An Extensive Review on Similarity Validation Based Nonlocal Means Image Denoising

Akata Chadhar[1], Versha Sharma[2]

[1]M.Tech. Scholar, [2]Guide

Department of Computer Science and Engineering, UIT RGPV, Bhopal

Abstract - When an Image is formed various factors such as lighting spectra, source, intensity and camera Characteristics (sensor response, lenses) affect the image. The major factor that reduces the quality of the image is Noise. It hides the important details of images and changes value of image pixels at key locations causing blurring and various other deformities. To remove noise from the images without loss of any image information, Noise removal is the preprocessing stage of image processing. There are many types of noise which corrupt the images. These noises appeared on images in different ways: at the time of acquisition due to noisy sensors, or due to faulty scanner or due to faulty digital camera, due to transmission channel errors, due to corrupted storage media. This paper presents a comparative study of image de-nosing algorithms based on non local means.

Keywords- Image de-noising, Wavelet, Fuzzy logic, Wiener filter, Image Enhancement, Non-Local Means Image Denoising.

I. INTRODUCTION

Image denoising has become a critical step in processing of images and removing unwanted noisy data from the image. The image denoising algorithms have to remove the unwanted noisy elements and keep all the relevant features of the image. The image denoising algorithms have to tradeoff between the two parameters i.e. effective noise removal and preservation of image details [1].

Images play a very important role in many fields such as astronomy, medical imaging and images for forensic laboratories. Images used for these purposes have to be noise free to obtain accurate results from these images.

There are different sources of noise in a digital image. For example, dark current noise is due to the thermally generated electrons at sensing sites; it is proportional to the exposure time and highly dependent on the sensor temperature. Shot noise is due to the quantum uncertainty in photoelectron generation; and it is characterized by Poisson distribution. Amplifier noise and quantization noise occur during the conversion of the number of electrons generated to pixel intensities. The overall noise characteristics in an image depend on many factors, including sensor type, pixel dimensions, temperature, exposure time, and ISO speed. Noise is in general spatial position and channel dependent. Blue channel is typically the noisiest channel due to the low transmittance of blue filters. In single-chip digital cameras, demosaicking algorithms are used to interpolate missing color components; therefore, noise is not uncorrelated for different pixels. An often neglected characteristic of image noise is the spatial frequency [3].

A very large portion of digital image processing is devoted to image restoration. This includes research in algorithm development and routine goal oriented image processing. Image restoration is the removal or reduction of degradations that are incurred while the image is being obtained. Degradation comes from blurring as well as noise due to electronic and photometric sources. Blurring is a form of bandwidth reduction of the image caused by the imperfect image formation process such as relative motion between the camera and the original scene or by an optical system that is out of focus. When aerial photographs are produced for remote sensing purposes, blurs are introduced by atmospheric turbulence, aberrations in the optical system and relative motion between camera and ground. In addition to these blurring effects, the recorded image is corrupted by noises too. A noise is introduced in the transmission medium due to a noisy channel, errors during the measurement process and during quantization of the data for digital storage. Each element in the imaging chain such as lenses, film, digitizer, etc. contributes to the degradation [11].

Image denoising is often used in the field of photography or publishing where an image was somehow degraded but needs to be improved before it can be printed. For this type of application we need to know something about the degradation process in order to develop a model for it. When we have a model for the degradation process, the inverse process can be applied to the image to restore it back to the original form. This type of image restoration is often used in space exploration to help eliminate artifacts generated by mechanical jitter in a spacecraft or to compensate for distortion in the optical system of a telescope. Image denoising finds applications in fields such as astronomy where the resolution limitations are severe, in medical imaging where the physical requirements for high quality imaging are needed for analyzing images of unique events, and in forensic science where potentially useful photographic evidence is sometimes of extremely bad quality [4].

The basic idea behind this work is the estimation of the uncorrupted image from the distorted or noisy image, and it is also referred to as image "denoising". There are various methods to help restore an image from noisy distortions. Selecting the appropriate method plays a major role in getting the desired image. The denoising methods tend to be problem specific. For example, a method that is used to denoise satellite images may not be suitable for denoising medical images [4].

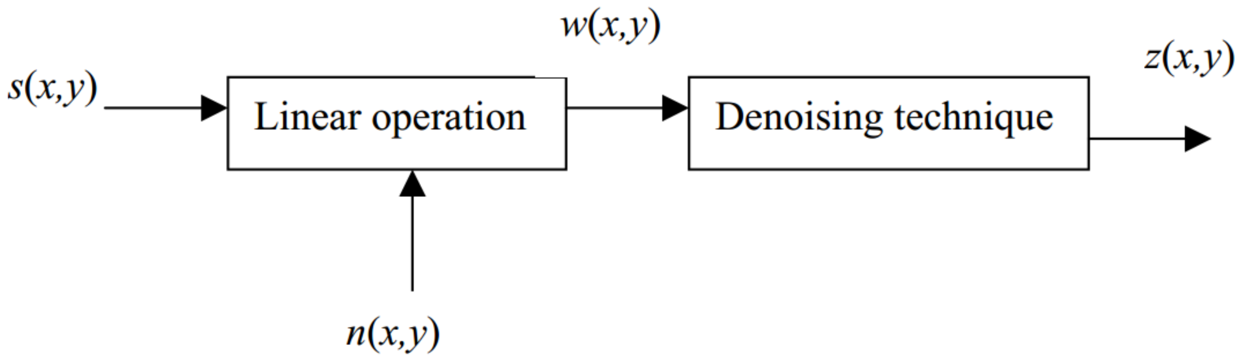

Figure 1.1 Image Denoising Concept.

The image s(x,y) is blurred by a linear operation and noise n(x,y) is added to form the degraded image w(x,y). This is convolved with the restoration procedure g(x,y) to produce the restored image z(x,y). The "Linear operation" shown in Figure 1.1 is the addition or multiplication of the noise n(x,y) to the signal s(x,y). A review on different popular techniques is studied in this work. Noise removal or noise reduction can be done on an image by filtering, by wavelet analysis, or by multifractal analysis. Each technique has its advantages and disadvantages.

Gaussian image denoising techniques can be exploited to deal with Poisson noise as well. In the Poisson case, a Variance Stabilizing Transform (VST), e.g., the Anscombe [1] transform is used in order to convert the signal-dependent noise to a Gaussian additive white noise with unit variance. Then, NLM can be applied on the transformed noisy image. Finally, an inverse transform is applied on the denoised image.

II. CLASSIFICATION OF DENOISING TECHNIQUES

Image Noise is random variation of brightness or color in an image. It can be produced by any circuitry such as sensor, scanner or digital camera. Image noise is an undesirable signal, its produce by image capturing device that add extra information. In many cases, it reduces image quality and is especially significant when the objects being imaged are small and have relatively low contrast. This random variation in image brightness is designated noise. This noise can be either image dependent or image independent. There are different approaches are there to remove noise from image enhance the quality of image or denoising images. Some of the most popular image denoising algorithms are given [6].

A. Spatial Filtering:

It has two further classifications:

a) Non Linear Filters:

Without explicitly determining the noise this algorithm is used. These filters assume that the noise lies in the high frequency region. Low pass filters are employed to separate image from noise. Spatial filters remove noise to a good extent but cause blurring of images which makes the edges in pictures not visible.

a) Linear Filters:

1. Mean Filter:

A mean filter is the optimal linear filter for Gaussian noise in the sense of mean square error. They perform poorly in the presence of signal dependent noise. Linear filters too tend to blur sharp edges, lines and other valuable image details.

2. Wiener Filter:

It works well only if the underlying signal is smooth. The wiener filtering method requires details about the spectra of the noise and the original signal [7].

B. Transform Domain Filtering:

It is further classified according to the choice of basis function. The basis function is of two type's data adaptive and non-adaptive.

a. Non data Adaptive Transform Domain Filtering:

i. Spatial Frequency Filtering:

Spatial-frequency filtering uses low pass filters using Fast Fourier Transform (FFT). In frequency smoothing methods the removal of the noise is achieved by obtaining a frequency domain filter and a cut-off frequency when the noise components are DE correlated from the useful signal in the frequency domain. These methods take a lot of time and depend on the cut-off frequency and the filter function behavior. They may produce artificial frequencies in the processed image [13].

ii. Wavelet Domain:

Linear Filters:

Linear filters such as Wiener filter in the wavelet domain yield optimal results when the signal corruption is of the Gaussian type and the criteria are Mean Square Error (MSE). However, designing a filter based on this assumption frequently a result in a filtered image that is visually revolting than the original noisy signal, even though the filtering operation successfully reduces the MSE [13].

Non Linear Threshold Filtering:

It is the most sought after method based on wavelet domain.

The procedure makes use of two properties:

1. Sparsity property of wavelet transforms

2. Wavelet transformation maps white noise in signal domain to white noise in transform domain.

The important fact that signal energy gets concentrated into few coefficients in the transform domain while noise energy does not is used for the separation of signal from noise.

Hard Thresholding: small coefficients are removed while others left unchanged. This method causes spurious blips called artifacts as it is not successful in removing large noise coefficients.

C. Non-Local Means Algorithm

The NLM algorithm is inspired by the neighborhood filters. It takes advantage of the high degree of redundancy in any natural image by assuming that every small patch in a natural image has many similar patches in the same image. One can define a search region centered at pixel i, of size $M\ x\ M$, such that [1]

$$S_i = \{ j \mid |i - j| < M - 1\}.$$

Specifically, in Texture synthesis, a sub-set of similar pixels, denoted $k\ E\ S^S\ C\ S_i$, is extracted such that a patch around k resembles to a patch around i, by defining an adequate similarity measure. All pixels in that sub-set can be used for predicting the value at i. The fact that such a self-similarity exists proves image redundancy and matches the image regularity assumption [4].

Standard NLM, all the pixels that are included in Si are used for the weighted averaging process, such that the weights are determined based on their resemblance to the POI, Estimation theory determines that if the original and observed images are considered as a realization of two random fields X and Y , then the best estimate of X is given by the conditional expectation.

D. Advantages and Limitations

NLM was found to be significantly better than current low-pass filters at reducing noise while preserving edges. There were also several issues identified, such as smearing of fine details and streak artifacts in the reconstructed volume. This algorithm is considered to be the first one to reconstruct data from similar patches [14].

To preserve local structures, error for nearby pixels is made greater than for pixels far away in a noisy image, Non-local means weights fail to detect similarities in long distance. So far, the best way to stabilize the similarity detector is to limit the search to a small window [4].

III. LITERATURE SURVEY

SR. NO.	AUTHORS	TITLE	YEAR	METHODOLOGY
1	M. Sharifymoghaddam, S. Beheshti, P. Elahi and M. Hashemi [1]	M. Sharifymoghaddam, S. Beheshti, P. Elahi and M. Hashemi,	2015	A pre-processing hard thresholding algorithm that eliminates those dissimilar patches. The method denoted by Similarity Validation Based Nonlocal Means (NLM-SVB)
2	A. Kethwas and B. Jharia [2]	Image de-noising using fuzzy and wiener filter in wavelet domain,	2015	First technique is ATMAV (Asymmetrical Triangular Moving Average Filter) ATMED (Asymmetrical Triangular Median Filter) with HAAR wavelet transform.
3	Chujian Bi, H.	SAR image change detection	2014	Employ the optimized FCM called FLICM

	Wang and Rui Bao [3]	using regularized dictionary learning and fuzzy clustering		algorithm to undertake the task which aims to segment the difference map into two classes
4	S. Anissa, S. Hassene and B. b. Ezzedine [4]	Adaptive median filter based on ANFIS for impulse noise suppression,	2014	A new approach based on adaptive neuro-fuzzy inference system (ANFIS) was presented
5	M. S. Raval, M. V. Joshi and S. Kher, [5]	Fuzzy Neural Based Copyright Protection Scheme for Superresolution,	2013	fuzzy logic to build the perceptual mask, embeds watermark in the low frequency coefficients for robustness with edge preservation and use neural network at the receiver
6	T. Lin and S. Bourennane [6]	Hyperspectral Image Processing by Jointly Filtering Wavelet Component Tensor,	2013	The hyperspectral imaging (HSI) domain, such as classification and target detection, to achieve good performances.
7	I. Dagher and C. Taleb [7]	Improved wavelet wiener estimator in image denoising,"	2012	Improves the Wiener filter in the wavelet domain without the usual zero mean assumption

M. Sharifymoghaddam, S. Beheshti, P. Elahi and M. Hashemi,[1] Nonlocal means is one of the well known and mostly used image denoising methods. The conventional nonlocal means approach uses weighted version of all patches in a search neighbourhood to denoise the center patch. However, this search neighbourhood can include some dissimilar patches. In this letter, we propose a pre-processing hard thresholding algorithm that eliminates those dissimilar patches. Consequently, the method improves the performance of nonlocal means. The threshold is calculated based on the distribution of distances of noisy similar patches. The method denoted by Similarity Validation Based Nonlocal Means (NLM-SVB) shows improvement in terms of PSNR and SSIM of the retrieved image in comparison with nonlocal means and some recent variations of nonlocal means.

A. Kethwas and B. Jharia,[2] Nowadays images are very fundamental type data for transmission. In this research, a mixed domain image denoising method based on the wavelet transform median filter and nonlinear diffusion are proposed. The wavelet transform is used to convert the spatial domain image to wavelet domain coefficients. Wavelet transform produces approximation, horizontal, vertical and diagonal detailed coefficient which represents the various spatial frequency bands. These coefficients may be filtered by wiener filter or fuzzy filter separately. One is based on median and moving average, while other one used on probabilistic way, respectively. Research presents the two different techniques for image denoising; first technique is ATMAV (Asymmetrical Triangular Moving Average Filter) with HAAR wavelet transform and second is ATMED (Asymmetrical Triangular Median Filter) with HAAR wavelet transform.

Both techniques are based on fuzzy logic based filters. Comparative analytical study based on PSNR and mean square error shows that HAAR with ATMED wavelet is better technique for image denoising.

Chujian Bi, H. Wang and Rui Bao,[3] In this research, we propose and present a novel unsupervised change detection(CD) algorithm for synthetic aperture radar(SAR) images based on regularized dictionary learning and fuzzy clustering. The regularized sparse reconstruction technique is introduced to generate a de-noised, low time consuming reconstructed image by using K-SVD dictionary learning. In order to obtain proper difference image, minus and ratio maps are discussed with the comparison of the other state-of-the-art approaches. Finally, to transfer the difference map into change map, we employ the optimized FCM called FLICM algorithm to undertake the task which aims to segment the difference map into two classes: changed and unchanged. Experimental results clearly show that the proposed approach consistently yields superior performance (accuracy, efficiency and robustness) compared to several well-known change detection techniques on both noise-free and noisy satellite images, further optimization methods are discusses in the end.

S. Anissa, S. Hassene and B. b. Ezzedine,[4] mage enhancement and restoration in a noisy environment are fundamental problems in image processing. Various filtering techniques have been developed to suppress noise in order to improve the quality of images. Among diverse de-noising techniques, median filter is a well-known filter to deal with impulse noise in digitals images. However, due to some limitations associated with the standard median filtering approach, several new improved versions of the median filtering method have been proposed by researchers. In this study, a new approach based on adaptive neuro-fuzzy inference system (ANFIS) was presented for restoring digital images corrupted by salt and pepper noise by a dynamic median filter that will adapt itself to the local noise intensity. Simulation results indicate that the proposed approach shows a high-quality restoration of filtered images than those using static median filter or others filters, in terms of peak signal-to-noise ratio (PSNR).

M. S. Raval, M. V. Joshi and S. Kher,[5] uperresolution is an algorithmic approach, for constructing high resolution de-noised image from its low resolution and noisier version. A new method to address the problem of copyright violation for super resolution is presented in this research. The goal is to design an improved watermarking technique, while minimizing distortion in the super resolved image. The approach employs, fuzzy logic to build the perceptual mask, embeds watermark in the low frequency coefficients for robustness with edge preservation and use neural network at the receiver. Novelty lies in providing copyright protection jointly to the low resolution and the super resolved images. The distortion due to watermark insertion is compensated by: 1. use of fuzzy perceptual mask tuned to human visual system, 2. use of trained neural network estimator during watermark extraction, 3. utilize image degradation model during watermark extraction. Effectiveness of the proposed approach is shown by conducting the experiments on natural images and comparing it with the state of the art techniques.

T. Lin and S. Bourennane,[6] Denoising is an important preprocessing step for several applications in the hyperspectral imaging (HSI) domain, such as classification and target detection, to achieve good performances. Because the signal-dependent photonic noise has become as dominant as the signal-independent noise generated by the electronic circuitry in HSI data collected by new-generation hyperspectral sensors, the reduction of the additive signal-dependent photonic noise becomes the focus of the current research in this field. To reduce the optoelectronic noise from HSIs, a new method is developed in this research. First, a prewhitening procedure is proposed to whiten noise in HSIs. Second, a multidimensional wavelet packet transform (MWPT) in tensor form is presented to find different component tensors of the HSI. Then, to jointly filter a component tensor in each mode, a multiway Wiener filter is introduced. Moreover, to determine the best transform level and basis of the MWPT, a risk function is proposed. The effectiveness of our method in denoising and classification is experimentally demonstrated on a real-world HSI acquired by an airborne sensor.

I. Dagher and C. Taleb,[7] Image denoising involves the manipulation of the image data to produce a visually high quality image. This research improves the Wiener filter in the wavelet domain without the usual zero mean assumption. An improved LESE (local expected square error) formula is derived. For each wavelet block, the center coefficient is estimated by comparing the LESE given by the usual Wiener filter and the improved LESE. The minimum between them is chosen. The improved filter gave a higher PSNR for all the test images and all the noise variances that we have used.

IV. PROBLEM FORMULATION

Denoising images can be achieved by a spatial averaging of nearby pixels. This method removes noise but creates blur. Henceforth, neighborhood filters, which perform an average of neighboring pixels under the condition that their grey level is close enough to the one of the pixel in restoration, creates shocks and staircasing effects. There are numerous methods proposed to reduce compression artifacts. Some methods are introduced as a part of the encoding process, such as the lapped transform. Since these methods require modification of the codec, alternative post-processing methods, which do not require any codec changes, have become main focus in the area. The post-processing methods can be categorized into two: enhancement based algorithms and restoration based algorithms. Enhancement based algorithms try to improve the perceptual quality without an explicit optimization process; on the other hand, restoration based algorithms try to recover the original image based on some optimization criteria. Another way of categorizing these methods is spatial domain vs. transform domain, depending on which domain the image is processed.

V. CONCLUSION

This paper deals with the brief survey and study of image denoising techniques. Many image denoising algorithms exist none of them are universal and their performance largely depends upon the type of image and the type of noise. It is imperative to critically analyze denoising techniques as they are application dependent. An empirical study of the optimal parameter values for the bilateral filter in image denoising applications and a multi resolution image denoising framework. Since selection of the right denoising procedure plays a major role, it is important to experiment and compare the methods.

REFERENCES

[1] M. Sharifymoghaddam, S. Beheshti, P. Elahi and M. Hashemi, "Similarity Validation Based Nonlocal Means Image Denoising," in IEEE Signal Processing Letters, vol. 22, no. 12, pp. 2185-2188, Dec. 2015.

[2] A. Kethwas and B. Jharia, "Image de-noising using fuzzy and wiener filter in wavelet domain," 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, 2015, pp. 1-5.

[3] Chujian Bi, H. Wang and Rui Bao, "SAR image change detection using regularized dictionary learning and fuzzy clustering," 2014 IEEE 3rd International Conference on Cloud Computing and Intelligence Systems, Shenzhen, 2014, pp. 327-330.

[4] S. Anissa, S. Hassene and B. b. Ezzedine, "Adaptive median filter based on ANFIS for impulse noise suppression," 2014

IEEE 23rd International Symposium on Industrial Electronics (ISIE), Istanbul, 2014, pp. 950-953.

[5] M. S. Raval, M. V. Joshi and S. Kher, "Fuzzy Neural Based Copyright Protection Scheme for Superresolution," 2013 IEEE International Conference on Systems, Man, and Cybernetics, Manchester, 2013, pp. 328-332.

[6] T. Lin and S. Bourennane, "Hyperspectral Image Processing by Jointly Filtering Wavelet Component Tensor," in IEEE Transactions on Geoscience and Remote Sensing, vol. 51, no. 6, pp. 3529-3541, June 2013.

[7] I. Dagher and C. Taleb, "Improved wavelet wiener estimator in image denoising," 2012 2nd International Conference on Advances in Computational Tools for Engineering Applications (ACTEA), Beirut, 2012, pp. 311-314.

[8] R C Gonzalez and R .E.Wood Digital image processing Prentice hall, upper saddle river, N J.,2nd edition, 2002.

[9] W. K. Pratt, Digital Image Processing, 2nd ed. New York: Wiley, 1991.

[10] J. S. Lim, Two-Dimensional Signal and Image Processing. Englewood Cliffs, NJ: Prentice-Hall, 1990.

[11] H. C. Andrews and B. R. Hunts, Digital Image Restoration, Englewood Cliffs, NJ: Prentice-Hall, 1977.

[12] Li Ke, Weiqi Yuan and Yang Xiao, “An Improved Wiener Filtering Method in Wavelet Domain”, IEEE Trans., ICALIP, pp. 1527-1531, August 2008.

[13] Nevine Jacob and Aline Martin “Image Denoising In the Wavelet Domain Using Wiener Filtering” December 17, 2004.

[14] Haiping Hu and Zhenxin Xie, "A image denoising by modified nonlocal means method based on generalized cross-validation," International Conference on Computational Problem-Solving, Lijiang, 2010, pp. 12-15.