A N_8(P) Detail Preserving Adaptive Filter For Impulse Noise Removal

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Abstract— **This paper proposes a N_8(p) detail preserving adaptive filter for impulse noise removal. Impulse noise degrade the digital images due to which these images cannot be used for high level processing. Thus, image restoration becomes important. In this paper an effective and efficient method of impulse noise removal is proposed which not only removes noise but also preserves image details. The algorithm first classifies all the pixels as noise and noise free based on its N_8(p) neighbours using averaging parameters introduced here and then replaces the noise pixels by the adaptive median of the pixel. The algorithm uses adaptive median as it provides better denoising and since the proposed algorithm performs prior classification of pixels as noise and noise free this preserves image details.**

Keywords— ***Image restoration, Impulse noise, $N_8(p)$, adaptive median filter.***

I. INTRODUCTION

Restoration of an image aims at improving the image in some predefined sense. Restoration recovers an image which has been degraded. Thus, it involves modeling the degradation and then applying a reverse phenomenon to recover the original image. The principal reason of degradation in images is noise. Noise arises during image acquisition and transmission, due to malfunctioning of imaging sensors mainly. The performance of imaging sensors is affected by a number of factors such as environmental conditions and the quality of sensing elements itself [1]. Salt-and-pepper impulse noise is one commonly encountered noise type during image and video communication [2]. Impulsive noises can be commonly found in the sensor or transmission channel during the acquisition and transfer procedure for the digital signals images. To remove impulsive noise nonlinear filter algorithms are mostly used [3]. The Standard Median (SM) filter is based on the statistic ordering is the most commonly used for this type of noise case. The SM filter is applied uniformly across the entire image, it modifies both noise and noise free pixels. This procedure is effective in low density noise cases but in high density it performs poorly as it loses a lot of image details and thus degrades the image. To overcome these shortcomings some improved median filter algorithms have been proposed such as Progressive Switching Median (PSM) filter [4], Extremum Median (EM) filter [5], Adaptive Median (AM) filter [6] and Weighted Median (WM) filter [7] and some other methods like those in [12, 13].These filters unlike the SM first classify the pixels as noisy and noise free pixels and then perform filtering only on the noisy pixels. These filters though perform better than the standard median filter yet suffer with some shortcomings like large computation time, poor denoising in high density noise, loss of image details, blurring of edges etc. The most serious problem is of losing image details and edge blurring in the denoising procedure. This paper presents a novel salt & pepper noise removal algorithm for grayscale images based on neighborhood averaging concept. In the proposed work the noise and noise free pixels are first discriminated by using averaging of N_8(p) neighbors along each direction as threshold and then the noise pixels are filtered out of the image by replacing them with the adaptive median of the pixel.

II.NOISE MODEL

Impulse noise is one common noise type in communications [8,9,10]. It is also known as salt and pepper noise. In this type of noise the noise has either maximum (I_{max}) or minimum value (I_{min}) of the image

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intensity range. An image X corrupted with impulse noise is formulated as

$$x_{i,j} = \begin{cases} n_{i,j}, with\ probability\ p, \\ s_{i,j}, with\ probability\ 1-p \end{cases} \quad (1)$$

where $n_{i,j} \in [I_{min}, I_{max}]$ is the noisy impulse at the location (i,j) , p represents the probability of noisy pixel , $n_{i,j}$, $s_{i,j}$ is the noise free pixel with probability 1-p. Impulse noise appears as salt and pepper granules randomly distributed over the image.

III. PROPOSED ALGORITHM

In this paper a novel algorithm based on neighborhood averaging for noise removal and detail preservation is proposed. The algorithm works in two stages the first stage identifies noise pixels by averaging parameters introduced in this work so that those points which seem to be noise points but are actually a part of the image are not replaced. The second stage performs filtering. The details of each stage are as follows:

1. Identification of salt pepper noise: A sliding window W_M of size M X M, where M = 2L + 1 centered at x_{ij} is used for detection of pixels as noise free and noise candidates. S is the set of noise free pixels and NC is the set containing noise candidate pixels,

$$x_{ij} \in \begin{cases} S \quad if \quad \min [W_M] < x_{ij} < \max [W_M] \\ NC \quad if \quad x_{ij} = \min[W_M]\ or\ x_{ij} = \max[W_M] \end{cases} \quad (2)$$

Once the noise candidates are identified they are separated from points which are a part of smooth regions that is those points that are maximum or minimum points but are not noise, for this four averaging parameters one in each direction, i.e., horizontal A_H, vertical A_V, main diagonal A_{MD} and auxiliary diagonal A_{AD} are calculated using the N_8(p) of a pixel. The N_8(p) of $x_{i,j}$ are shown in figure 1:

x(i-1,j-1)	x(i-1,j)	x(i-1,j+1)
x(i,j-1)	x(i,j)	x(i,j+1)
x(i+1,j-1)	x(i+1,j)	x(i+1,j+1)

Fig. 1 N_8(p) of a pixel.

$$A_H = \frac{1}{2}\sum_{i=1}^{2} \Delta_{ih} \quad (3)$$

where $\Delta_{1h} = |x_{i,j} - x_{i,j-1}|$ and $\Delta_{2h} = |x_{i,j} - x_{i,j+1}|$

$$A_V = \frac{1}{2}\sum_{i=1}^{2} \Delta_{iv} \quad (4)$$

where $\Delta_{1v} = |x_{i,j} - x_{i-1,j}|$ and $\Delta_{2v} = |x_{i,j} - x_{i+1,j}|$

$$A_{MD} = \frac{1}{2}\sum_{i=1}^{2} \Delta_{imd} \quad (5)$$

where $\Delta_{1md} = |x_{i,j} - x_{i-1,j-1}|$ and $\Delta_{2md} = |x_{i,j} - x_{i+1,j+1}|$

$$A_{AD} = \frac{1}{2}\sum_{i=1}^{2} \Delta_{iad} \quad (6)$$

where $\Delta_{1ad} = |x_{i,j} - x_{i-1,j+1}|$ and $\Delta_{2ad} = |x_{i,j} - x_{i+1,j-1}|$

ζ = mean { A_H , A_V , A_{MD} , A_{AD} } (7)

where $0 \leq \zeta \leq 1$

For an image with gray levels in the interval (0, 1), the pixels in the set NC are identified as Noise pixels based on the value of ζ. If for a pixel ζ is very close or equal to 1 (i.e., in between 0.90 and 1, here 1 represents the maximum possible gray level for an image and 0.90 is 90% of the maximum value. For an image in the range (0,255) these values will be 230 and 255 respectively), this implies that this pixel is an isolated maximum or minimum point and thus a salt or pepper noise. Hence, it belongs to the set N of noise pixels.. When ζ is less than 0.90 the pixel is a noise free pixel even though it is a maximum or minimum point but it is not noise as it may be a part of a smooth region or edge and belongs to the set S.

$$x_{ij} \in \begin{cases} N \quad if \quad 0.90 \leq \zeta \leq 1 \\ S \quad otherwise \end{cases} \quad (8)$$

2. Filtering: When the noise pixels are identified they are filtered out. The filtering process is as important as identification since filtering is also responsible for losing image details. Thus, in this paper filtering is done as follows:

$$y_{ij} = \begin{cases} M_{ad} \quad if \quad x_{ij} \in N \\ x_{ij} \quad if \quad x_{ij} \in S \end{cases} \quad (9)$$

Where M_{ad} is the adaptive median. If M_{ad} is used better denoising is obtained. In a M X M window when the median is calculated it is possible that the median itself is a noise i.e. it is a maximum or minimum point , if this is the condition then the window size for median calculation is increased by 2 and again the median is calculated. This process is repeated until the maximum window size is reached or a noise free median is obtained [1]. The proposed algorithm (PA) is as follows:

1. Input noisy image.
2. For all pixels in the image check
   - 2.1 $x_{ij} \in S$ if $\min [W_M] < x_{ij} < \max [W_M]$
   - 2.2 $x_{ij} \in NC$ if $\min[W_M] = x_{ij}\ or\ x_{ij} = \max [W_M]$
3. For all pixels in NC calculate A_H , A_V , A_{MD} , A_{AD} and ζ and check
   - 3.1 If $0.90 \leq \zeta \leq 1$ then $x_{ij} \in N$
   - 3.2 $x_{ij} \in S$ otherwise
4. For all pixels in N
   - 4.1 Calculate M_{ad}.
   - 4.2 Replace each pixel in N by its M_{ad}.

IV. EXPERIMENTAL RESULTS

In order to study the performance of the proposed algorithm, images have been contaminated with a salt pepper noise. The denoising results were compared with several existing methods in both visual image quality and restored signal quantity. Standard Lena grey image was taken as the test image. Noise of different densities was added ranging from 30% to 90%.The proposed method was compared with standard median (SM) filter and the adaptive median (AM) filter as AM filter shows relatively better performance for noise suppression than other SM filter based methods. Fig. 2 shows the original test image LENA. Fig. 3,4,5and 6 show the filtering results after adding the salt-and-pepper noises with the noise ratio of 30% ,60%,80% and 90% respectively. For the subjective comparison it is seen that the restoration results using the proposed method are significantly better than the ones by other methods. For the low density noise the result in Fig.3 (d) seems almost the same with the original uncorrupted image Fig.2. When the noise ratio reaches as high as 80%, the promising restoration result can be still achieved by using the proposed method, much better than other two filters. Thus, it is seen that the proposed method gives better results than the other methods.

Figure 2 Standard test image LENA

Figure 3 Restored LENA images using different filters (a) image corrupted with 30% salt pepper noise (b) SM (c) AM (d) PA

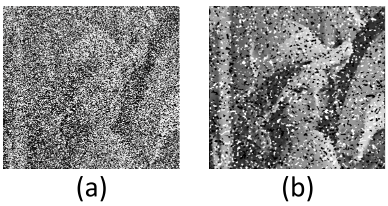

Figure 4 Restored LENA images using different filters (a) image corrupted with 60% salt pepper noise (b) SM (c) AM (d) PA

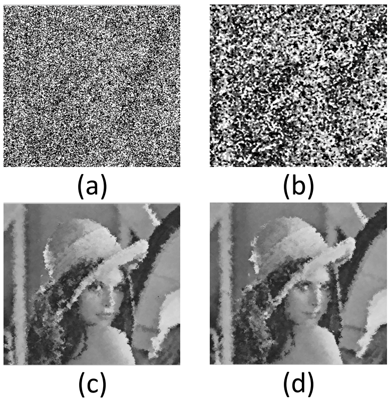

Figure 5 Restored LENA images using different filters (a) image corrupted with 80% salt pepper noise (b) SM (c) AM (d) PA

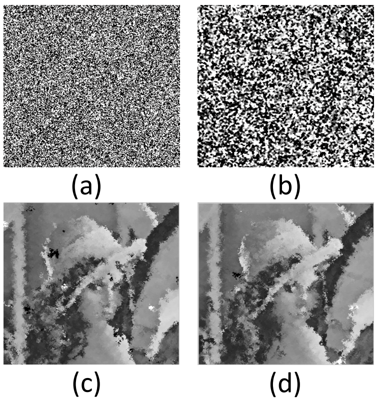

Figure 6 Restored LENA images using different filters (a) image corrupted with 90% salt pepper noise (b) SM (c) AM (d) PA

The results were measured quantitatively using PSNR (Peak Signal to noise Ratio) which is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. PSNR is a measure of the quality of the reconstruction. A higher PSNR would normally indicate that the reconstruction is of higher quality. It is most easily defined via the mean squared error (MSE) which for two $m \times n$ images I and K where one of the images is considered a noisy approximation of the other is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \qquad (10)$$

The PSNR is defined as:

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$
$$= 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \qquad (11)$$

Here, MAX_I is the maximum possible pixel value of the image.Table1 shows the PSNR values of three filters for different noise densities. It is observed that at low density noise the proposed algorithm and adaptive median filter give almost equal PSNR, but at high density the proposed algorithm (PA) gives much better PSNR than the Adaptive median filter.

TABLE I
PSNR OF DIFFERENT FILTERS FOR DIFFERENT NOISE DENSITIES

Noise level	**Standard Median**	**Adaptive Median**	**Proposed Algorithm**
30%	22.1454	28.8738	28.8873
60%	12.0530	24.3270	24.3708
80%	8.1378	21.3660	21.4381
90%	6.6231	18.3907	19.2222
95%	5.9764	14.3164	16.3190

V. CONCLUSION

A $N_8(p)$ detail preserving adaptive filter for impulse noise removal is proposed in this paper. The algorithm first identifies noise and noise free pixels based on the $N_8(p)$ neighbors of a pixel. The algorithm works in two stages first it separates the noisy pixels and noise free pixels so that the edges and details of the image are preserved and it removes only the noisy pixels. After identification of noise pixels filtering is done to restore the image. The noisy pixels are replaced by the adaptive median which is calculated recursively by increasing the window size upto a maximum window size. Replacing the noise pixels with adaptive median preserves image details and gives better denoising. Since the proposed method employs a good identification scheme for noise pixels, it shows better performance for the noise removal, edge preservation and preserving image details as compared to other methods. The peak signal to noise ratio also shows improvement as compared to other methods.

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