Noise Exclusive Adaptive Mean Filter using Global Characteristic for Removal of Impulse Noises from Images

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ABSTRACT
Removal of noises from the images is a critical issue in the field of digital image processing. This paper describes a new technique for the design of noise exclusive adaptive mean filter using global characteristic for removal of impulse noises efficiently from images, aimed at removing the impulse noise (salt and pepper noise) from the image and reducing distortion in the image while preserving image details. This filter solves the dual purpose of removing the impulse noise from the image and reducing distortion in the image. It can achieve the filtering operation of an image corrupted with impulse noise up to 70%. This proposed technique provides much better results than that of the existing mean and median filtering techniques. The Peak Signal to Noise Ratio (PSNR) of the filtered image using the proposed technique is much higher than that of the filtered images obtained by the existing mean filtering techniques. Extensive experimental results show that the proposed technique performs significantly better than many existing state-of-the-art algorithms. Due to its low complexity, the proposed algorithm is very suitable for hardware implementation. Therefore, it can be used to remove impulse noise in many consumer electronics products such as digital cameras and digital television (DTV) for its performance and simplicity.

Key Words
Image Denoising; Tolerance Value, Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE;) Mean Square Error (MSE); Peak Signal To Noise Ratio (PSNR); Adaptive Filter;

1. INTRODUCTION
Noise, unwanted information to contaminate an image, occurs from a number of sources. While transmitting through sensors and communication channels, image may very often get contaminated by noise. As a result of this interference of noise, the results of some processing like edge detection, image segmentation, data compression and object recognition are affected. Hence, before dealing with other image processing, it is of vital importance to restore the image or filter it. The Linear Filter has poor performance in the presence of noise that is not additive. If a signal with sharp edges is corrupted by high frequency noise, however, in some noisy image data, the linear filters, designed to remove the noise, also smooth out signal edges. In addition, impulse noise can not be reduced sufficiently by linear filters. As already known, signals are not linear in nature. Generally, when the filters are not linear, they show better performance than when they are linear in the removal of impulse noise from the image. The salt and pepper type noise occurs when the picture elements in the camera sensors do not function well or error in the memory location or during digitization process. A non linear scheme is called median filtering with success in this situation [1].

There are a good number of algorithms based on various filtering techniques, available at present, to recover the original image from its noise. Some filtering techniques perform better subject to the types of noise[2].
Most of these filtering techniques assume the presence of salt and pepper type of impulse noise. The detection of salt and pepper type of noise is relatively easy as there are only two intensity levels i.e. 0 or 255 in the noisy pixels. However, the study reveals that in case of uniformly distributed impulse noise, these techniques do not perform well. In this paper a new algorithm is presented which improves the performance of switching median filter as a result of efficient detection of impulse noise when the impulse amplitude is uniformly distributed [3].

In traditional median filtering [2] called standard median filter (SMF), the filtering operation is performed across to each pixel without considering whether it is uncorrupted. So, the image details, contributed by the uncorrupted pixels are also subjected to filtering and as a result the image details are lost in the restored version. To alleviate this problem, an impulse noise detection mechanism is applied prior to the image filtering. In switching median filters [7,8] a noise detection mechanism has been incorporated so that only those pixels identified as “corrupted” would undergo the filtering process, while those identified as “uncorrupted” would remain intact. The progressive switching median filter (PSMF) [4] was proposed which achieves the detection and removal of impulse noise in two separate stages. In first stage, it applies impulse detector and then the noise filter is applied progressively in iterative manners in second stage. In this method, impulse pixels located in the middle of large noise blotches can also be properly detected and filtered. The performance of this method is not good for very highly corrupted image. Nonlinear filters such as adaptive median filter (AMF) [5] can be used for discriminating corrupted and uncorrupted pixels and then apply the filtering technique. Noisy pixels will be replaced by the median value, and uncorrupted pixels will be left unchanged. AMF performs well at low noise densities but at higher noise densities, window size has to be increased to get better noise removal which will lead to less correlation between corrupted pixel values and replaced median pixel values. An efficient decision-based algorithm (DBA) was proposed [6] using a fixed window size of 3×3, where the corrupted pixels are replaced by either the median pixel or neighborhood pixels. It shows promising results, a smooth transition between the pixels is lost with lower processing time which degrades the visual quality of the image.

Most of the schemes discussed above use a fixed window size and median value for noise filtering. The window size is larger in high density impulse noise and smaller in low density noise. Use of fixed window size for noise filtering in digital image is an unrealistic assumption, because in real time applications the percentage of corruption is unknown. Filtering each and every pixel of a high density noisy image with a fixed large window, without the knowledge of number of non-noisy neighboring pixel, not only produce distortion but also takes more execution time. So a scheme of dynamic window size must be adopted for a test pixel based on the density of corruption in its neighboring pixels. The optimal window size for filtering is selected based on the presence of non-noisy neighbors in the window. In this paper, we propose a Noise Exclusive Adaptive Mean Filter (NEASMF) for removing high density salt and pepper noise. This scheme only filters the pixels, those are having distance from the mean of its non noisy neighbours defined by the selected sub-window exceeds a threshold value. The histogram plot of the noisy image is used for detection of the non noisy neighbours in a sub-window .At the beginning of the filtering process; the scheme decides the window size for the test pixel locally and is adaptive due to the selection of a proper window size during run time. As the non-noisy neighbors of the pixel in the current window is used for filtering, we are using a mean filter instead of a median filter which can work better both in low as well as high density noise.

This paper is organized as follows. The section-2 discusses the types of noise and its model, the section 3 presents the performance measures, section-4 proposed technique, section-5 presented the simulation and result. Finally, section 6 concluded about the paper.

2. TYPES OF NOISE AND ITS MODEL

Generally, image is affected by different types of noise. The most common types of noise encountered, in image are Impulse noise, Gaussian noise and the combination of both called mixed noise [20]. Impulsive noise can be classified as salt-and-pepper noise (SPN) and random-valued impulse noise (RVIN)[1, 2, 3, 5]. An image containing impulsive noise can be described as follows:

$$x(i,j) = \begin{cases} \eta(i,j)\ with\ \ probability\ \ \ p \\ y(i,j)\ with\ \ probability\ 1-p \end{cases} \qquad (1)$$

$x(i,j)$ denotes a noisy image pixel, $y(i,j)$ denotes a noise free image pixel and $\eta(i,j)$denotes a noisy impulse at the location(i,j). In salt-and-pepper noise, noisy pixels take either minimal or maximal values i.e. $\eta(i,j) \in \{L_{min}, L_{max}\}$ and for random-valued impulse noise, noisy pixels take any value within the range minimal to maximal value i.e. $\eta(i,j) \in [L_{min}, L_{max}]$, where L_{min}, L_{max} denote the lowest and the highest pixel luminance values within the dynamic range respectively. So that it is little bit difficult to remove random valued impulse noise rather than salt and pepper noise [3]. The main difficulties, which have to face for attenuation of noise, is the preservation of image details. Figure-1 may best describe the difference between SPN and RVIN. In the case of SPN the pixel substitute in the form of noise may be either$L_{min}\,(0) or L_{max}\,(255)$. Where as, in RVIN situation it may range from $L_{min}\,to L_{max}$. Cleaning such noise is far more difficult than cleaning fixed-valued impulse noise since for the later, the differences in gray levels between a noisy pixel and its noise-free neighbours are significant most of the times. In this paper, we focus only on salt-and-pepper noise and schemes are proposed to eliminate such noises.

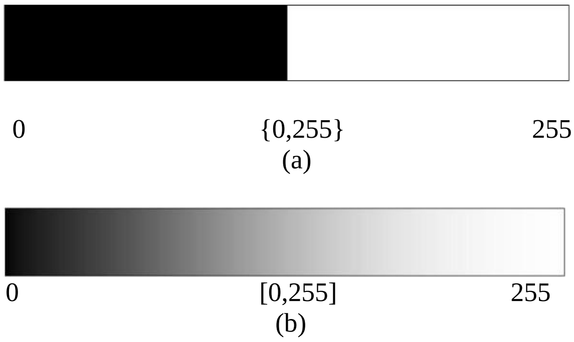


Figure 1: Representation of (a) Salt & Pepper Noise with $R_{i,j} \in \{n_{min}, n_{max}\}$ (b) Random Valued Impulsive Noise with $R_{i,j} \in [\,n_{min}, n_{max}\,]$

3. PERFORMANCE MEASURES

There are basically two classes through which we can measure the performance and quality of an image. These are Objective quality and the Subjective or Qualitative or Distortion measure. The metrics used for performance comparison among different filters are defined below[1,2,3,5]:

1) *Mean Squared Error (MSE) And Mean Absolute Error*

In statistics, the mean squared error or MSE of an estimator is one of many ways to quantify the amount by which an estimator differs from the true value of the quantity being estimated. Here, it is just used to calculate the difference between an original image with a restored image. Given that original image $X$of size $(M \times N)$ pixels and as reconstructed image $\hat{X}$, the MSE is defined as:

$$\mathbf{MSE} = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (\boldsymbol{X_{i,j}} - \boldsymbol{\hat{X}_{i,j}})^2 \qquad (\mathbf{2})$$

$$MAE = \frac{1}{MN} \sum_{ij} |X_{ij} - \hat{X}_{ij}| \qquad (3)$$

2) *Peak Signal to Noise Ratio (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. Reconstructed images with higher PSNR are judged better. Given that original image X of size $(M \times N)$ pixels and as reconstructed image$\hat{X}$, the PSNR (dB) is defined as:

$$PSNR(dB) = 10\ log_{10} \left(\frac{255^2}{MSE} \right) \qquad (4)$$

4. PROPOSED METHOD

The noise exclusive adaptive Mean filtering technique is modified by the introduction of two additional features. In the first phase, to detect the locations and values of impulse noise, the two peaks T1 and T2 occurred at two different places the histogram of the noisy image have been selected. In the second phase, the mean value of the selected pixels of the current window has been used for the replacement of the pixels. Initially the process chooses a 3x3 sub window and calculates the numbers of pixels whose values are lies within T1 and T2 and considered as non-noisy neighbours. If the number of such non-noisy neighbours pixels are equal or more than the window size then the mean of these pixels are taken and compared with the center or test pixel of the sub-window. Otherwise go for the next higher window size adaptively till the number of non-noisy neighbours pixels are greater than or equal to the current window size. If the center pixel divert from the mean value by a defined threshold T, it is considered as noisy and replaced by the mean value. The steps of the NEASMF algorithm are given below.

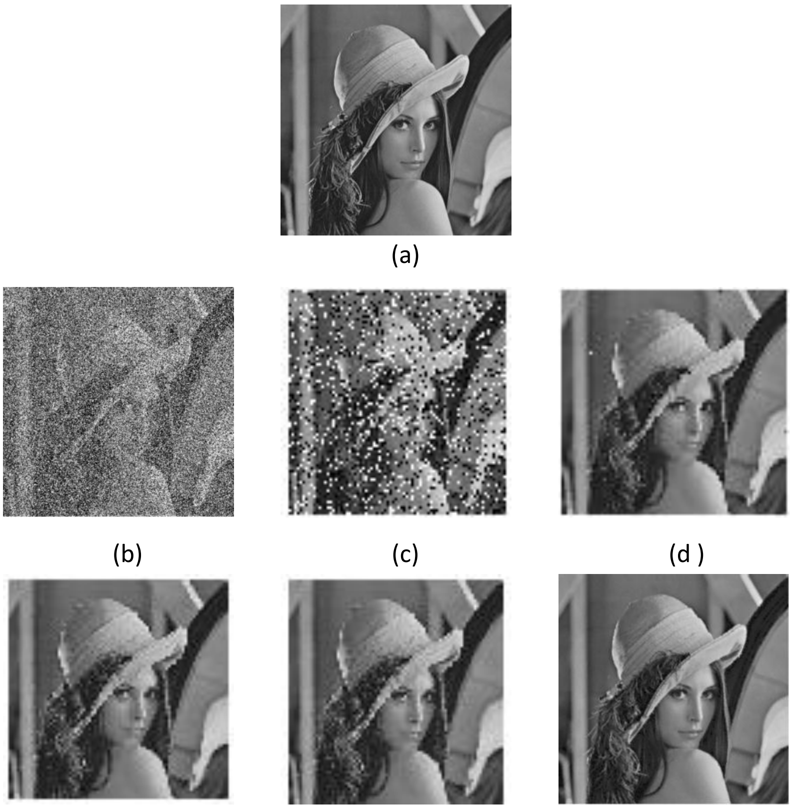
Algorithm- NEASMF	
Step 1.	Detect the locations and values of impulse noise based on the histogram of the noisy image
Step 2.	Initialize a sub-window size, $w = 3$
Step 3.	Find out all the pixels under sub-window which are lies between the two peak location of the histogram T1 and T2 respectively.
Step 4.	If the number of such pixels are greater than or equal to 'w' then find out the mean of these pixels; otherwise increase the size of the window to w= w+2 and go to step-3.
Step 5.	If the difference between the current pixel and the mean of its surrounding noise exclusive pixels is greater than a threshold T, then replace the current pixel by the mean value; otherwise(else) leave it and move to next pixel and go to step-2 .

4. SIMULATION AND RESULT

To validate the proposed scheme NEASMF, simulation has been performed on standard images, likes Lena, Boat of size 512×512. The images are subjected to as low as 10% noise density to as high as 95% noise density. The proposed scheme as well as the recently suggested few well performing schemes like SMF, PSMF, AMF, and DBA are applied to the noisy images. The simulation is carried out using MATLAB 7.0. There are basically two classes of metrics like Objective quality and the Subjective or Qualitative or Distortion measure through which performance measure and quality of restored image are evaluated to show the efficacy of the proposed scheme as compared to other standard and recently proposed schemes. The performance measures discussed above are used to prove the superiority of the proposed method.

The performance parameter values such as PSNR obtained after applying the various filters are compared by varying the noise density from 10% to 70% are shown in Table-1. From the quantitative values shown in the tables, it is very clear that NEASMF algorithm outperforms all other noise removal filters. Fig2 (a-f) shows the original Lena image, the image corrupted with 60% noise, and represent the processed images for SMF, AMF, PSMF, DBA and proposed method (NEASMF) respectively.

Noise Density (%)	PSNR (dB)				
	SMF	PSMF	AMF	DBA	NESAM
10	34.3624	36.8431	39.526	39.085	**39.8248**
20	29.5833	33.2382	34.868	36.595	**37.1055**
30	23.8910	30.9431	32.387	34.293	**35.3849**
40	19.0081	27.5024	30.243	32.259	**33.8307**
50	15.2828	26.2964	28.461	30.388	**32.4346**
60	12.2427	24.8570	26.833	28.458	**30.9630**
70	9.9588	20.9470	25.021	26.364	**29.4003**
80	8.1050	13.7021	23.291	23.794	**27.0644**
90	6.5740	7.7175	20.621	20.133	**23.6756**



(a) (b) (c) (d) (e) (f) (g)

Figure 6:Results of various filters for Lena image corrupted by 60% noise densities. (a) Original Lena image. (b) Noisy Image(c) Output of SMF. (d) Output of PSMF. (e) Output of AMF. (f) Output of DBA.(g) Output of NESAMF

5. CONCLUSION

In this paper, we propose a new adaptive switching mean filtering scheme, namely, NESAMF to recover images corrupted with salt and pepper noise. The filter works in two phases, namely, identification of corrupted locations followed by the filtering operation. The window size for any test pixel is selected adaptively. Subsequently, it applies the mean filter considering only the non-corrupted neighbours in the window. The mean value od such is used to replace the noisy pixel value. The performance of the algorithm has been tested at different noise densities on different standard grey scale images. The proposed scheme is evaluated both qualitatively as well as quantitatively. The comparative performance analysis in general shows that the proposed scheme outperforms the existing schemes both in terms of noise reduction and retention of images details at high densities impulse noise upto 70%.

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