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Review of Image Restoration Technique by using Impulsive Noise Filters

Neeraj Vishwakarma
Research scholar in Computer Science & Engineering Department, Radharaman Institute of Science & Technology, Ratibad, Bhopal, Madhya Pradesh, India

Prof. Shivank Kumar Soni
Assistant Profeser in Computer Science & Engineering Department, Radharaman Institute of Science & Technology, Ratibad, Bhopal, Madhya Pradesh, India

Prof. Anurag Jain
Head of Computer Science & Engineering Department, Radharaman Institute of Science & Technology, Ratibad, Bhopal, Madhya Pradesh, India

Abstract— Image from various sources may be corrupted either during its transmission phase or in the acquisition phase. This cause the poor visibility and corruption in the significant pixels. Amongst all categories of noise, impulse noise is more frequent in nature. The impulse noise is further classified in to two categories: first one is salt and pepper noise and second is random value impulse noise. So many methods have been suggested to remove the impulsive noise using the non-linear filtering. Ideas are also given to detect this noise before the filtering. As seen, the performances of such filters are solely dependent upon the detection of corrupted pixels in the image. In this paper, the impulsive noise along with their detection and filtering methods has been reviewed and their performances have been discussed with respect to PSNR (peak signal to noise ratio).

Keywords— MSM, TSM, PWMAD, SDROM, DWM. Etc.

I. INTRODUCTION

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 a digital image. The field of digital image processing refers to processing digital images by means of a digital computer. Digital image is collection of a finite number of elements, each of which has a particular location and value. These elements are known an image essentials, picture elements or pixels. We can also state that an image is a two dimensional array, which can be manipulated during several techniques, like, convolution edge detection, mathematics, trend removal, filters, and image analysis. An image can be processed optically or digitally with a computer. The whole process of image and its analysis starting from the receiving of visual information to the giving out explanation of the scene, may be divided into three major stages, which are also considered as major sub-areas, and are given below:

- **a. Discretization and representation:** Converting visual information into a discrete form, appropriate for computer processing, approximating of visual information to save storage space as well as time requirement in consequent processing.
- **b. Processing:** Improving image quality by using filtering etc. compressing data to save storage and channel capacity during transmission.
- **c. Analysis:** Extracting image features, quantifying shapes, registration and recognition. In the initial stage, the input is a scene (visual information), and the output is corresponding digital image.

1. Noise Models

Unwanted data which may reduce the contrast each imaging system suffers with a common problem of “Noise”. Unwanted data which may reduce the contrast failing the shape or size of objects in the image and blurring of edges or dilution of fine details in the image may be termed as noise .it may be due to one or more of following reasons:

- a) Physical nature of the system.
- b) Shortcoming of image acquisition devices.
- c) Image developing mechanism.
- d) Due to environment.

2.1 Impulse Noise

In general terms Impulse Noise (IN) can be defined as intensity value of a single pixel, corrupted by any means and value of signal pixel can be dark or bright spots that are not authentic imagery. Or Impulse noise may corrupt any signal including digital images just due to occasional inversion of a single bit representing the intensity value in some pixel

The general model of impulse noise is

$$g(x,y)=\begin{cases} p_n, \eta(x,y) \\ 1-p_n, f(x,y) \end{cases}$$

Where p_n is the probability of distortion ($p_n * 100$ in percents is called the corruption rate) , $\eta(x, y)$ Noise gray level at location x,y.

Impulse noise can be classified mainly in two categories namely as.

- Salt and pepper noise (SPN).
- Random value impulse noise (RVIN).

2.1.1. Salt and Pepper Noise Model

It is also called impulse noise, shot noise, or binary noise This degradation can be caused by sharp, unexpected disturbances in the image signal; its appearance is randomly scattered white or black (or both) pixels over the image. The salt-and-pepper noise are also called shot noise, impulse noise or spike noise that is typically caused by faulty memory locations, broken pixel elements in the camera sensors, or there can be timing errors in the process of digitization .In the salt and pepper noise there are only two expected values exists that is a and b and the probability of each is less than 0.2.If the numbers greater than this numbers the noise will change out image. For 8-bit image the typical value for 255 for salt-noise and pepper noise is 0.

Salt-and-Pepper impulse noise replaces the intensity values in the image $f(x,y)$ by 0s and 255s with some certain probabilities

$$g(x,y)=\begin{cases} p_0, & 0 \\ p_{255}, & 255 \\ 1-(p_0+p_{255}), & f(x,y) \end{cases}$$

Since 0 is black and 255 is white, a corrupted image is covered by white and black impulses ("salt-and-pepper"),The corruption rate is $(p_0 + p_{255})\cdot 100\%$

Reasons for Salt and Pepper Noise*:*

a. By memory cell malfunction.
b. By faulty of camera's sensor cells.
c. By synchronization errors in image digitizing or communication.

2.1.2 Random valued impulse noise (RVIN)

Random value impulse noise (RVIN) also known as uniform noise is a type of noise in which pixel value can be closer to the neighbouring pixel value. RVIN is harder to detect and remove due to its characteristics.Random impulse noise replaces the intensity values in the image $f(x,y)$ by uniformly distributed random numbers with some certain probability.

$$g(x,y)=\begin{cases} p_n, & \eta(x,y)=random[\eta_{\min},\eta_{\max}] \\ 1-p_n, & f(x,y) \end{cases}$$

$\eta_{\min},\eta_{\max}$ are min and max intensities of impulses,The corruption rate is $p_n \cdot 100\%$

II. RELATED WORK

Previously there are many works take place in this field which is describe below

Firstly discuss about the **Tri-state median filter** in this they used the combination of standard median filter and center- weighted median filter. Here by the use of this combination it identify whether the image is corrupted or not. If image is corrupted than find its threshold level and removed the destroyed image or pixels by use this combination of filters.

Secondly discuss about the **RORD noise detector** which is combined with simple weighted mean filter which is make an effective algorithm where this combination used to remove random valued impulse at randomly. In this propose method they used an image as reference image and apply this combination and restoration take place.

Thirdly discuss about removal of random value impulsive noise. Here to remove this type of noise we used **Effective noise detector and a pixel-restoration operator**. By the use of this combination a highly performance filter is deign which is removed RIN (Relative intensity noise) of the image. RIN is a biggest problem of researcher for a long time because they destroy the pixels of an image.

Another discussion used of **recursive and adaptive median filter** which is used to remove high density impulsive noise. In this method a centered noisy pixels used which is work as center window if noise is not occur then we goes to another selected window or matrix. As we goes to next process if error not occur. Here they also make comparison this filter to another filter in the term of PSNR and IEF (image enhancement factor). Through this author achieve good result as compare to previous work.

Further discussion **adaptive non-local switching median (ANSM) detector** used for the high noise densities. Based on the ASWM or this ANSM, a two-phase scheme is presented to remove random-valued impulse noise whether the noise level is low or not. More exactly, in the first phase, the adaptive switching median filter or the adaptive non-local switching median filter is used to recognize the noise candidates. In the second phase, only the noise candidates' values are restored by the edge-preserving regularization method. Simulation results show that the proposed two-phase scheme is considerably better to some of the state-of-the-art methods both visually and quantitatively with a noise level as high.

Final discussion on the **adaptive dual threshold median filter** which is used to remove random impulse value noise. In this method this filter is work on two stages which is noise detection and noise removal. For noise detection averaging based dual threshold method is used and for removal of noise simple median filter is used. By use of this the value of PSNR ratio is increased highly.

III. FILTERS

Filtering is an image processing is a foundation function that is used to complete many tasks such as interpolation noise, reduction and re-sampling. Filtering image data is a standard process used in approximately all image processing systems. The alternative of filter is determined by the environment of the task performed by filter and performance and type of the data. Filters are used to eliminate noise from digital image while maintenance the details of image preserved is a required part of image processing.

3.1 Spatial Filtering

Spatial filtering is preferred when merely additive noise is present in an image. In spatial filtering, procedures are performed directly on the pixels of an image.

3.1.1 Basics of Spatial Filtering

A small-image also called a filter, kernel, mask, pattern or window, window is moved over an image from point to point and the result which is sum of products of filter coefficients and the equivalent image pixels in the area spanned by the filter mask is calculated as:

$$S=w1x1+ w2x2+...+ wmnxmn.$$

$$S= \sum_{i=1}^{mn} w_i x_i$$

Where *w* and *x* correspond to mask coefficients and image gray levels correspondingly and *mn* is the whole number of coefficients in the mask. In spatial filtering, there are three major classes of filters for noise removal.

1. Smoothing Filters/ Average
2. Order-Statistic/s Filters
3. Adaptive Filters

A. W1	*B.* W2	*C.* W3
D. W4	*E.* W5	*F.* W6
G. W7	*H.* W8	*I.* W9

Fig.: A 3X3 Spatial Filter Mask

3.1.2 Average / Smoothing Filters

Average or Smoothing filters are used in reprocessing steps for reduction and noise blurring. Blurring removes small details from images earlier to object removal and bridges small gaps in curves or lines.

3.1.3 Arithmetic Mean Filter

Average of gray levels in the neighbourhood defined by filter mask is calculated and is replaced with each pixel in an image is defined as follows.

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t)$$

Where $\hat{f}(x,y)$ and g(s,t) are restored and noisy images respectively and Sxy represent the set of coordinates in a rectangular sub-image window of size m× n. Edges are the main features of an image and are usually represented by sharp details. This filter reduces noise and smoothes the local variation but also undesirable results for sharp details.

3.1.4 Geometric Mean Filter

This filter also smoothes the local variations other than it tends to suffer less image details as compared to arithmetic mean filter.

In the geometric mean technique, the color value of every pixel is replaced with the geometric mean of color values of the pixels in a nearby region. A larger region (filter size) yields a stronger filter effect with the disadvantage of some blurring.

The geometric mean is defined as:

$$\hat{f}(x,y) = \left(\prod_{(s,t)\in S_{sy}} S(s,t) \right)^{\frac{1}{mn}}$$

The geometric mean filter is enhanced at removing Gaussian type noise and preserving edge description than the arithmetic mean filter. The geometric mean filter is extremely vulnerable to negative outliers.

3.1.5 Harmonic Mean Filter

This filter is well cortege for *salt* and *Gaussian* or uniform noise in the image excluding it fails for *pepper* noise.

In the harmonic mean mode, the color value of each one pixel is replaced with the harmonic mean of color values of the pixels in a contiguous region.

The harmonic mean is defined as:

$$\hat{f}(x,y) = \frac{mn}{\sum_{(s,t)\in S_{xy}} \frac{1}{g(s,t)}}$$

A well-built region (filter size) yields a stronger filter effect with the problem of some blurring. The harmonic mean filter is better at removing Gaussian manner noise and preserving edge sort than the arithmetic mean filter. The harmonic mean filter is incredibly good at removing positive outliers.

3.1.6 Contra-harmonic Mean Filter

This filter works fine for conquering the effects of impulse noise as well as for *salt and pepper'* noise.

$$\hat{f}(x,y) = \frac{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q}}$$

where Q is the order of the filter With positive Q eliminates pepper noise , while with negative Q Eliminates salt noise With Q=0 reduces to the arithmetic mean filter, and with Q=1 – to the harmonic mean filter

3.17 Order-Statistics Filters

Order-statistics filters are well suited non-linear spatial filter as compared to linear filters. A filter of this class is based on ordering (ranking) of gray levels in the neighborhood defined by filter mask. The best known example in this category is *median filter*.

3.1.8 Median Filter

Median Filter is best known order-statistics filter among excellent noise reduction capabilities and also very efficient for uni-polar and bi-polar impulse noise. It exchanges the value of a pixel by the median of the gray levels in the neighborhood of that pixel and can be shows as

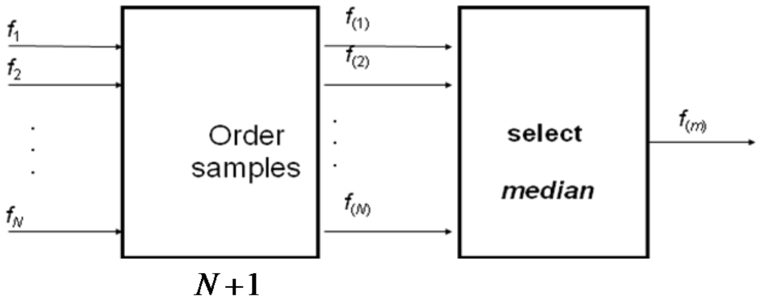
Median filter replaces an intensity value in each pixel by a local median taken over a local n x m processing window:

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\}$$

Where S_{xy} is a local m x n window around the pixel (x,y) in the image g (to be processed), and MED is the median value taken over the window S_{xy} .To implement the median filter with an n x m processing window, it is necessary to build a variational series from the elements of the processing window S_{xy} around the pixel (x,y) (to be processed) The central element of the variational series is the median of the intensity values in the S_{xy} window. Median filter is highly efficient for impulse noise filtering.Median filter with 3x3 window can almost completely remove impulse noise with the corruption rate up to 30% Applied iteratively, it can remove even noise with a higher corruption rate.

Median filter removes impulse noise, but it also smoothes (“washes”) all edges and boundaries and may “erase” all details whose size is about n/2 x m/2, where n x m is a.

window size.As a result, an image becomes “fuzzy” Median filter is not so efficient for additive Gaussian noise removal, it yields to linear filters.



$$m = \frac{N+1}{2} \qquad f_{(1)} \le f_{(2)} \le f_{(3)} \le \cdots f_{(N)}$$

N is odd

Fig.- Median filter

3.1.9 Max and Min Filter

Max filter is useful in finding the brightest points and removing *pepper* noise while the Min filter helps in finding the darkest points and removing *salt* noise in an image.

Max Filter:

$$\hat{f}(x,y) = \max_{(s,t)\in S_{xy}} \{g(s,t)\}$$

Min Filter:

$$\hat{f}(x,y) = \min_{(s,t)\in S_{xy}} \{g(s,t)\}$$

Max filter is good for pepper noise and min is good for salt noise

3.1.10 Midpoint Filter

This filter is a mixture of order-statistics and averaging filter. This filter performs Well for randomly distributed, Gaussian or uniform noise. In the midpoint means, the color value of every pixel is replaced with the average of maximum and minimum (i.e. the midpoint) of color values of the pixels in a immediate region. A larger region (filter size) yields a stronger effect. The midpoint filter is in general used to filter images containing short tailed noise such as Gaussian and uniform type noise.

$$\hat{f}(x,y) = \frac{1}{2}\left[\max_{(s,t)\in S_{xy}} \{g(s,t)\} + \min_{(s,t)\in S_{xy}} \{g(s,t)\}\right]$$

It is Good for random Gaussian and uniform noise

3.1.11 Adaptive Filters

The filters discussed so far are applied to an entire image without any regard for how image characteristics vary from one point to another. The behaviour of **adaptive filters** changes depending on the characteristics of the image inside the filter region. We will take a look at the **adaptive median filter.** The filters discussed so far are applied to an entire image without any regard for how image characteristics vary from one point to another. The behaviour of **adaptive filters** changes depending on the characteristics of the image inside the filter region. We will take a look at the **adaptive median filter.**The performance of adaptive filters is much better than smoothing and order-statistics filters. We can separate it into two categories.

3.1.12 Adaptive, Local Noise Reduction Filter

The adaptive filter is based on two parameters, mean and variance because these parameters are intimately related to the appearance of an image. Mean gives the compute of average gray level in the region over which mean is computed and the inconsistency gives measure of average contrast in that region. The behaviour of the filter is as follows.

1. If inconsistency is zero (zero noise), noisy image will be equal to restored image.
2. If local inconsistency is high then the filter returns a value close to noisy image and for high variance it ruins preserved.
3. If two variances are equal then restored image get the average value.

3.1.13 Adaptive Median Filter

This filter can handle impulse noise with larger probabilities and conserve the details while smoothing non-impulse noise. It has three major purposes:

1. Removes *salt and pepper* noise
2. Smoothing for non-impulse noise
3. Reduce distortion (Thing or thickening of object boundaries)

Many Filters are proposed to remove random-valued impulse noise; we will review a few of them.

3.1.14 Adaptive Centre-Weighted Median Filter (ACWM)

It devises a novel adaptive operator, which forms estimates based on the conflicts between the current pixel and the outputs of center-weighted median (CWM).filters by varied center weights. It employs the switching scheme based on the impulse detection mechanisms. It utilizes the center-weighted median filter that have varied center weights to describe a more common operator, which realizes the impulse detection by using the differences defined among the outputs of CWM filters and the current pixel of concern. The crucial output is switched between the median and the current pixel itself.

3.1.15 Multi-State Median Filter (MSM)

It proposes a popularize framework of median based switching schemes, called multi-state median (MSM) filter. By using simple thresholding logic, the output of the MSM filter is adaptively switched through those of a group of center weighted median (CWM) filters that have different center weights. The MSM filter is corresponding to an adaptive CWM filter with a space varying center weight which is dependent on local signal statistics.

3.1.16 Tri-State Median Filter (TSM)

It is proposed used for preserving image details whereas effectively suppressing impulse noise. It incorporates the standard median(SM) filter and the center weighted median (CWM) filter into a noise detection framework to determine whether a pixel is corrupted, before applying filtering unconditionally. Noise detection is realized by an impulse detector, which takes the outputs from the SM and CWM filters and compares them with the origin or center pixel value in order to make a tri-state decision. The switching logic is controlled by a threshold.

The threshold affects performance of impulse detection. An attractive merit of the TSM filter is that it provides an adaptive decision to detect local noise merely based on the outputs of these filters.

3.1.17 Advanced Impulse Detection Based on Pixel-Wise MAD (PWMAD)

It is a robust estimator of variation, MAD (median of the absolute deviations from the median), is modified and used to efficiently tear noisy pixels from the image details. The algorithm is complimentary of varying parameters, requires no previous training or optimization, and successfully removes all form of impulse noise. The pixel-wise MAD thought is straightforward and low in complexity. The median of the complete deviations from the median-MAD is used to estimate the presence of image details, thus provided that their efficient parting from noisy image pixels. An iterative pixel-wise variation of MAD (PWMAD) provides reliable removal of randomly distributed impulse noise.

3.1.18 Signal-Dependent Rank Order Mean (SDROM) Filter

It is a new framework for removing impulse noise from images, in which the nature of the filtering method is conditioned on a state variable separate as the output of a classifier that operates on the differences with the input pixel and the residual rank-ordered pixels in a sliding window. First, a simple two-state approach is described in which the algorithm switches between the output of an independence filter and a rank-ordered mean (ROM) filter. The technique achieves an outstanding trade-off between noise suppression and feature preservation with tiny increase in computational complexity over the simple median filter. For a small complementary cost in memory, this simple strategy is only generalized into a multistate approach by weighted. Combinations of the identity and ROM filter in which the weighting coefficients preserve be optimized using image training data. Furthermore, the method can efficiently return images corrupted with Gaussian noise and mixed Gaussian and impulse noise.

3.1.19 Directional Weighted Median Filter (DWM)

Another method for elimination of random-valued impulse noise is directional weighted median filter (DWM). This filter uses a new impulse detector, which is based on the differences between the recent pixel and its neighbours associated with four main directions. After impulse detection, it does not basically replace noisy pixels identified by outputs of median filter but continue to utilize the information of the four directions to weight the pixels in the window in instruct to preserve the details as removing noise. First it considers a 5X5 window. Now it considers the four directions: horizontal, vertical and two diagonal. Each direction there is 5 pixel points. It then calculates the weighted difference in each direction and takes the minimum of them. The minimum value is compared with a threshold value and if it is greater than the threshold value then it is a noisy pixel otherwise not. In filtering phase, it calculates the standard deviation in four directions. Because the standard deviation describes how tightly all the values are clustered around the mean in the set of pixels shows that the four pixels aligned with this direction are the closest to each other. Therefore, the center value should also be close to them. Now it calculates the weighted median, giving extra weight on that direction in which direction standard deviation is small and replaces the noisy pixel with this median value. It is an iterative method. This method repeats 8 to 10 times. It gives the good performance when noise level is high too.

IV. COMPAROSION

Table 1 Lena image

Methods	*Noise density 20%*	*Noise density 30%*	*PSNR 40%*	*PSNR 50%*
SM	*33.35*	*23.56*	*19.19*	*13.23*
TSM	*35.01*	*19.91*	*15.53*	*12.84*
MSM	*27.16*	*27.26*	*33.15*	*33.26*
EPRIN	*21.55*	*21.25*	*22.15*	*22.16*
DERIVATIONAL	*21.59*	*21.61*	*21.66*	*2165*
ADTM	*35.30*	*35.31*	*33.09*	*28.39*

Table 2 Baboon image

Methods	*Noise density 20%*	*Noise density 30%*	*PSNR 40%*	*PSNR 50%*
SM	*22.689*	*21.773*	*20.164*	*20.164*
PWMAD	*23.513*	*20.933*	*16.494*	*18.675*
TSM	*16.228*	*16.098*	*18.010*	*16.128*
MSM	*22.046*	*20.036*	*21.816*	*16.151*
EPRIN	*21.473*	*21.914*	*21.091*	*21.091*
DERIVATIONAL	*21.678*	*21.336*	*21.091*	*20.772*

Table 3 Bridge image

Methods	*Noise density 20%*	*Noise density 30%*	*PSNR 40%*	*PSNR 50%*
SM	*25.365*	*23.726*	*22.211*	*20.932*
PWMAD	*23.578*	*21.130*	*18.609*	*16.499*
TSM	*16.668*	*16.627*	*16.711*	*16.617*
MSM	*24.184*	*21.137*	*18.665*	*16.557*
EPRIN	*24.578*	*23.932*	*22.588*	*22.938*
DERIVATIONAL	*24.258*	*23.784*	*23.284*	*22.652*
ADTMF	*38.091*	*39.671*	*31.450*	*29.150*

V. CONCLUSION

In this paper, various filtering techniques for the removal of random impulsive noise have been discussed. As seen, complex procedures remove noise satisfactorily but at higher cost, while simple noise is not effective under multifaceted noisy environment condition. It is seen that, all the effective filtering depend on the detecting procedure of noise. The detection of corrupt pixels heavily depends upon the statistical parameter such as mean, variance, standard deviation and thresholds selection rules. Also, it is seen that, some techniques are ineffective if the noise density exceeds above 40%. In this paper, some filtering algorithms are compared with respect to PSNR and noise density. In future one can extends the work to reduce the false and miss detection count to improve the detector capability.

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