Therefore wavelet transform methods can introduce many visual artifacts in the denoising output [4].

2. Image Denoising Method Based on DCT Basis and Sparse Representation

From this method which is based on the K-SVD algorithm by learning dictionary from the noisy image itself. From this Over-complete dictionary, it can be describe the image's content effectively. Combine with the sparse representation coefficients which are obtained from the pursuit algorithm; which results the denoised image at last. This can be describe the problem as a model like: $y = Y_0 + v'Y_0$ is the ideal image and v is an zero-mean white and homogeneous Gaussian noise with a known standard deviation u , so y is the noised image. Our aim is to design an algorithm that can remove the noise and returning as close as possible to the original image y . This method is based on the over-complete dictionary and sparse representation. The atom in the dictionary can represent the image's small patches models. So every model has its sparse representation in the dictionary which only include the image content while the noise don't have the sparse representation in this dictionary.

Advantage: Our method based on learned can be better to denoise the white noise and keep the edge information, improving the value of PSNR and get a more comfortable effect.

Disadvantage: The computation of this method is slow, that's why there is requirement of a higher speed method which will generate a better result in a small time [8].

3. Based on pixel-component-analysis

The idea behind this method is to show a relationship the similar image pixels. For instance, consider an image is divided multiple segments. Each segment is labelled by using pixel value. Then mean of each pixel are taken to find out the average value. By determining the average value, which are having pixel value closer to average value are combined together for image analysis. Each pixel is estimated as the weighted average of all the pixels in the image, and the weights are determined by the similarity between the pixels. This technique can also be correlated with patch matching and sparse 3D transform. A sparse 3D transform is then applied to 3D images and noise was concealed by applying wiener filtering in the transformed domain.

Advantages: The results are particularly encouraging especially because of the comparison with the other techniques like wavelet transform and frequency domain methods. This is a simplistic method for improving the standards of an image by pixel alignment with all possible screening performances as a classification feature.

4. Image Denoising Using the Gauss–Hermite Expansion

In this paper, a novel marginal statistical model is proposed for the wavelet coefficients of images by using the Gauss–Hermite (GH) expansion. This expansion is used in view of the fact that it allows higher order moments to be incorporated in the probabilistic modelling of the wavelet coefficients. A method of choosing a finite number of terms in the GH series such that the resulting PDF matches well with the empirical PDF of the wavelet coefficients of the images and at the same time remains non-negative is proposed.

The proposed PDF is then applied as a prior function in the subband-adaptive and locally adaptive Bayesian MMSE-based noise reduction algorithms, in view of the fact that they offer lower computational burden as compared to the method using intersubband dependency. It is shown that the introduction of the more accurate prior in the proposed noise reduction technique results in a performance better than that of the subband-adaptive and locally adaptive wavelet-based Image Denoising algorithms that use standard PDFs having limited number of parameters, in terms of both the visual perception and standard indices.

Advantage: It has a uniform mean square convergence, the parameters can be expressed in terms of higher order moments in closed-form and the polynomials can be estimated recursively.

Disadvantage: The results are good but not enough [10].

Disadvantages: It is found in particular that pixel variations may be vast in some cases which potentially tend to develop irregularities in the image [9].

5. Fractal-Wavelet Image Denoising

Fractal-wavelet transforms used to reduce the blockiness and computational complexity that are inherent in fractal image compression. Here by extending the application of this fractal denoising scheme to the wavelet domain of the image. It is found that when the wavelet transform of the noisy image is simply fractaliy coded, a significant amount of the noise is suppressed. However at next stage an estimate the fractal code of the wavelet transform of the original noise-free image from that of the wavelet transform of the noisy image. It is shown that the extraction of fractal code from the noisy image can be performed in wavelet domain. The resulting smoothing can be analyzed in terms of wavelet theory. Itf will also assess and compare the performance of these fractal-based smoothing schemes, as applied in the spatial and the wavelet domains of the noisy image, respectively.

Advantage: The main advantage of the wavelet-based fractal denoising scheme over the standard fractal demising scheme is that it is computationally less expensive.

Disadvantage: A problem with this technique is that only negligible noise smoothing is generally performed in the vicinity of edges [11].

6. *Image Denoising Algorithm Based on PSO Optimizing Structuring Element*

The particle swarm optimization algorithm (PSO) in the Structuring Elements (SE's) size selection process. The transformed value of particles' position is taken as the SE's size. Taking the PSNR of the image as the fitness function, It is proposed that an adaptive algorithm of the structuring element unit (SEU) which composed of a zero square matrix and simulate it in MATLAB7.0. Experimental results show that the proposed method can effectively remove impulse noise and maintain information of images, especially for denoising of the image whose signal to noise ratio is low. The paper proposed an Image Denoising algorithm based on particle swarm optimizing structuring element and used it to remove noise from the image whose noise density is greater than 30%. The SEU composed of zero square matrix is proposed, and the PSO algorithm is introduced to optimize the SE's size. These make the SE's description more flexible. The proposed algorithm takes the PSNR as a fitness function, so that it can self-adaptively get the SE's size according to noise density. These help to improve morphological noise reduction performance.

Advantage: The proposed algorithm has good adaptability and has obvious superiority in low SNR image noise reduction.

Disadvantage: Result is not enough to outcome [12].

7. *Image Denoising Based on Haar Wavelet Transform*

Wavelet transform has widely applied in Image Denoising, and how to select the threshold is the key to wavelet Image Denoising. First, the image with noise is decomposed by Haar wavelet transform, and then selects the soft threshold to clean the image noise. The paper put forward the algorithm for Image Denoising based on Haar wavelet transform. The algorithm can effectively clean the noise of image and reserve the detail and veins of image, and obtain a good visual of image. The experiment shows that the algorithm can reduce noise effectively, and raise the PSNR value of image. In the frequency area ,the main algorithm of Image Denoising is wavelet, the Image Denoising method of wavelet mainly includes three steps .The first step is carry on wavelet transformation to the image with noising; The second step is carry on a certain processing to the wavelet coefficient, and clean the noise of image. The third step is carrying on wavelet negative transformation, get the denoised image. This method used the soft threshold method to clean the image noise.

Advantage: The main key point is that the Wiener filter is used in this method which can obtain higher PSNR after cleaned the image noise.

Disadvantage: A problem with such techniques is that Wiener filter will produce the low frequency [13].

IMAGE DENOISING METHODS

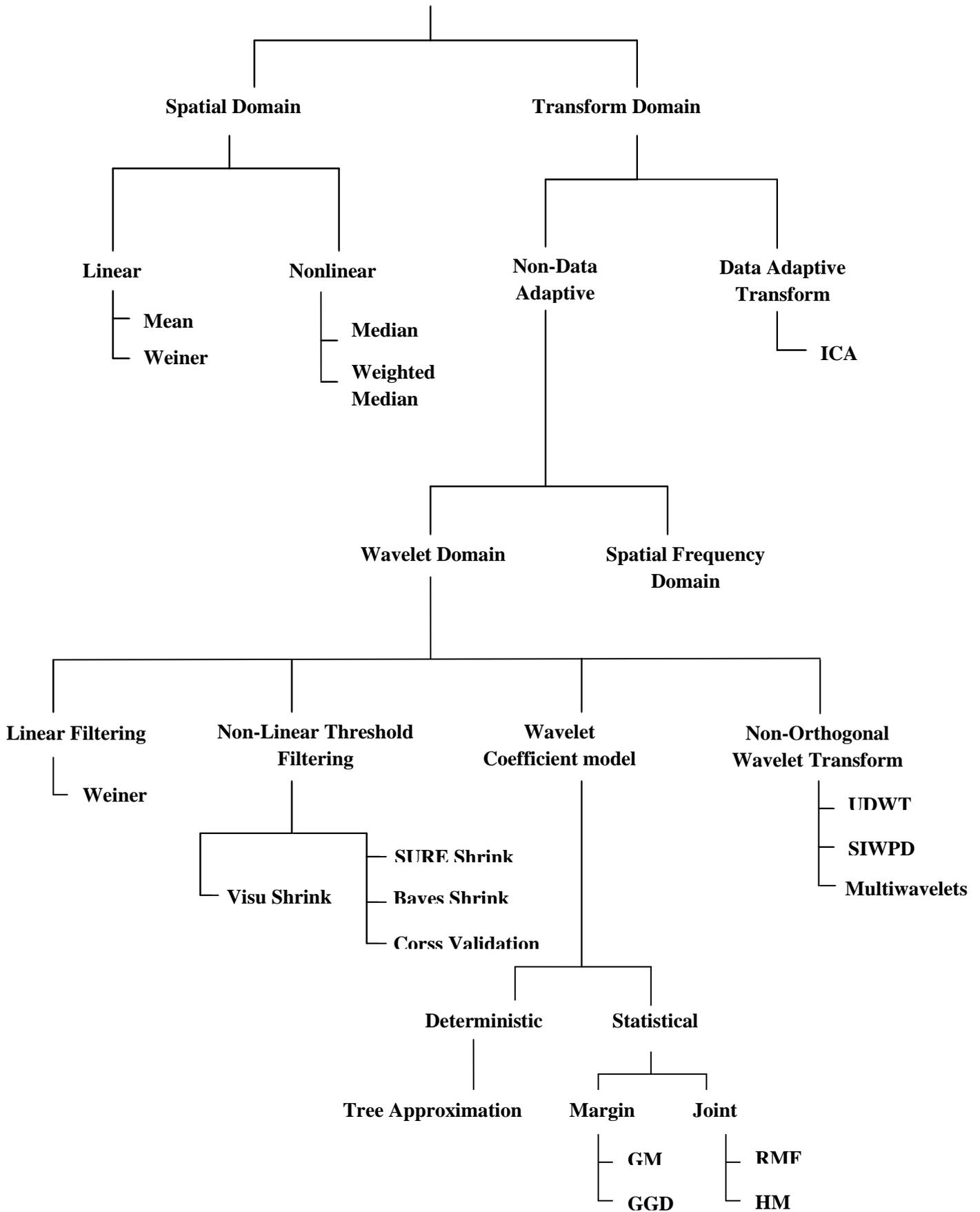


Fig.-1: Classification of Image Denoising Methods [7]

Discrete wavelet transform of an image produces a non redundant image representation that provides better spatial and spectral localization of image formation, compared to other multi scale representation [5]. The Discrete Wavelet Transform (DWT) analysis, is based on the assumption that the amplitude rather than the location of the spectra of the signal to be as different as possible from the amplitude of noise. This allows clipping, thresholding, and shrinking of the amplitude of the coefficients to separate signals or remove noise. It is the localizing or concentrating properties of the discrete wavelet transform that makes it particularly effective when used with this nonlinear filtering method.

In this approach, the processing is carried on in the transform domain. The DWT of the signal is calculated and the resultant wavelet coefficients are compared to some thresholds. Since the wavelet transform is good at energy compaction, the small coefficients are more likely due to noise that has its energy spread over a large number of coefficients and large coefficients due to important signal features.

These small coefficients can be thresholded without affecting the significant features of the signal. Thresholding is a simple non-linear technique, which operates on one wavelet coefficient at a time.

Advantage: In this method, translation invariant performed better performance in both PSNR and visual quality than wavelet denoising (hard thresholding or soft thresholding).

Disadvantage: Wavelet thresholding method is still a regularization process and estimator presents oscillations in the vicinity of signal discontinuities [14].

A comparative analysis of all the above techniques is shown in the table.1 below:

Table.1: Comparative Analysis of Techniques

S No.	Method Name	PSNR value
1	Pixel-Component-Analysis	34.20dB
2.	Based on DCT Basis and Sparse Representation	30.98dB
3.	Fractal-Wavelet Image Denoising	30.01dB
4.	Gauss-Hermite Expansion	29:09dB
5.	Image Denoising Based on Haar Wavelet Transform	27.84dB
6.	Image Denoising Algorithm Based on PSO Optimizing Structuring Element	26.26dB
7.	Wavelet Transform	25.15 dB
8.	Image Denoising Based on Discrete Wavelet Transform	23.16dB

In this research survey work is divided into 3 phases. Here it is focused on the concept of Image Denoising first. Then discuss the hierarchy of Image Denoising methods. The comparative analysis of all the Image Denoising techniques is done in the last. Performance of all Denoising Algorithms is measured using Quantitative Performance measures such as Peak Signal-to-Noise Ratio (PSNR).

REFERENCES

- [1] Priyam Chatterjee and Peyman Milanfar, "Fundamental Limits Of Image Denoising: Are We There Yet?", Department of Electrical Engineering University of California, Santa Cruz, CA 95064, USA, ICASSP 2010, pp.1358-1361.
- [2] Raghuram Rangarajan, Ramji Venkataramanan, Siddharth Shah, "Image Denoising Using Wavelets", Thesis on Wavelets & Time Frequency December 16, 2002, pp.3-12
- [3] Peihua Qiu and Partha Sarathi Mukherjee, "Edge Structure Preserving 3D Image Denoising by Local Surface Approximation", IEEE Transactions On Pattern Analysis And Machine Intelligence, Vol. 34, No. 8, August 2012, pp. 1457-1468.
- [4] Li Hongqiao1, Wang Shengqian2, "A New Image Denoising Method Using Wavelet Transform", 2009 International Forum on Information Technology and Applications, 2009 IEEE, pp.111-114..
- [5] KinTak U, Nian Ji, Dongxu Qi, Zesheng Tang, Ruixia Song, "A Novel Image Denoising Algorithm based on Non-Uniform Triangular Partition and Interpolation", 2010 International Conference on Future Power and Energy Engineering, © 2010 IEEE, pp.67-70.
- [6] M.Vijay,S .V. Suhha, K.Karthik, "Adaptive Spatial and Wavelet Multiscale Products Thresholding Method For Medical Image Denoising", 2012 International Conference on Computing, Electronics and Electrical Technologies [ICCEET], 20 1 2 IEEE, pp.1109-1114.
- [7] Mukesh C. Motwani, Mukesh C. Gadiya, Rakhi C. Motwani, "Survey of Image Denoising Techniques", Frederick C. Harris, Jr. University of Nevada, Reno Dept of omp. Sci. & Engr., Reno, NV 89557 USA (775) 784-6571, pp.1-7.
- [8] Zhang Fen, Xie Kai, "A Novel Image Denoising Method Based on DCT Basis and Sparse Representation", 2011 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference, 2011 IEEE, pp.1307-1310.
- [9] Tongzhou Zhao, Yanli Wang, Ying Ren, Yalan Liao, "Approach of Image Denoising Based on Discrete Multi-wavelet Transform", Hubei Provincial Department of Education in China (D20081507), 2009 IEEE, pp.1-4.
- [10] S. M. Mahbubur Rahman, M. Omair Ahmad, "Bayesian Wavelet-Based Image Denoising Using the Gauss-Hermite Expansion", IEEE Transactions On Image Processing, VOL. 17, NO. 10, OCTOBER 2008, 2008 IEEE, pp.1755-1771.
- [11] M. Ghazel, G.H. Freeman, E.R. Vrscay, "Fractal-Wavelet Image Denoising", IEEE ICIP 2002, pp.1836-1839.
- [12] Zhu youlian, Huang cheng, "Image Denoising Algorithm Based on PSO Optimizing Structuring Element", Jiangsu Teachers University of Technology natural science funds # KYY09020 and # KYY10043, 2012 24th Chinese Control and Decision Conference (CCDC), 2012 IEEE, pp.2404-2408.
- [13] L. Zhang , X. Li D. Zhang, "Image Denoising and zooming under the linear minimum mean square-error estimation framework", The Institution of Engineering and Technology 2012, IET Image Process., 2012, Vol. 6, Iss. 3, pp. 273-283.
- [14] Harnani Hassan, Azilah Saparon, "Still Image Denoising Based on Discrete Wavelet Transform", 2011 IEEE International Conference on System Engineering and Technology (ICSET), 2011 IEEE, pp.188-191.