ISSN: 2321-7782
Volume 1, Issue 3, August 2013
International Journal of Advance Research in Computer Science and Management Studies
Research Paper
Available online at: www.ijarcsms.com

# A Survey of Linear and Non-Linear Filters for Noise Reduction

**Pragati Agrawal** [1]
M.Tech Scholar
Oriental College of Technology
Bhopal - India

**Jayendra Singh Verma** [2]
M.Tech Scholar
Oriental College of Technology
Bhopal - India

***Abstract:** Now-a-days there are so many methods that are available to remove noise from digital images. Most of the novel method comprises two stages: the first stage is to detect the noise in the image. At this stage, based on the intensity values, the pixels are roughly divided into "noise-free pixel" and "noisy pixel". Then, the second stage is to eliminate the noise from the image. At this stage, only the "noise-pixels" are processed. The "noise free pixels" are copied directly to the output image. This paper explores the various novel methods for the removal of noise (Gaussian or Impulse noise) from the digital images. The noise is exactly estimated through the various filters having so many pros and corns. The distinctive feature of the all the proposed filters is that it offers well line, edge, detail and texture preservation performance while, at the same time, effectively removing noise from the input image. Some filter is capable of removing Impulse noise and another is used to eliminate Gaussian noise. In later section, we present a short introduction for various methods for noise reduction in digital images. These methods are suitable to be implemented in consumer electronics products such as digital televisions, cameras, etc.*

***Keywords:** Image degradation, Image denoising, Image restoration technique, median filter, adaptive fuzzy switching median filter, fuzzy inference system, Impulse noise , Gaussian Noise, Center Weighted Median filter, GFIF, SD-ROM etc.*

## I. Introduction

The image processing is a technique that enhances the raw images received from cameras or pictures taken in day-to-day life for many applications, but there are still some bottlenecks on which researchers have their focus. Unfortunately, the image taken by digital cameras could be affected by noise due to random variation of pixel elements in the camera sensor. There are so many causes of noise by which digital images are corrupted [1] such as malfunctioning pixels in camera sensors, faulty memory locations in hardware or transmission of image in a noisy channel and some other causes also. Noise represents unwanted information which destroys the image quality. It also affects the accuracy of many image processing applications such as image segmentation, image classification, edge extraction, image compression, etc.

## II. Image Denoising

A fundamental problem is to effectively remove noise from an image while keeping its fundamental structure constituting of edges, corners, etc., intact or retaining as much as possible the important signal features. This method is called Image Denoising [1]. The nature of noise removal depends on the type of the noise corrupting the images.

The most common type of noise model is salt and pepper impulse noise, random valued impulse noise, Gaussian Noise, Additive noise and multiplicative noise. In salt and pepper impulse noise, the pixels are corrupted by maximum and minimum value [3].

$$Y = \begin{cases} 0 \text{ to } 255 & \text{with probability } p \\ x & \text{with probability } 1-p \end{cases}$$

Where, ‘y’ is the noisy pixel and ‘x’ is the original value. For random valued impulse noise, the noise can take the value between the minimum and maximum values.

$$Y = \begin{cases} 0 \text{ to } 255 & \text{with probability } p \\ x & \text{with probability } 1-p \end{cases}$$

Where, ‘y’ is the noisy pixel, n is the noise value and ‘x’ is the original value. For Gaussian noise, each and every pixel of the image gets affected. For Additive noise [2], pixel values are independent from the original image. This has the effect of not altering the average brightness of the image. Whereas, in multiplicative noise the magnitude of a noisy pixel is related to the value of the original pixel, the image denoising can be done either by applying linear filtering or non-linear filtering methods [2].

## III. Image Degradation

Image Degradation is a process by which image is blurred. The degradation is often modelled as a linear function which is often referred as point-spread function. There are so many different causes of image degradation are: Improper opening & closing of the shutter, atmospheric turbulence, miss the focus of the lens, relative motion between camera and object which causes motion blur [1].

## IV. Image Restoration Technique

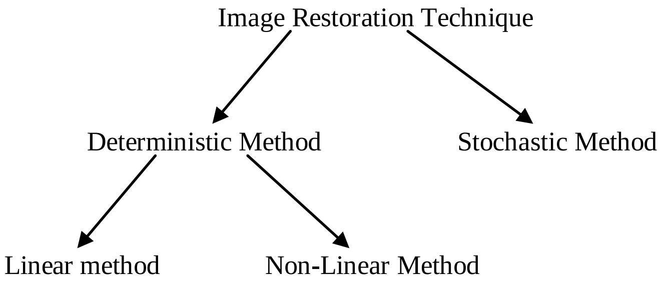


Image restoration techniques can be broadly classified into two types depending upon the knowledge of degradation. If the prior knowledge about degradation is known then the deterministic method of image restoration can be employed. If it is not known then the stochastic method of image restoration has to be employed.

The linear image restoration techniques [2] are: (a) inverse filter (b) pseudo-inverse filter (c) wiener filter (d) constrained least-square filter. If we know the exact PSF (Point Spread Function) model in the image degradation system then, the noise effect can be easily ignored. The main drawback of this filter is, it will not perform well in the presence of noise. It will tend to amplify the noise. Inverse filter is a low pass filter that will pass only low frequency and restrict all the high frequency parts where the noise dominates over the image. So, to avoid this problem pseudo inverse filter comes into the picture that will pass all the frequencies that satisfies the particular threshold value ε.

$$
1/H = \begin{cases} 1/H & \text{if } H > \varepsilon \\ E & \text{if } H <= \varepsilon \end{cases}
$$

The value of ε affects the restore image. With no clear objective selection of ε, restored image is generally noisy and not suitable for further analysis. Wiener Filter is an optimum filter used to minimize the mean square error. A wiener filter has the capability of handling both the degradation function and noise as well. The drawback of such filter is to have prior knowledge of the power spectral density of the original image which is unavailable in practice. Constrained Least Square Filter which adds the Lagrange multiplier, λ, to control the balance between noise artifacts and consistency with the observed data, this approach requires some additional knowledge of the original scene to be recovered then this knowledge should contribute to the more faithful restoration of the image.

A linear image restoration technique [2] is capable of producing a result directly from the observed data but requires some form of the inverse operator to be applied. Non-Linear technique does not explicitly implement the inverse. It uses an iterative approach to produce successive improvement to the restoration until a termination condition is reached. It can cope up with some missing frequency components, with non-Gaussian noise and non- negativity etc. There are so many types of non-linear filters that are efficient to suppress salt and pepper noise. The median filter tends to preserve thin line edges, sharpness and fine details from an input image. The variants of median filters are (a) weighted median filter (b) center-weighted median filter (c) max-median filter. If a color image is corrupted by salt-and –pepper noise, we cannot apply a median filter directly. First to divide the color image into three different planes (red, green and blue) and then apply the median filter to all the three planes individually so that the impact of salt-and-pepper noise is suppressed whereas, in the center weighted median filter have the capability to suppress impulse noise effectively. Along with noise removal, Blurring effect can be controlled by reducing the number of 'interested' neighbour pixels. CWM filter trims the 'un-interested pixels' from the center pixel based on the statistical criteria. In max-min filter, each pixel in an image changed with a new value equal to the maximum and minimum value in a neighbourhood around that pixel.

## V. Related Work

Many image processing algorithms cannot work well in noisy environments. Specifically for the removal of noise from an input image there are several filters that can be considered as the state-of-art methods given their impressive performance. For instance, Median pass filter [12] is used in a variety of applications to remove impulse noise from corrupted images. But the conventional Median pass filter methods can treat all the pixels in the image equally. This will result the elimination of fine details such as thin lines and corner, blurring and distortion in the image. So, to overcome this problem, various types of filters are coming into the picture such as a Switching median filter, Center weighted median filter, rank ordered mean filter, noise detection based median filter.

There are many filters that are used to remove impulse noise from digital corrupted images. ROR-NAFSM-FCM [3] (Robust- out lying Ratio with Noise Adaptive Fuzzy Switching Median Filter and Fuzzy c-Means Segmentation) filter that effectively suppress high density salt-and-pepper noise from corrupted images; It achieves a high PSNR value when noise density is above than 80%. First to separate noise free pixel and noisy pixel separately by using ROR NL-means filter. After that ROR detection is carried out by separating undetected pixels in the first stage. The NASFM filter is used to process only noisy pixels and is replaced by the optimized value of median and fuzzy reasoning. Now, the second stage of filtering is done by fuzzy c-Means segmentation. It segments the noisy pixels and noise free pixels into individual levels. The main drawback of such filter is to suppress only high density salt-and-pepper impulse noise in an input image.

CM filter [4] is based on cloud model for impulse noise removal. The CM model can deal with the uncertainty present in an input image. This filter consists of two features randomness and fuzziness. To deal with uncertainty, the cloud can be characterized by three parameters: expected value Ex, entropy En and the hyper-entropy He. In traditional switching median filter, they identify noise free pixel and noisy pixel separately and then use a noise map to record the information of the noise pixels. According to the map; the filters remove the noise pixels one by one. They scan the noise image twice. So, to overcome this drawback the cm filters remove a pixel immediately after the pixel has been identified as corrupted. It can work on 512*512 8- bit greyscale images only. The drawback of such filter is that it can run 20 times in the same running environment. And this type of filter can detect only fixed-valued impulse noise. The noise adaptive weighted median filter [5] uses BDND (Boundary Discriminative Noise Detection) method for determining the corrupted pixels in the noisy image. There is a fixed window size of 3*3. The noisy pixels are replaced by the weighted median value of the encrypted pixels in the filtering window. The drawback of this method is, only suitable for high density impulse noise. It can work on greyscale images.

Many methods have been introduced in the literature to remove either Gaussian or impulse noise. However, not all the methods are able to deal with images which are simultaneously corrupted with a mixture of Gaussian and impulse noise. A Noble Cluster Averaging technique [6] is presented to remove the combination of both the noise. The Noble cluster is defined as a fuzzy set that takes a noble group as support set and where the membership degree of each noble group will be given by fuzzy similarity with respect to the pixel under processing. But, this approach does not provide a completely satisfactory representation of the peer groups. CAFSM (Cluster Based Adaptive Fuzzy Switching Median) filter [7] is capable of filtering all kinds of impulse noise. The center weighted median filter, which a weighted median filter, is giving more weight only to the central value of each window. This filter can preserve image details while suppressing additive white and/or impulsive-type noise. The noise density ranges from 5% to 50%. It can work on greyscale images of size 512*512. The no. of iterations by CAFSM filter does not exceed 4 iterations. The fixed size of window 3*3 is used in detection phase.

A Hybrid filter [8] is a combination of wiener filter, median filter and novel adaptive Neuro fuzzy inference system (ANFIS). The noise is estimated through the proposed operator. ANFIS construct a fuzzy inference system whose membership value is tuned by a parameter using either by back propagation algorithm. It requires training parameter. This approach is suitable for impulse noise having a density of 15%. Another method for noise elimination is a Random Valued Impulse Noise (RIN) Model [9] from corrupted images. The model consists of two capabilities mainly: noise detection and pixel restoration. As compared to FIN (Fixed-valued Impulse noise) model, RIN (Random-Valued Impulse Noise) model, corrupted pixel can take any value within the dynamic range with equal probability. On the basis of the intensity value of the surrounding pixel, if a pixel is detected to be corrupted pixel then, this method is triggered to replace it. After this, the noise free pixels are restored by using Triangular-Based Linear Interpolation method. This requires training parameter. It can work on 256*256 pixels sized greyscale images. This method is more robust both at low and high noise density. But it increases the computational complexity.

In paper [10], presents two fuzzy filters for suppressing Gaussian noise as well as Impulse noise in color images. These filters are also capable of eliminating a mixture of these two noises. For eliminating the impulse noise, two filters are used one for the detection of noisy pixels along with the amount of noise by utilizing three membership functions: Large, Unlike and Extreme. The second filter makes use of relation between different color components of a central pixel and neighbourhood pixel so as to determine the weight. The average weight of the entire neighbourhood pixel helps to eliminate the Gaussian noise. It is noticed that the filtered image is somewhat blurred and the blurring is tolerable up to the impulse noise density of 15% and the Gaussian noise generated with $\sigma = 10$. In paper [11], presents a way to remove impulse noise only from highly corrupted digital images. This novel method has two stages. The first stage is to detect the impulse noise in the image. At this stage, based on only the intensity values, the pixels are roughly divided into two classes, which are "noise-free pixel" and "noise pixel". Then, the second stage is to eliminate the impulse noise from the image. At this stage, only the "noise-pixels" are processed. The "noise free pixels" are copied directly to the output image. The method adaptively changes the size of the median filter based on the number of the "noise-free pixels" in the neighbourhood. For the filtering, only "noise-free pixels" are considered for the finding of the median value. The results from this proposed method is that it can efficiently work on highly corrupted images, where the noise percentage is up to 95%. It can process the image of 1600*1200 size. This method does not require any training parameter. This method is adaptive because unlike other filters it does not fix the size of filtering window.

In paper [12], the first phase that is to identify pixels which are likely to be corrupted by noise by using adaptive center-weighted median filter and the second phase is to restore the noise candidates iteratively by using median filter based method. This method is used to remove random valued impulse noise only. It can work on 512*512 8-bit greyscale images. The size of the window is 3*3. It can restore the results for the 30% to 50% corrupted image. The idea behind is that both noise detection and restoration results carried out simultaneously.

Genetic-based Fuzzy Image Filter [13] (GFIF) is to remove additive identical impulse noise from highly corrupted images. The GFIF filter consists of a fuzzy number construction process, a fuzzy filtering process, a genetic learning process, and an image knowledge base. First, the fuzzy number construction process receives sample images as input or the noise-free image and then constructs an image knowledge base for the fuzzy filtering process. Second, the fuzzy filtering process contains a parallel fuzzy inference mechanism, a fuzzy mean process, and a fuzzy decision process to perform the task of noise removal. Finally, the genetic algorithms applied to adjust the parameters of the image knowledge base. GFIF results in a higher quality of global restoration. It can efficiently work with image size of 100*100 pixels. In this paper, they use trapezoidal function to adjust the parameter of fuzzy variable of fuzzy sets. In future, GFIF is used to process color images as well.

An Adaptive Two-Pass Rank Order Filter to Remove Impulse Noise in Highly Corrupted Images [14], when the noise rate is high, median filters cannot give satisfactory results. So, better approach is to apply the filter twice that's why it is called Two-Pass filtering approach. An adaptive process is used to detect irregularities present in an input image. This adaptive process selectively replaces some pixels changed by the first pass of filtering with their original observed pixel values. These pixels are then kept unchanged during the second filtering. In adaptive process, the second filter eliminates more impulse noise and restores some pixels that are mistakenly altered by the first filtering. So, the quality of a given image increases. The main aim is first, to remove more noise than in normally the case when the noise ratio is high. Another aim is to settle down or correct the mistakes that are made in the first pass of the filtering operations. The computational time of applying adaptive two-pass filtering is longer than one-pass filtering. In paper [15], propose a decision-based signal adaptive median filtering algorithm for removal of impulse noise. Noise detection is carried out in two stages: Noise candidate is first selected using the homogeneity level (Homogeneity level is defined for the pixel values based on their global and local statistical properties) and then refining process is carried out to eliminate false detection. The main issue of the decision-based filter lies in building a decision rule, or a noisy measure, that can differentiate the encrypted pixels from the corrupted on and searching for an optimal threshold value. In this paper, the value that is closed to the maximum and minimum in a filter window are discarded and the remaining average pixels ew are processed. If the difference between the center pixel and ew exceeds the threshold, the center pixel is replaced by ew otherwise, unchanged. This method leads to degrade the little bit quality of an image when the decision making scheme iteratively detects the corrupted image pixels. It uses 512*512 size images that are corrupted by 10%, 20% and 30% of impulse noise. In this, the filtering operation is selectively applied to the pixels that are classified as corrupted.

In paper [16], present a novel approach to the restoration of noise-corrupted image. This is accomplished through a fuzzy smoothing filter constructed from a set of fuzzy membership functions for which the initial parameters are derived in accordance with input histogram is incorporated with input statistics to adjust the initial parameters so as to minimize the discrepancy between reference intensity and the output of defuzzification process. The proposed filter has the benefits that it is simple and it assumes no a priori knowledge of specific input image, yet it shows superior performance over conventional filters (including MF) for the full range of impulsive noise probability. The experiment uses image size of 256*256 satellite picture corrupted by impulsive noise. The method estimated the histogram of the source image. After that configuring the membership functions using histogram statistics or setting the initial parameters of a set of fuzzy membership functions derived from the estimated histogram. This approach is suitable for the images having similar statistics. If an image has different statistics, study on another functional optimization property of HFF comes into picture in near future. Another problem is to get a histogram of Gaussian noise. It can easily work with impulse noise only.

Another novel Noise Adaptive Soft-Switching Median (NASM) Filter [17] to achieve much improved filtering performance in terms of efficiency in removing impulse noise and robustness against noise density variation ranges from 10% to 70%. NASM filter contains a switching mechanism to identify each pixel's characteristic, followed by invoking proper filtering operation as outlined. In noise detection scheme, global or local pixel statistics are utilized in the first and the remaining two decision making levels, respectively. Most of the true pixels are successfully identified as "encrypted pixels" in the first decision-making level. Other remaining unidentified pixels will be further discriminated in the remaining two decision levels as "isolated impulse noise", "non-isolated impulse noise" or "edge pixel". Now, the concept of fuzzy is exploited in the latter stag for soft switching. In filtering scheme, does not filter those identified encrypted pixels. The isolated impulse noise possesses the intensity which is relatively higher or lower that of its neighbouring samples. Non-isolated noise refers to the pixel that belongs to a noise blotch; whereas, edge pixel is imply a true pixel that falls on the edge of an image object. The isolated impulse noise, Non-isolated impulse noise is filtered by standard median filter whereas, edge pixel is filtered by the fuzzy weighted median filter. The experiment uses 512*512 size of input image. The input image is processed on the basis of the noise from which an input image is full. After that, noise is estimated by applying the filter.

Other filter such as Multi-dimensional Weighted Fuzzy Mean (MWFM) filter [18] used in color image restoration. MWFM is the extensions of Weighted Fuzzy Mean (WFM) filter because MWFM is used to overcome the drawback of WFM by adding a fuzzy detector has the responsibility of evaluating the amplitude of impulse noise and the dynamic selection procedure so to overcome the problem of fine signal structure preservation. It can work smoothly when the noise density exceeds 50%. In paper [19], SD-ROM Filter is an efficient nonlinear algorithm to suppress impulse noise from highly corrupted images while preserving details and features. The method is applicable to all impulse noise models both fixed valued (equal height or salt and pepper) impulses and randomly valued (unequal height) impulses, covering the whole dynamic range. The algorithm is based on a detection-estimation strategy. If a signal sample is detected as a corrupted sample, it is replaced with an estimation of the true value, based on neighbourhood information. Otherwise it is kept unchanged. The technique achieves excellent suppression of noise and preserving the details and edges. This method works efficiently on highly corrupted images and removes impulse noise only.

In paper [20], the center weighted median (CWM) filter, which is a weighted median filter giving more weight only to the central value of each window. This filter can preserve image details while suppressing additive white and/or impulsive-type noise. It is shown that the CWM filter can outperform the median filter. In WM (weighted median) filter gives more weight to some values within the window. In order to improve CWM filter, a new adaptive CWM filter having a variable central weight is proposed. This method works only on removing impulse noise as well as additive white noise only. It can work with image of size 256*256. It can enhance the images corrupted by signal independent noise or signal dependent noise. It is clearly seen in this paper that the ACWA (Adaptive center weighted average) filter cannot suppress impulses while the others can.

## VI. Conclusion

In this paper, there are so many algorithms that are used to remove so many types of noises from the corrupted images. In this paper, the purpose of using all these filters offers well line, edge, detail and texture preservation while, at the same time, effectively removing noise from the given input image. For filtering any image, there are three aspects in image denoising are important that merit our attention. First, the accuracy of the noise detection is a very important factor. Second, the computational efficiency is also an important factor to the denoising filters because in the real-time work, the filters with lower computational efficiency may not obtain the satisfactory results. Finally, large uncertainties exist in the noise. Some filters can use fuzzy reasoning to deal with the uncertainty present in the local information. These filters provide better performance as compared to other filters based on the criteria of Mean Absolute Error and Mean Square Error. Although all the above filters are either eliminating impulse noise or Gaussian noise, work with either highly corrupted images or low corrupted images, work with color images or grayscale images. However, we can improve the performance of all the above filters and these extensions will be given in our forthcoming papers.

## References

1. ”Digital Image Processing” R. C. Gonzalez and R. E. Woods, 2nd Ed., Englewood Cliffs, Nj: Prentice Hall, 2002.
2. ”Digital Image Processing” S Jayaraman, S EsaKkirajan, T VeeraKumar, Tata McGraw Hill, 2009.
3. A novel approach to noise reduction for impulse noise and Gaussian noise” P. Krishnapriya, Mr. S. Sanjeev Kumar, IJETAE, International Conference on Information Systems and Computing, vol.-3, January 2013.
4. Cognition and Removal of Impulse Noise with Uncertainty” Zhe Zhou, IEEE Transactions on Image Processing, Vol. 21, No. 7, July 2012.
5. “Noise Adaptive Weighted Switching Median Filter for Removing High Density Impulse Noise” Madhu S. Nair and P.M. Ameera Mol, ACC 2011, Part III, CCIS, pp. 193-204,2011. Springer-Verlag Berlin Heidelberg 2011.
6. ”Non Linear Algorithm for Removal of Mixed Gaussian Noise and Impulse Noise Using Fuzzy Filters” P. Venkatesan and G. Nagarajan, ICCCI 2011, January 11-12, 2011.
7. ”Cluster-Based Adaptive Fuzzy Switching Median Filter for Universal Impulse Noise Reduction” Kenny Kal Vin Toh, Student Member, IEEE, and Nor Ashidi Mat Isa, Member, IEEE. IEEE Transactions on Consumer Electronics, Vol. 56, No. 4, November 2010.
8. ”A Hybrid Filter based on an adaptive neuro-fuzzy inference system for efficient removal of impulse noise from corrupted digital images” Zhang Lei, Song Hongxun, IEEE 2nd Conference on Environmental Science and Information Application Technology, 2010.
9. “Removal of Random-Valued Impulsive Noise” Pinar Civicioglu, Contributed Paper Manuscript received August 26, 2009.
10. ”Fuzzy Filters for Noise Reduction in Color Images” Om Prakash Verma, Madasu Hanmandlu, Anil Singh Parihar and Vamsi Krishna Madasu, ICGST-GVIP journal, Vol.9 Issue 5, September 2009.
11. “Simple Adaptive Median Filter for the Removal of Impulse Noise from Highly Corrupted Images” Haidi Ibrahim, Member, IEEE , Nicholas Sia Pik Kong, Student Member, IEEE, and Theam Foo Ng, IEEE Transactions on Consumer Electronics, Vol. 54, No. 4, November 2008.
12. ”An Efficient Method for Removing Random-Valued Impulse Noise” Jianjun Zhang, Qin Wang, IEEE 2008.

 

13. "Genetic-Based Fuzzy Image Filter and Its Application to Image Processing" Chang-Shing Lee, Shu-Mei Guo, and Chin-Yuan Hsu, IEEE Transactions on Systems, Man, and Cybernetics—part b: cybernetics, vol. 35, no. 4, August 2005.
14. "Adaptive Two-Pass Rank Order Filter to Remove Impulse Noise in Highly Corrupted Images" Xiaoyin Xu., IEEE Transactions on Image Processing, Vol. 13, No. 2, February 2004.
15. "Selective Removal of Impulse Noise based on Homogeneity Level Information" Gouchol Pok, Jyn-Charn Liu and Attoor Sanju Nair, IEEE Transactions on Image Processing, Vol. 12, No. 1, January 2003.
16. "Histogram-Based Fuzzy Filter for Image Restoration" Jung-Hua Wang, Wen-Jeng Liu, and Lian-Da Lin,, IEEE Transactions on Systems and Cybernetics, vol. 32, no. 2, April 2002.
17. "Noise adaptive Soft-Switching Median Filter" H. I. Eng and K. K. Ma, IEEE Trans. Image Process., vol. 10, no. , pp. 24-251, Feb. 2001.
18. "Multi-dimensional WFM Filter" Chang-Shing Lee and Yau-Hwang Kuo, An application to color Image Restoration," IEEE Trans., 1996.
19. "A Signal Dependent Rank Ordered Mean Filter.A new Approach for Removal of Impulses from Highly Corrupted Images" E. Abreu and S.k. Mitra, IEEE 1995.
20. "Center weighted median filters and their applications to image enhancement" S. J. Ko and S. J. Lee, IEEE Trans. Circuits Syst., vol.15, no. 9, pp.-984-993, Sep. 1991.


**ISSN: 2321-7782**