A Review on Various Restoration Techniques in Digital Image Processing

Abhilash Bag[1]

[1]*MPhil Scholar Department of CSA, Sambalpur University, Odisha, India*

Abstract - *The field of digital image processing deals not only with the extraction of features, analysis of images and restoration of images but also with the process of enhancement, filtering and restoration of images. Image restoration is one of the basic steps of processing that deals with making certain improvements in a digital image based on some predefined criteria Restoration is the process of reconstruction of an uncorrupted image from a blurred or noisy image. Various restoration techniques like wiener filter, adaptive median filter, novel median filter, Lucy Richardson techniques, inverse filtering Threshold Wiener filter are described. However, this paper presents a comprehensive review of some proposed methods and techniques used for restoration along with its advantages and limitations of each approach.*

Key Words: **Image Restoration, Wiener Filter, Median Filter, Lucy Richardson Algorithm, PSNR**

1. INTRODUCTION

Image processing is a branch of study where 2 D image signal is processed directly in spatial domain or indirectly on frequency domain. Image processing begins with the image acquisition process. An image can be defined as a two-dimensional function f (x, y) where x and y are spatial coordinates and the amplitude of 'f' at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point. When x, y and the amplitude values of f are all finite, discrete quantities we call the image as a digital image.

At the time of image acquisition and/or image transmission the original image may be corrupted or degraded. The process of reconstructing or recovering an image that has been degraded by some degradation function. It works both for spatial domain and frequency domain.

1.1 Image noise

Noise in digital image occurs during the time of image acquisition or transmission. During image acquisition, the performance of imaging sensors is affected by a variety of factors like the quality of sensing elements, the environmental conditions etc. Images are also corrupted during transmission due to interference in channel used for the transmission.

1.2 Image Restoration

To keep the originality of the image, the noise must be reduced. Image restoration is the process of removal or reduction of degradations which are included during the acquisition of images which may be Noise, pixel value errors, out of focus blurring.

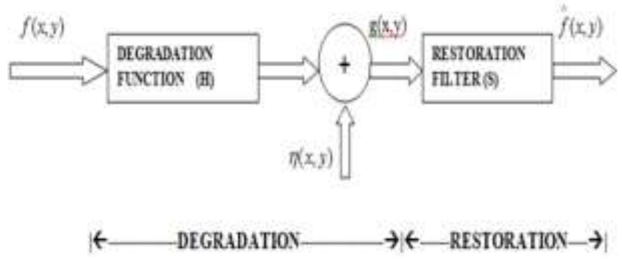

Fig -1: A model of the Image Degradation/ Restoration process

The degradation process model is defined as a degraded image g(x, y) is produced when a degradation function H and an additive noise $\eta(x, y)$ operate on the input image $f(x, y)$. The objective of restoration is to obtain an estimate $\hat{f}(x, y)$ of the original image by using some restoration filters. We always want to estimate $\hat{f}(x, y)$ be as close as possible to the original input image $f(x, y)$. This can only be possible, the more we know about H and η.

1.2 Restoration techniques

1.2.1 Median filter

The best-known order static filter is median filter. As its name it replaces the value of a pixel by the median of the intensity levels in the neighborhood of that pixel. The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorted according to the magnitudes. It is based upon moving a window over an image and computing the output pixel as the median value of the brightness within the input window. It is mostly used for salt & pepper noise. It is used widely and can reduce the noise in image excellently.

1.2.2 Linear filter

In this, each pixel is replaced by the linear combination of its neighbor. Sharpening, smoothing and edge enhancement are the operations implemented in linear filtering. This type of filter has implementation in salt and pepper and gaussian noise.

1.2.3Adaptive filter

It is a type of linear filter which has a transfer function controlled by a variable parameter. It is used for removal of impulse noise and gives good noise suppression results, preserves edges in a better way and hence yield better quality.

1.2.4Direct inverse filter

The blurring function of the corrupted image is known or can be developed then it has been proved as the quickest and easiest way to restore the distorted image. Blurring can be considered as low pass filtering approach and use high pass filtering action to reconstructed the blurred image without much effort.

1.2.5 Wiener filter

This is a standard image restoration approach proposed by N. Wiener. It includes both degradation function and statistical characteristic of noise into the restoration function. It is one of the best deblurring linear methods which reconstructs an image from degraded image by known PSF. The main objective of the method is to find an estimate value of the uncorrupted image value such that the mean square error between the is minimized.

The drawback of inverse filtering is that they are noise sensitive but Wiener filtering is not noise sensitive. Its response is better in presence of noise.

1.2.6 Lucy Richardson techniques

The image restoration is divided into blind and non-blind deconvolution. In nonblind PSF is known. It is the most popular techniques in the field of astronomy and medical imaging because of its ability to produce reconstructed images of good quality in the presence of high noise levels.

The inverse Fourier transform of optical transfer function (OTF) in the frequency domain is the PSF, where OTF gives linear, position invariant system the response to an impulse. The Fourier transform of the PSF is OTF.

1.3 PERFORMANCE MEASURE

The metrics used for performance comparison of different filters are described below.

1.3.1 PSNR

PSNR analysis uses a standard mathematical model to measure an objective difference between two images. It estimates the quality of a reconstructed image with respect to an original image. The basic idea is to compute a single no. that reflects the quality of reconstructed image. Reconstructed images with higher PSNR are judged better. The original image Y of size (M x N) pixels and a reconstructed image, the PSNR (dB) is defined as

$$PSNR(dB) = 10\log_{10}\left\{\frac{255^2}{\frac{1}{MXN}\sum_{I=1}^{M}\sum_{j=1}^{N}(Y_{i,j}-\hat{Y}_{i,j})}\right\} \quad ..1$$

1.3.2 PSP (Percentage of Spoiled Pixels)

PSP is a measure of percentage of non-noisy pixels changes their gray scale values in the reconstructed image. In other words, it measures the efficiency of noise detectors. Hence, lower the PSP value better is the detection, in turn better is the filter performance.

$$\mathbf{PSP} = \frac{\text{number of non noisy pixel changed their value}}{\text{total no.of non noisy pixel}} \mathbf{X100}$$

…….2

1.3.3Mean Square Error (MSE):

The MSE is the cumulative squared error between the compressed and the original image.

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y) - I'(x,y)]^2$$

……………………………….3

Where I(x, y) is the original image, I"(x, y) is the approximated version (which is actually the decompressed image) and M, N are the dimensions of the images. A lower value for MSE means lesser error.

2. LITRETURE REVIEW

Hani M. Ibrahem 2013In this paper, an efficient and simple method to remove salt-and-pepper noise is proposed. It is composed of three stages as: (1) Data extraction from the unnoisy image. (2) Noise detection. (3) Noise cancellation. In this method, only the noise pixels are changed by filter operation, while the noise free pixels are kept unchanged. In addition, the window size is altered among 3X3 and 5X5 based on the noise and noise free pixels within the window. An algorithm to extract the data from the no noisy image and form it in the linear equation system is presented. This method can remove salt-and-pepper-noise with a noise level as high as 97%, and it's relatively fast.[2]

G. Pok et al., 2009 proposed a decision-based, signal adaptive median filtering algorithm for removal of impulse noise. we presented a new framework for the removal of impulse noise in which filtering operation is selectively applied to the pixels that are classified as corrupted. Our algorithm achieves accurate noise detection and high SNR measures without smearing the fine details and edges in the image. The notion of *homogeneity level* is defined for pixel values based on their global and local statistical properties. The cooccurrence matrix technique is used to represent the correlations between a pixel and its neighbors, and to derive the upper and lower bound of the homogeneity level. Noise detection is performed at two stages: noise candidates are first selected using the homogeneity level, and then a refining process follows to eliminate false detections. The noise detection scheme does not use a quantitative decision measure, but uses qualitative structural information, and it is not subject to burdensome computations for optimization of the threshold values. Empirical results indicate that our scheme performs significantly better than other median filters, in terms of noise suppression and detail preservation. [3]

Iyad F. Jafar et al., 2013 proposed two modifications to the filtering step of the Boundary Discriminative Noise Detection (BDND) algorithm. BDND method is an example of the switching median filter. BDND algorithm filters the noisy image in two steps. First, it detects the noisy pixels in a localized window based on clustering. It differentiates the noisy and non-noisy pixels using the intensity differences in the ordered set of pixels in the window. Secondly in the filtering step, a strict condition is applied on the size of the filtering window and it uses the median filter technique. The proposed method made some modifications to the BDND method and the median filter. They modified it by loosening the condition in the expansion of the filtering window. One another modification has made to incorporate the spatial information of the uncorrupted pixels in the filtering window and the deviation of their intensities from the median when computing the estimated value of the noisy pixel. The proposed method produces higher quality images with high noise density which is visually sharper and more distinctive as compared to the BDND method. [4]

Z. Wang et al., 1999A new median-based filter, progressive switching median (PSM) filter, is proposed to restore images corrupted by salt–pepper impulse noise. The algorithm is developed by the following two main points: 1) switching scheme—an impulse detection algorithm is used before filtering, thus only a proportion of all the pixels will be filtered and 2) progressive methods—both the impulse detection and the noise. A main advantage of such a method is that some impulse pixels located in the middle of large noise blotches can also be properly detected and filtered. The MSE curves demonstrate that our PSM algorithm is better than other median-based methods, especially when noise ratios are high. They show the restoration results of different filtering methods for test image "peppers" highly corrupted with 50% impulse noise.[5]

Hussain Dawood et.al., 2014 Weber law is an efficient way to identify noise, as it describes the information of the neighbor pixels to the central pixel. Thus, it can identify impulse noise in the current block with improved accuracy. Here Mr. Dawood et al. proposed a robust noise detection method by considering the phenomena of Weber's Law known as Weber's Law Noise Identifier (WLNI). By using switching techniques based on WLNI binarization, the pixels of the noisy image are classified as either noisy or noise free pixels. The classified noisy pixels are then processed by the proposed Modified Switching Median Filter (MSMF). This MSMF replaces the noisy pixels in two ways. In first case the central value is replaced by the median value of the current block where as in second case, the central value is replaced by the mean value of the current block. The proposed WLNI method outperforms the state-of-the-art image denoising methods in visual quality, structural similarity (SSIM) and PSNR quality. [6]

Neeraj kumar et al, used Wiener filtering techniques for restoration of images distorted by systems with noisy PSF and additive detection noise has been considered. This filter is solution to the restoration problem based upon the hypothesized use of a linear filter and minimize mean square error (MMSE). Performance of Wiener filter in frequency domain for image restoration is compared with that in the space domain on images degraded by white noise. It is also observed that the Wiener filter having better performance for images corrupted by white noise compared to another linear filter. [7]

Swati Sharma et al., proposed a modified Lucy Richardson algorithm for restoration of image in presence of gaussian noise and motion blur.

DWT has excellent spatial localization and multiresolution characteristics, which are similar to the theoretical models of the human visual system. The original image is decomposed into four sub-band images by DWT. After that modified Lucy Richardson algorithm is applied on it.

They have taken two performance evaluation metrics: PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error). The proposed algorithm has high value of PSNR than the other deblurring methods in the presence of both Gaussian blur as well as motion blur. Furthermore, the proposed algorithm has low value of mean square error than Wiener filtering and Lucy Richardson algorithm in the presence of both Gaussian Blur as well as motion blur.[8]

Marian Kazubek used thresholding with Wiener filter to denoise degraded image. Before applying Wiener filter Marian used a thresholding operation which results into higher PSNR values and gives better result than the standard Wiener filter.[9]

Table -1: Comparison Table

MOTIVATION	AUTHOR	FILTER USED	TECHONLOGY USED	FINDINGS
An Efficient and simple switching filter for removal of high density salt and pepper noise	**Hani M. Ibrahem et al.,**	Simple Switching Filter	extract the data from the non noisy image as $X=A^{-1}B$	works well for high-density salt & pepper noise even up to a noise density of 97%.
Selective removal of impulse noise based on homogeneity level information	**G.Pok et al.,**	Conditional Signal-Adaptive Median (CSAM) Filter	cooccurrence matrix technique	performance measured in PSNR and the perceptual quality. Referring to Table III, the proposed CSAM filter achieved significant improvement over other techniques, ranging from 2.3 dB to 8.3 dB in PSNR.
Efficient Improvements on the BDND Filtering Algorithm for the Removal of High-Density Impulse Noise	**Iyad F. Jafar et al.,**	Median filter	Modified BDND method	Visually sharper and more distinctive images are produced as compare to BDND method.
Progressive switching median filter for the removal of impulse noise from highly corrupted images	**Z. Wang et al.,**	progressive switching median (PSM) filter		MSE performance impulse noise ratios ranging from 5% to 70%.
Removal of high-intensity impulse noise by Weber's law Noise Identifier	**Hussain Dawood et al.,**	Modified Switching Median Filter (MSMF)	Weber's Law Noise Identifier (WLNI)	Identifies 100% of impulse noise and effectively replaces the noisy pixel values. Highly edge preserving and better PSNR and SSM values with other state-of-theart algorithms by varying noise intensities ranging from 50% to 90%.
Wiener Filter Using	**Neeraj Kuma**	Wiener Filter		Wiener filter works

Digital Image Restoration	**r et al.,**			better for white noise than other linear filter
Image Restoration using Modified Lucy Richardson Algorithm in the Presence of Gaussian and Motion Blur	**Swati Sharma et al.,**	Modified Lucy Richardson algorithm	DWT, Thresholding	Proposed method works better than Wiener filter and Lucy Richardson algorithm
Wavelet Domain Image Denoising by Thresholding and Wiener Filtering	**Marian Kazubek**	Thresholding and Wiener filter	thresholding	Result is better than the standard Wiener filter with high PSNR values
Novel Median Filter for Impulse Noise Suppression from Digital Images	**Geeta Hanji et al.,**	Novel Median Filter (NMF)	Overlapping adaptive window	Performed best to remove impulse noise at higher densities. As compare to SMF & AMF filters, proposed method shows high PSNR and least MSE results

3. CONCLUSION

Restoration of images is a difficult problem to resolve. The main objective of this work is to carry out a comparative study. Though every technique has got its own way of dealing with the problem and have their own pros and cons. It is concluded from the above explanations that usage of the techniques is governed by the understanding, requirement and the standard of the output needed. Before the application of the any filtering technique; it is supposed to have the better understanding that is it requires proper analysis, though some of the researches have categorically claimed that wiener and Lucy Richardson are expected to give the better results and median filter works better for impulse noise.

REFERENCES

[1] R. C. Gonzalez and R. E. Woods. Digital Image Processing. Addison Wesley, 2nd edition, 1992.

[2] Hani M. Ibrahem, "An Efficient and simple switching filter for removal of high density salt and pepper noise" I.J. Image ,Graphics and signal processing, published online October 2013,12,1-8 in MECS.

[3] G. Pok, J.-C. Liu, and A. S. Nair, "Selective removal of impulse noise based on homogeneity level information," IEEE Trans. Image Processing, vol. 12, pp. 85–92, Jan. 2003.

[4] Iyad F. Jafar, Rami A. AlNa‟mneh, and Khalid A. Darabkh, "Efficient Improvements on the BDND Filtering Algorithm for the Removal of High-Density Impulse Noise", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 22, NO. 3, MARCH 2013.

[5] Z. Wang and D. Zhang, "Progressive switching median filter for the removal of impulse noise from highly corrupted images," IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing, 1999, vol. 46, no. 1, pp.78-80.

[6] Hussain Dawood, Hassan Dawood, Ping Guo, "Removal of high-intensity impulse noise by Weber‟s law Noise Identifier", Pattern Recognition Letters 49 (2014)121–130.

[7] Neeraj Kumar, Karambir & Kalyan Singh, "Wiener filter using digital image processing". International journal of Electronics Engineering, 3(2), 2011, pp. 345-348.

[8] Swati Sharma, Shipra Sharma and Rajesh Mehra, "Image Restoration using modified Lucy Richardson algorithm in presence of Gaussian and Motion blur", Advance in Electronic and Electric Engineering, volume3, Number 8(2013), pp. 1063-1070.

[9] Marian Kazubek, "Wavelet Domain Image Denoising by Thresholding and Wiener Filtering", IEEE SIGNAL PROCESSING LETTERS, VOL. 10, NO. 11, NOVEMBER 2003

[10] Geeta Hanji, M. V. Latte, "Novel Median Filter for Impulse Noise Suppression from Digital Images" , International Journal of Computer Applications (0975 – 8887) Volume 106 – No.8, November 2014.