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Study of Image Enhancement Techniques in Image Processing: A Review

Ramandeep Kaur ^a, Kamaljit Kaur ^b

^a Student, Village Urdhan, Tehsil Ajnala, Amritsar, Punjab and 143103, India

^b Assistant Professor, Department Computer Engineering and Technology, Guru Nanak Dev University, Amritsar, Punjab and 143001, India

Abstract

Image denoising plays extremely important role in digital image processing. The primary objective of this paper is to explore highlighted challenges of the image filtering techniques. The comprehensive study has evidently shown that the one of most challenging issue in image filtering is edge preserving while removing the noise. Because edges deliver the most important information to the human visual system. This paper has compared different recent image filtering methods based upon certain factors. The comparisons have shown that the noise reduction using wavelet coefficients based on OMP has quite effective improvements over available methods. Challenging issue in image filtering technique is removing the multiplicative noise and high density of noises is still found.

Index Terms: Image denoising, Over Complete Dictionary, Orthogonal Matching Pursuit (OMP) and Wavelet Coefficients based on Orthogonal Matching Pursuit (WCOMP).

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1. Introduction

Digital Image Processing is a wide field which provides the different fundamentals for the digital image. A digital image is really a depiction of two dimensional images as a finite group of digital values. It concentrates on two important tasks. Primary is a pictorial data for human elucidation. Next is finalizing of image data with regard to storage, transmission and illustration for autonomous machine observation. Digital image is double dimensional image consists of a finite quantity of element all of with a particular position and value. These elements are referred to as picture element, image element, pels or pixels. The pixel is a smallest controllable element of a picture represented on the screen. There are five main fundamentals include in digital image processing. And the image enhancement is one of most commonly used class of Image Processing operations.

* Corresponding author. Tel.:

E-mail address:

The most important function of the image enhancement is to improve the quality of the image, reduce the noise content, and sharpen the image detail. It is subjective to the observer and the image. It is only to emphasize certain feature of interest in an image. An instance of enhancement is while raise the contrast of an image for the reason that "it looks better or improved." Tasks involved in this similar to

- Brightness
- Contrast Adjustment
- Edge Enhancement
- Noise Reduction
- Filtering

Under the image enhancement in recent years the technology of the remote sensing is growing rapidly and with this making it possible to offer a huge quantity of spatial information for the remote sensing image analysis applications like target detection[23] and sub pixel mapping [23]. Remote sensing is the acquisition of information regarding an object not including physical contact among the object .The remote sensing images are basically disturbed by sensor noise, absorption, atmospheric scattering which reduce the image visual quality[1].

The noise is the outsider element of image which occurs variation in the image quality similar to brightness, color intensity etc. In digital image processing, various types of noises are to be removed by different methods. The noise in the image decreases the performance of visual image quality and computerized analysis [3]. The process of getting the better original image as of the noisy image is called as image reconstruction. The reconstruction of the image require the sample of the image as of which the original image is improved [5]. Noise is an unwanted signal in digital images. It produces the undesirable effects such as unseen lines, unrealistic edges, corners, disturb background scenes and blurred objects. There are different types of noise in image processing some are defining below:-

- *Gaussian noise*

In this each pixel in the image distorted by the little quantity from the original intensity value of the image. It is as well called a normal noise. It's having modeled for represent this kind of noise that is called Gaussian distribution. The 'p' probability density function of a Gaussian random 'z' variable is known by:

$$p(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(z-\mu)^2/2\sigma^2} \quad (1)$$

Where z represents intensity, μ the mean value and σ the standard deviation, the standard deviation σ^2 is called the variance of z.

- *Impulse noise*

It is also called the salt and pepper noise. This type of noise occurring in white and black pixels in the image. For this noise median filter is very effective noise reduction method. The probability density function for impulse noise is known by:

$$p(z) = \left\{ \begin{array}{ll} Pa & \text{for } z = a \\ Pb & \text{for } z = b \\ 0 & \text{otherwise} \end{array} \right\} \quad (2)$$

If $b > a$, intensity b will be come out like a light point in an image and a will be come out like a dark point in

an image. If P_a or $P_b = 0$, the impulse noise is called the unipolar.

- *Poisson noise*

Poisson noise is an electronic noise which can be modeled by a poisson process. It occurs in optical devices and originates from electric charge. It is basically removed by median filter.

- *Speckle noise*

It is a granular noise and degrades the quality of the medical ultrasound and radar images. These suffer from common phenomenon called speckle that are like bright and dark dots in an image. The adaptive filter model is used for this type of noise reduction [3].

Many strategies have been used to reduce the noise of a remote sensing image[1 Sparse representation will be the most widely used representation involving images in addition to signals for most applications related to image processing and signal. Some of these applications consist of things like image filtering, feature extraction, edge detection and picture compression and many others. The Sparse representation is truly what represents this signal using the few volume of elementary atom. It necessitate the technique of the overcomplete dictionary in which elementary atom filled by means of dictionary. The overcomplete dictionary involves the fundamental atoms employed for reconstruction intent. The Orthogonal Matching Pursuit (OMP) algorithm can be a best alternative for signal recovery. [5]. And other various approaches are used to recover the signal including OMP algorithm, Matching Pursuits [24], K-SVD algorithm which is used in a various fields like denoising, updating the dictionary and compressing image. It has achieved good results. [12]. Another technique is Multiscale Geometric Analysis such as Curvelet [22], Contourlet [8], and Gabor Dictionaries are basically used for restoration of textures [15]. And the wavelet coefficients based on OMP (WCOMP). In this introduce the coefficients of wavelet transform into a greedy strategy that are combine with OMP algorithm to improve the performance of the image compare to another approaches. In this paper OMP algorithm combine with K-SVD decomposition with the DCT (discrete cosine transform) to achieve the sparse representation of the image and after reconstruct this image. The goal of this method is to improve the final performance of the image noise reduction. The WCOMP method performs better than the conventional image denoising methods such as wavelet, Contourlet and K-SVD [1]. It is under the image enhancement fundamental of the digital image processing.

The work in this paper has been organized as follows: Section 2 presents the different image enhancement approaches and divides the different approaches into different categories. These categories are presented in the tabular form. Section 3 has presented the parameterized comparison of selected strategies under image enhancement. Section 4 presents the various challenges occur in image enhancement noise reduction techniques. Finally Section 5 presents the conclusions of overall paper and discuss about the scope of future.

2. Approaches for Image Enhancement and Related Work

It is a wide and first fundamental in image processing. There are different categories arise under the image enhancement. Basically three categories are highlighted like Contrast, Noise Reduction or Filtering.

2.1. Contrast enhancement

Contrast is an important factor of image quality. It is the subjective to the observer. It is evaluated by the difference in the brightness and color of the object background objects. There are many methods used for contrast enhancement have been developed and then applied to issues and problems in image processing. Xiwen Liu proposed the new fuzzy enhancement operator and continuous membership function for solving the issues in traditional old fuzzy algorithm. Proposed method enhances the quality of the image and improves

image edges [28]. Shailendra Singh Negi and Yatendra Singh Bhandari have proposed the Image Sharpening and Contrast Stretching techniques for boundary enhancement, noise, and contrast adjustment. Proposed method improves the contrast, adjust the contrast and enhance the boundaries of the image [31]. Vaishali Ahirwar and Himanshu Yadav proposed the Hybrid Model(DCT, DWT) for preserving the brightness of the digital image. This hybrid technique removes the noise, preserve the brightness and enhance the contrast of the image[30].

Table 1. Different Techniques of the Contrast under the Image Enhancement Are Below

| Contrast enhancement technique/algorithm | Operating domain | Quality metrics | Transform | Features | Limitations |
|--|------------------|---------------------------|-------------------------|---|---|
| Adaptive unsharp mask algorithm (AUM)[26] | Spatial domain | Contrast, local mean | NA | Enhance the high detail area of medical images | No sharp the edges and not work on low area details |
| Laplacian filter in AUM[27] | Spatial domain | MSE,PSNR | NA | It produces the better edge sharpness and contrast adjustment | It only focus on the edges sharpness |
| Improved Image Enhancement Algorithm[28] | Spatial domain | Contrast, histogram | Fuzzy based | Increase the contrast of the image and also enhance the edges and blur of the image | It will good result after two or three times enhance the image not only once time |
| Histogram equalization[29] | Spatial domain | PSNR, AMBE | NA | It generate the high quality contrast enhancement image without losing the image features | Lead to degraded edges |
| Hybrid model[30] | Frequency domain | PSNR,MSE | Frequency based-DCT,DWT | It preserve the brightness and enhance the visual quality of the digital image | Lead to degraded edges |
| Image sharpening and contrast stretching[31] | Spatial domain | Histogram, laplacian mask | NA | It is simultaneously enhances boundaries and adjust the contrast and provide good quality | Lead to degraded edges |

2.2. Noise reduction or filtering

Noise reduction would be the main technique of removing noise from the image. There are a variety of noise are generally arise inside image including uniform noise, gaussian noise, salt and pepper noise, gamma noise, poisson noise and speckle noise.. There are many methods used for noise reduction in enhancement have been developed and then applied to issues and problems in image processing. Jean-Luc Starck and Emmanuel J. Candes proposed the curvelet transform technique for the noise removal in the signal or image which is exact reconstruction of the image by remove the noise in the image [22]. Xia La, Liangpei Zhang at el describes the new three stage haze removal algorithm for the single image haze removal by remote sensing. Proposed method recovers the image from the blur and noise of the image [6]. Joel A. Tropp proposed the OMP algorithm for solve the issues of the signal recovery from random measurements. This new algorithm provides the faster and easier implementation for the signal recovery problems in the image [12]. Filtering is the basic process or function which is used to attain the several tasks for instance noise reduction and filters are used to eliminate the noise as of the image by using different types of filters such as mean filter and median filter. There are many methods used for filtering in image enhancement have been developed and then applied to issues and problems in image processing. Tiejong Zeng and Francois Malgouyres has proposed the Gabor Dictionaries for solve the issue image denoising. By this Gabor filter obtained better results [15]. Marian Kazubek proposed a thresholding and wiener filtering for the image denoising which denoise the image and increase the performance with the thresholding method [20]. Michael Elad and Matan Protter proposed the K-SVD algorithm for the image denoising. The proposed technique K-SVD algorithm provides the improved result as contrast to other strategies for denoising and improves denoising performance [9]. There are more different techniques and algorithms for different issues in the noise reductions or filtering some are spatial domain and some are frequency domain in image enhancement are define below.

Table 2. Spatial Domain Based Techniques under the Noise Reduction Are Given Below

| Noise reduction enhancement technique/algorithm | Operating domain | Noise type | Quality metrics | Transform based | Features | Limitations |
|--|------------------|----------------------------|---------------------------|----------------------|--|---|
| Neighbour wavelet coefficient dependency[32] | Spatial domain | Gaussian White noise | PSNR | NA | Remove the noise by threshold and customized wavelet filter by using Simulated Annealing At the same time. | Not work in Multi wavelets in image denoising |
| Denoising and enhancing for mammographic images[33] | Spatial domain | Gaussian noise | Local contrast, histogram | NA | It is useful for noise removal and enhance the edge and local contrast | Extend the denoising technique Include non-Gaussian noise. |
| Fuzzy impulse noise detection and reduction method (FIDRM)[34] | Spatial domain | Impulse and Gaussian noise | PSNR | Fuzzy Based | Remove the impulse noise and leave that pixels which are noise free | Very low execution time |
| Two pass hybrid method[35] | Spatial domain | Impulse noise | MSE | Neural network based | Remove the impulse noise in efficient manner and works better than other methods are compared | Expand the existing method and use other detectors and the use the better estimators in highly corrupted impulse noise. |

| | | | | | | |
|---|----------------|---|-------------------------|-------------------|---|---|
| Curvelet and wavelet transform[36] | Spatial domain | Gaussian noise (additive noise) Speckle noise (multiplicative noise) | SNR, PSNR | Fuzzy Based | It provides the better smoothness in image background while keeping the edge preserved and removal the fuzzy edges | Not affected true edges |
| Improve neighshrink method[37] | Spatial domain | Gaussian noise | PSNR | NA | Remove the noise and improve the denoising performance | Lead to degraded edges |
| Exponential mixture models for Noise reduction[38] | Spatial domain | Gaussian noise | Least mean square error | NA | Remove the noise from observed data for clustering and improve the performance | Lead to degraded edges |
| Adaptive filter algorithm[44] | Spatial domain | Speckle noise | MSE, MMSE | NA | Eliminates the noise from radar images by adaptive filter | Need to develop the edge detection algorithm for radar images |
| Context based filtering[46] | Spatial domain | Gaussian noise | OCR | NA | Remove the noise from images and loss the compression performance due to preserving the quality of the image and OCR accuracy | Lead to degraded edges |
| Median filter for color image enhancement[47] | Spatial domain | Gaussian noise | Contrast | NA | Eliminates the noise from the color images by chromaticity diffusion | Not preserve the edges |
| Hybrid method using cellular automata and fuzzy logic[42] | Spatial domain | Impulse noise | PSNR, MSE | Fuzzy Based | Remove the impulse noise. It is very simple and robust | Not work efficient on high noisy images |
| Rank ordered filter[51] | Spatial domain | NA | Contrast, histogram | Fuzzy Based | It provide the better edge, boundaries enhancement and edge detection | Not work on the low contrast areas |
| Neuro-fuzzy network based Filtering[53] | Spatial domain | Impulse noise | MSE.PSNR | Neuro-fuzzy based | Reduce the noise and improve the optimization performance, easier implementations | Not work well on low contrast areas |

Table 3. Frequency Domain Based Techniques under the Noise Reduction Are Given Below

| Filtering enhancement technique/algorithm | Operating domain | Noise type | Quality metrics | Transform based | Features | Limitations |
|--|------------------|-------------------------------|---------------------|----------------------|---|--|
| Noise Filtering by Use of Local Statistics[43] | Frequency domain | Gaussian noise, Speckle noise | MSE | Frequency based-FFT | It improve the contrast enhancement and remove the noise from the image | Extend the existing method to image restoration and degradations |
| Wavelet-based image denoising[39] | Frequency domain | White gaussian noise | PSNR | Frequency based-DWT | Remove the noise through thresholding | Not Sharp the edges |
| Fractal conservation law for denoising[40] | Frequency domain | White gaussian noise | SNR | Frequency based-DFT | Simultaneous denoising and enhancement. It amplifies the low and medium frequencies and eliminates the high frequencies | Lead to degraded edges |
| Wavelet transform domain filter[45] | Frequency domain | White gaussian noise | SNR | Frequency based- FFT | It remove the noise and preserve and sharp the edges | Does not work on low contrast background images |
| Modified Gabor filter[48] | Frequency domain | Random noise | TGF,MGF | Frequency based-DFT | It enhance the fingerprint images and achieve better performance | Does not proper work on edges |
| Modified high pass filtering method[49] | Frequency domain | Random noise | Contrast | Frequency based-DCT | It sharpen the image very efficiently and useful in color image sharpness, remote sensing and medical image enhancement | No work on little information areas |
| Bounded block matching and 3D filtering[50] | Frequency domain | White gaussian noise | PSNR | Frequency based-DCT | Remove the noise from image and achieve better visual performance | Lead to degraded edges |
| Frequency domain filtering[52] | Frequency domain | NA | Canny edge detector | NA | Improve the contour detection performance from the images by canny edge detector | Only work on edges |

3. Parameterized Comparison of Selected Strategies under Image Enhancement

There are different strategies of the image enhancement that have different parameters. These parameters define the each strategy in an efficient manner. There are some techniques are based on spatial domain and some are transform domain. There are very less techniques that are preserve the edges and over-smoothing in noise reduction. There are some techniques working linear and pixel/window based.

Table 4. Different Parameters Working on Different Strategies that are Given Below

| Parameters Strategy | Spatial/Transform Domain | Edge Preservation | Linear | Pixel/Window Based | Over- smoothing |
|--|-----------------------------|-------------------|--------|-----------------------|--------------------|
| Matching pursuit algorithm [24] | Frequency transform | No | Yes | Window based | No |
| Sub pixel target detection [23] | Spatial domain | No | No | Pixel based | No |
| Curvelet Transform [22] | Transform domain | Yes | Yes | Frequency based | No |
| Scale Mixtures of gaussians in the wavelet domain [21] | Spatial domain | No | Yes | Window based | No |
| Morphological transformations [19] | Spatial domain | No | Yes | Window based | No |
| Thresholding and wiener filtering [20] | Spatial domain | No | Yes | Pixel based | No |
| Greedy algorithm, orthogonal matching pursuit (OMP) [18] | Spatial domain | No | Yes | Window based | No |
| Neighbouring wavelet coefficients [17] | Transform domain | No | Yes | Window based | No |
| Doubly local wiener filtering [16] | Spatial domain | No | Yes | Window based | No |
| K-SVD algorithm[14] | Spatial domain | No | Yes | Window based | No |
| Gabor dictionaries[15] | Transform domain | No | Yes | Window based | No |
| OMP algorithm [12] | Spatial domain | No | Yes | Window based | No |
| SURE-LET approach[13] | Transform domain | No | No | Window based | No |
| Comparisons of contourlets curvelets and wavelets [10] | Spatial domain | No | Yes | Window based | No |
| Contourlet using Adaptive Windows [8] | Transform domain | Yes | Yes | Window based | No |
| Three stage Haze Removal Algorithm [6] | Spatial domain | No | Yes | Window based | No |

| | | | | | |
|--|------------------|-----|-----|--------------|----|
| Wavelet based Techniques and filtering [3] | Spatial domain | Yes | Yes | Window based | No |
| Patch based wavelet domain [2] | Spatial domain | Yes | Yes | Window based | No |
| Wavelet Coefficients based on OMP [1] | Transform domain | No | Yes | Window based | No |

4. Various Challenges in Image Enhancement Noise Reduction Techniques

Image denoising plays extremely important role with digital image processing. There are some most highlighted challenges for the image enhancement that are given below

- *Edge preservation*

One of most challenging issue in digital image processing is that the edge preserving while removal the noise from the images because edges deliver the most important information to the human visual system [2].

- *High density of noise*

Noise removal is also a one of the biggest challenging issue in the field of digital image processing. Various types of noise exist but the impulse noise elimination is one of the mainly important and necessary preprocessing steps in digital image processing. Impulse noise is type of highest density noise in an image. And what will be effect on the filter due to high density of noise.

- *Multiplicative Noise*

Multiplicative noise is most challenging issue in digital image processing. It is also known as speckle noise and very difficult to remove from the images. It considers how the filter give respond to remove this type of noise [54].

5. Conclusion and Future Work

Noise removal is found to be one of the biggest challenging issues in the field of digital image processing. Various types of noises exist but the impulsive noise elimination is one of the mainly challenging issue and necessary preprocessing steps in vision processing. The high density of impulsive noise is still an open are of research for vision researchers. This paper has presented various methods used for noise reduction. But none perform best in every case. The OMP based filter is best for the preservation of structure in digital image and it performs well only at low noise level. It does not work for preservation of edges or neighborhood of edges. However, the noise reduction by means of wavelet coefficient based on OMP less effects on the edges than available techniques but not as found in edge preservation techniques.

Therefore in near future we will propose a new technique which will use minimum patch based noise reduction by means of wavelet coefficient lying on OMP technique. To achieve the edge preservation, will select such a patch from noisy image that has minimum patch difference. Thus will have accurate results as not much modification is done in the input patch space i.e. image. However the image gradients will also be used as a post processing operation to preserve the edges in an efficient manner.

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Authors' Profiles



Ramandeep Kaur (born June 14, 1993) is a Student, Pursuing M.tech in Software System at Computer Engineering and Technology Department, Guru Nanak Dev University Amritsar. Her main interest area is digital image processing.



Kamaljit Kaur (born December 15, 1985) is an Assistant Professor at Computer Engineering and Technology Department, Guru Nanak Dev University Amritsar. She has completed M.tech in Computer Science and Engineering (2010) with Gold Medalist and currently pursuing PhD at Guru Nanak Dev University Amritsar. Her interest areas are Cloud Computing, Parallel Computing. She has around 22 publications at national and international level.

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