International Journal of Applied Science and Advance Technology
January-June 2012, Vol. 1, No. 1, pp. 13-16

AN ALGORITHM FOR DETECTION AND REMOVAL OF IMPULSE NOISE FOR CORRUPTED IMAGES

Sachin Singla, Anil Garg[1], and Shiv Singh[2]

Abstract: In this paper, an algorithm is proposed for removing Impulse (salt and pepper) noise from corrupted image. The proposed filtering algorithm employs two phases. First phase identify the noisy pixels from corrupted image and in second phase a filter is used to reconstruct the noisy pixel. The experimental result shows that the proposed algorithm performs better than simple median filter for removing the noise and preserves the edges. Since our algorithm is simple and it is suitable for many real time applications.

Index Terms: Image denoising, image restoration, impulse noise, salt-and-pepper noise, PSNR, MSE.

1. INTRODUCTION

Noise is any undesired information that corrupts an image. Noise appears in an image from a variety of sources. The salt and pepper type noise is typically caused by malfunctioning of the pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process, so an efficient denoising technique is necessary for various image applications. In the images corrupted by salt and pepper noise can take only the maximum and the minimum values in the dynamic range. Recently, many image denoising methods have been proposed to carry out the impulse noise suppression [2]-[16]. Some of them employ the standard median filter [2] or its modifications [3], [4] to implement the denoising process. However, these approaches [2]-[4] might blur the image since both noisy and noise-free pixels are modified. To avoid the damage on noise-free pixels, many image filters with an impulse detector are proposed in the literature [5]-[16]. The main advantage of these methods is that they employ an impulse detector to locate and filter the noisy pixels without processing the noise-free pixels. Many recent denoising techniques [12]-[16] use a fixed-size local window for processing and perform image denoising simply and efficiently. In [12], a new impulse detector (NID) for switching median filter was proposed. NID used the minimum absolute value of four convolutions which are obtained by using one-dimensional Laplacian operators to detect noisy pixels. The differential rank impulse detector (DRID), presented in [13], implemented the impulse detector based on a comparison of signal samples within a narrow rank window by both rank and absolute value. In [14], a simple fuzzy impulse detector (SFID) was proposed to remove the impulse noise. An alpha-trimmed mean-based method (ATMBM) was presented in [15]. It used the alpha-trimmed mean in impulse detection and replaced the noisy pixel value by a linear combination of its original value and the median of its local window. In [16], a decision-based algorithm (DBA) was presented to remove the corrupted pixel by the median or by its neighbouring pixel value according to the proposed decisions.

In [8], a two-phase scheme for salt-and-pepper noise removal is proposed. It identifies the noisy pixels with an adaptive median filter and then restores them by an edge-preserving method. Based on their idea, an efficient edge-preserving algorithm for impulse noise removal is proposed in this letter. We use a noise detector to detect the pixels corrupted by impulse noise. After detection, we employ an effective edge-preserving filter to preserve the edge features rather than reconstruct the noisy pixel values with standard median filter. The experimental results demonstrate that our method can obtain better performances in terms of both quantitative evaluation and visual quality than those state-of-the-art impulse denoising methods [12]-[16].

2. PEAK SIGNAL TO NOISE RATIO (PSNR)

The phrase Peak Signal to Noise Ratio is signal and a power of corrupted noise that affects the fidelity of its representation. PSNR is usually expressed in terms of the logarithmic decibel scale. The PSNR is most commonly used to measure of quality of restored image. It is easily define by Mean Square Error (MSE) which is for two $m * n$ monochrome images I and K, where one of the image is restores image and other is original image.

[1] Mharishi Markandeshwar Engg. College, Mullana, Distt. Ambala, India, *E-mail: sachinsingla88@rediffmail.com, agarg001@yahoo.com*

[2] Haryana College of Technology and Management, Kaithal, India., *E-mail: shivsingh917@gmail.com*

The MSE is defined as:

$$MSE = 1/mn \sum_{i=1}^{m-1} \sum_{j=0}^{n-1} (I(i, j) - K(i, j))^2 \qquad (a)$$

The PSNR is defined as:

$$PSNR = 10 \log_{10}(\mathrm{MAX}_I^2 / MSE) \qquad (b)$$
$$= 20\log_{10} (\mathrm{MAX}_I / MSE^{1/2})$$

Here MAX_I is the maximum pixel value of the image.

3. PROPOSED ALGORITHM

The noise considered in this letter is fixed-valued impulse noise, also called salt-and-pepper noise, with uniform distribution as practiced in [12]-[16]. The proposed algorithm is composed of two components: Efficient impulse detector and edge preserving filter. The former determines which pixels are corrupted by fixed-valued impulse noise. The latter reconstructs the noisy pixels by observing the spatial correlation and preserving the edges efficiently.

3.1 Impulse Detector

Let denote the current pixel at coordinate (i, j) and $y_{i,j}$ denote its pixel value. For each pixel in an image, we define a 3*3 window centred on it first. Let $W_{i,j}$ represent the set of pixels within a 3*3 window centred on $p_{i,j}$. Thus, it can be given as

$$W_{i,j} = \{p_{k,1} \text{ for } i-1 <= k <= i+1,\ j-1 <= 1 <= j+1\} \quad (1)$$

Assume that Maxin $W_{i,j}$ and Minin$W_{i,j}$ mean the maximum and minimum gray-scale values in the current working window $W_{i,j}$, respectively, and let $\mathrm{Max}_{i,j}$ and mean $\mathrm{Min}_{i,j}$ the maximum and minimum gray-scale values in those previously processed windows from the first one ($W_{0,0}$) to the current one ($W_{i,j}$). The relationships between them are given as follows:

$$\begin{aligned} \mathrm{Max}_{i,j} &= \mathrm{Max}_{i,j-1}, && \text{if } Max_{i,j-1} >= \mathrm{Maxin}W_{i,j} \\ &= \mathrm{Maxin}\, W_{i,j} && \text{otherwise} \end{aligned} \qquad (2)$$

$$\begin{aligned} \mathrm{Min}_{i,j} &= \mathrm{Min}_{i,j-1}, && \text{if } \mathrm{Min}_{i,j-1} >= \mathrm{Minin}W_{i,j} \\ &= \mathrm{Maxin}\, W_{i,j} && \text{otherwise} \end{aligned} \qquad (3)$$

Generally, the value of a pixel corrupted by fixed-valued impulse noise will be located at one of the two ends in the interval of possible pixel values in the image [14]. Based on the idea, we define two variables, $N_{\max}$ and $N_{\min}$, for efficient impulse detection. They are given as

$$\begin{aligned} N_{\max} &= \max_{i,j} && \text{if } \max_{i,j-1} = \max_{i,j-1} \\ &= 255, && \text{otherwise} \end{aligned} \qquad (4)$$

$$\begin{aligned} N_{\min} &= \min_{i,j,} && \text{if } \min_{i,j} = \min_{i,j-1} \\ &= 0, && \text{otherwise} \end{aligned} \qquad (5)$$

Where $N_{\max}$ and $N_{\min}$ can be treated as the estimated intensity values of "salt" and "pepper" noises, respectively, in those previously processed pixels ranging from $P_{0,0}$ to $P_{i,j}$. If $\mathrm{Max}_{i,j}$ is equal to $\mathrm{Max}_{i,j-1}$, it is very possible that the intensity value of "salt" noise in current image is identified. Hence, we set $N_{\max}$ to $\mathrm{Max}_{i,j}$. On the contrary, if $\mathrm{Max}_{i,j}$ is not equal to $\mathrm{Max}_{i,j-1}$, we cannot conclude that the value of $\mathrm{Max}_{i,j}$ is the intensity value of "salt" noise. In this case, we set to 255. Similarly, the estimated intensity value of "pepper" noise $N_{\min}$ can be determined. Finally, the impulse detection function is given as (6). If the intensity value of current pixel is equal to $N_{\max}$ or $N_{\min}$, the current pixel is treated as a noisy pixel and the edge-preserving filter mentioned later is employed to reconstruct its intensity value. If not, the current pixel is treated as a noise-free pixel and the original intensity value is outputted.

3.2 Edge-Preserving Image Filter

The proposed edge-preserving image filter adopts a directional correlation-dependent filtering technique based on observing the sample correlations of six different directions. For each noisy pixel, the image filter detects edges in six directions first and estimates the intensity value of the pixel accordingly. For simpler representation, let a, b, c, d, e, f, g and h represent those intensity values of pixels, $p_{i-1,j-1}, p_{i-1,j}, p_{i-1,j+1}, p_{i,j-1}, p_{i,j+1}, p_{i+1,j-1}, p_{i+1,j}$ and $p_{i+1,j+1}$ respectively, around the current pixel $p_{i,j}$ as shown in Fig. 1. The detailed steps of our edge-preserving image filter are described as follows.

1. Find the six directional differences around the pixel $p_{i,j}$ in $W_{i,j}$ in (7).

$$\begin{aligned} P_{i,j} &= \text{Noisy pixel}, && \text{if } (y_{i,j} = N_{\max \text{ or } N_{\min}}) \\ &\text{Noisy-free pixel} && \text{otherwise} \end{aligned} \qquad (6)$$

	j-1	j	j+1
i-1	a	b	c
i	d		e
i+1	f	g	h

Figure 1: Those Pixels Around the Current Pixel

$$\begin{aligned} D_1 &= (d-h)+(a-e), & D_2 &= (a-g)+(b-h), \\ D_3 &= (b-g)*2, & D_4 &= (b-f)+(c-g), \\ D_5 &= (c-d)+(e-f), & D_6 &= (d-e)*2 \end{aligned} \qquad (7)$$

2. Check whether the four pixels to be denoised later (e, f, g and h) are equal to $N_{\max}$ or $N_{\min}$, respectively. If yes,

the pixel might be corrupted, and thus we do not consider the directional differences containing it by setting those differences to 512.

3. Determine whether D_1, D_2, D_4 and D_5 are equal to 512, respectively. If at least one of D_1 and D_2 is equal to 512 and $p_{i+1,j+1}$ is noise-free, we consider an extra directional difference D_7 to improve image quality. Furthermore, if at least one of is D_4 and D_5 is equal to 512, and $p_{i+1,j+1}$ is noise-free, we add another directional difference D_8. Both of them are defined as follows:

$$\begin{aligned} D_7 &= (a-h)*2 \\ D_8 &= (c-f)*2 \end{aligned} \tag{8}$$

4. Find the minimum value among those directional differences and denote it as $D_{\min}$. The minimum directional difference has the strongest correlation and probably has an edge in its direction. Hence, the reconstructed value of the corrupted pixel $p_{i,j}$ is estimated as follows:

$$Y_{i+J} = \begin{cases} (a+d+e+h)/4, & \text{if } D_{\min} = D_1 \\ (a+b+g+h)/4, & \text{if } D_{\min} = D_2 \\ (b+g)/2, & \text{if } D_{\min} = D_3 \\ (b+c+f+g)/4, & \text{if } D_{\min} = D_4 \\ (d+e)/4, & \text{if } D_{\min} = D_5 \\ (a+h)/2, & \text{if } D_{\min} = D_6 \\ (c+f)/2 & \text{if } D_{\min} = D_7 \end{cases} \tag{9}$$

However, there is an exception for step 4. If $D_{\min}$ is equal to 512, it means that $p_{i,j+1}$, $p_{i+1,j-1}$, $p_{i+1,j}$, and $p_{i+1,j+1}$ are all corrupted. In this condition, no edge is considered. Here, we employ the two previously denoised pixels $p_{i-1,j+1}$ and $p_{i,j-1}$, and take the mean of them as the reconstructed value. In this case, $y_{i,j} = (c + d)/2$. Obviously, the proposed filter has a simple computation structure.

4. EXPERIMENTAL RESULTS

In this section, we compare our method with a existing denoising approach for removal of fixed-valued impulse noise. To verify the characteristics and performances of our algorithm, a variety of simulations are carried out on the well-known 512*512 8-bit gray-scale test image. In the simulations, images are corrupted by salt-and-pepper noise, where 255 represent the "salt" noise and 0 represents the "pepper" noise with equal probability.

Table 1
Comparisons of Restoration Results in PSNR (dB) for a Referance Image Corrupted by 10 to 90% Fixed-valued Impulse Noise

Noise Density	*Decision-based Algo*	*Edge Preserving Algorithm*
10%	P = 14.35	P = 16.09
20%	P = 11.32	P = 12.92
30%	P = 9.62	P = 11.05
40%	P = 8.32	P = 9.69
50%	P = 7.33	P = 8.66
60%	P = 6.54	P = 7.62
70%	P = 5.89	P = 6.91
80%	P = 5.30	P = 6.21
90%	P = 4.89	P = 5.62

Table 2
Comparisons of Restoration Results in MSE (M) for a Referance Image Corrupted by 10 to 90% Fixed-valued Impulse Noise

Noise Density	*Decision-based Algo*	*Edge Preserving Algo*
10%	M = 48.84	M = 39.99
20%	M = 69.20	M = 57.89
30%	M = 84.23	M = 71.45
40%	M = 97.78	M = 83.52
50%	M = 109.62	M = 94.03
60%	M = 120.02	M = 106.01
70%	M = 129.29	M = 115.07
80%	M = 138.48	M = 124.68
90%	M = 146.85	M = 133.44

A wide range of noise ratios varied from 10% to 90% with increments of 10% are tested. Two denoising methods are compared in terms of objective testing (quantitative evaluation) and subjective testing (visual quality): 1) Decision based algorithm and 2) Edge preserving algorithm.

We employ the peak signal-to-noise ratio (PSNR) to illustrate the quantitative quality of the reconstructed images for two methods. Table 1 lists the restoration results in PSNR (dB) of two algorithms for given image corrupted by fixed-valued impulse noise with various noise ratios. It is easy to see that our method provides the best results in PSNR. In Table 2, we compare the restoration results in MSE (M) of our method with decision based algorithm for given image corrupted by 20% fixed-valued impulse noise.

Obviously, our approach performs significantly better than decision based algorithm. The comparison of restoration results in PSNR for the reference image corrupted with various impulse noise ratios are shown in Figure 3. Apparently, the performances of our method are always the best. In order to explore the visual quality, we show the reconstructed images of two methods in restoring 20% corrupted image in Figure. The decision based algorithm brings out blurry restored images and not good enough with regard to edge preservation. In contrast, our method can remove noise efficiently while preserving edges very well, and it can produce visually pleasing images.

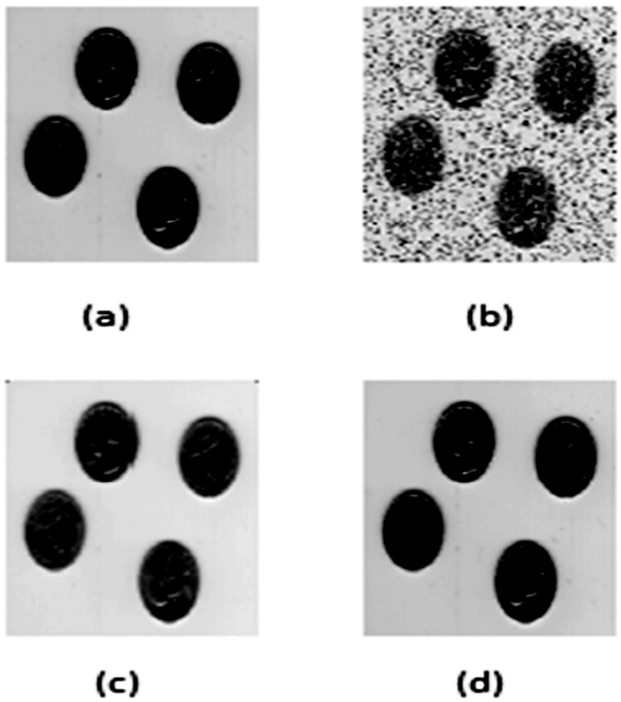

Figure 2: Shows Restoration Results of Two Methods in Restoring Corrupted Image (*a*) Original noise free, (*b*) corrupted image with 20% impulse noise, (*c*) Decision based algorithm (*d*) Edge preserving algorithm

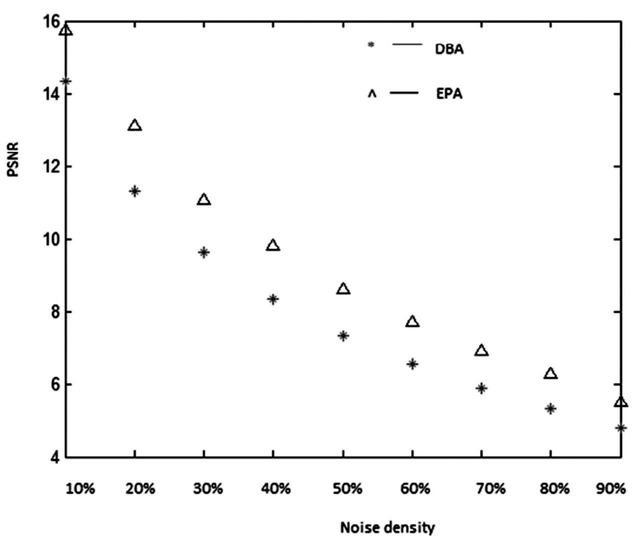

Figure 3: Comparison of Restoration Results in PSNR for Decision Based Algorithm and Edge Preserving Algorithm

5. CONCLUSION

A new denoising algorithm for removing salt-and-pepper noise is proposed in this letter. It can detect the impulse noise efficiently while preserving the edges very well. The simulation results demonstrate that our approach performs much better than decision based algorithm in terms of both quantitative evaluation and visual quality. It has high PSNR and less MSE for different values of noise density as compare to decision based algorithm. Particularly, it removes the noise from corrupted images efficiently and requires no previous training.

REFERENCES

[1] W.K. Pratt, "Digital Image Processing". New York: Wiley-Interscience,1991.

[2] T. Nodes and N. Gallagher, "Median Filters: Some Modifications and Their Properties", *IEEE Trans. Acoust., Speech, Signal Process*., **ASSP-30(5)**, pp. 739-746, Oct. 1982.

[3] I. Pitas and A. Venetsanopoulos, "Nonlinear Digital Filters: Principles and Applications". Boston, MA: Kluwer, 1990.

[4] S.J. Ko and Y.H. Lee, "Center Weighted Median Filters and their Applications to Image Enhancement", *IEEE Trans. Circuits Syst*., **38**, pp. 984-993, Sep. 1991.

[5] T. Sun and Y. Neuvo, "Detail-preserving Median Based Filters in Image Processing", *Pattern Recognit. Lett*., **15**, pp. 341-347, Apr. 1994.

[6] M. Nikolova, "A Variational Approach to Remove Outliers and Impulse Noise", *J. Math. Imag. Vis*., **20(1-2)**, pp. 99-120, 2004.

[7] L. Bar, N. Sochen, and N. Kiryati, "Image Deblurring in the Presence of Impulsive Noise", *Int. J. Comput. Vis*., **70(3)**, pp. 279-298, 2006.

[8] R.H. Chan, C.W. Ho, and M. Nikolova, "Salt-and-pepper Noise Removal by Median-type Noise Detectors and Detail-preserving Regularization", *IEEE Trans. Image Process*., **14(10)**, pp. 1479-1485, Oct. 2005.

[9] P.E. Ng and K.K. Ma, "A Switching Median Filter with Boundary Discriminative Noise Detection for Extremely Corrupted Images", *IEEE Trans. Image Process*., **15(6)**, pp. 1506-1516, Jun. 2006.

[10] P. Civicioglu, "Using Uncorrupted Neighborhoods of the Pixels for Impulsive Noise Suppression with ANFIS", *IEEE Trans. Image Process.,* **16(3)**, pp. 759-773, Mar. 2007.

[11] J.A. Guerrero-Colon, L. Mancera, and J. Portilla, "Image Restoration Using Space-variant Gaussian Scale Mixtures in Overcomplete Pyramids", *IEEE Trans. Image Process*., **17(1)**, pp. 27-41, Jan. 2008.

[12] S. Zhang and M.A. Karim, "A New Impulse Detector for Switchingmedian Filter", *IEEE Signal Process*. Lett., **9(11)**, pp. 360-363, Nov. 2002.

[13] I. Aizenberg and C. Butakoff, "Effective Impulse Detector based Onrank-order Criteria", *IEEE Signal Process*. Lett., **11(3)**, pp. 363-366, Mar. 2004.

[14] W. Luo, "Efficient Removal of Impulse Noise from Digital Images", *IEEE Trans. Consum. Electron*., **52**, pp. 523-527, May 2006.

[15] W. Luo, "An Efficient Detail-preserving Approach for Removing Impulsenoise in Images", *IEEE Signal Process*. Lett., **13(7)**, pp. 413-416, Jul. 2006.

[16] K.S. Srinivasan and D. Ebenezer, "A New Fast and Efficient Decision based Algorithm for Removal of High-density Impulse Noises", *IEEE Signal Process*. Lett., **14(3)**, pp. 189-192, Mar. 2007.