Image Denoising Based on Non-Local means Algorithm

N.Hemalatha[1]
PG-Scholar-M.E.VLSI Design
P.A.College of Engineering and Technology, Coimbatore, India
hmlatha09@gmail.com

D.Ganesh Kumar[2]
Professor, Department of EEE
P.A.College of Engineering and Technology, Coimbatore, India

Abstract: **A Novel impulse noise detection technique is presented here.Edge-preseving and a fine detail of the image is a main problem, i.e. noise suppression. In order to remove Impulsive noise, a new noise detection mechanism and also filtering techniques using Non-Local means (NLM) is proposed in this paper. Impulse noise is a most common noise which affects the image quality during image acquisition, transmission, reception or storage and retrieval process in the area of image denoising. For detection, first, the proposed method is the robust outlyingness ratio (ROR) for measuring the impulse noise. Second, different rules are used to identify the impulsive noise based on the accurate deviation to the mid value in each group. To achieve the detection results more robust and more accurate, the strategy coarse-to-fine stage and the iterative method are used. The proposed work concentrates on removal of both impulsive noise and mixed noise from images. The results show that the proposed impulse detector is finer to most existing impulse detectors, and the ROR-NLM produces better results in terms of high peak signal-to-noise ratio (PSNR).**

Keywords-Image denoising, impulse noise, gaussian noise, new impulse detector, nonlocal means (NL-means).

I. INTRODUCTION

The aim of digital image processing is to improve the potential information for human interpretation and processing of an image data for transmission, storage and representation for autonomous machine perception. The image quality get degrades due to addition of various types of noise. Additive white Gaussian noise, Rayleigh noise, Impulsive noise normally corrupt an image during the processes of acquisition, transmission and reception and storage and retrieval. For a useful and meaningful processing such as pattern recognition and image segmentation, and to have very good visuality in applications like mobile phone, television, digital cameras etc., the acquired signal of image must be denoised and deblurred. Image denoising and image deblurring are the two sub-areas of image restoration. Its objective is to reconstruct the original image or the better estimation from the noise data while preserving fine image details. Additive White noise, (i.e., Gaussian noise) is indicated by adding noise to each pixel in an image that is independent from the unknown image, and also it will affect the whole pixels of the image. Both impulse noise and gaussian is caused by malfunctioning pixels in the physical device such as camera sensors, fault memory locations in hardware or transmission of data in a noisy channel. The images corrupted by noisy pixels can take the maximum and minimum value in the dynamic range. It severely degrades the image quality and also there is a loss of information details. There are various techniques have been proposed for removing impulsive noise and gaussian noise from the test images. There are many and diverse denoising methods have been proposed. The *median filter* was one of the most popular nonlinear filters for removing the impulsive noise, i.e., fixed valued and random valued impulse noise. Median filter generally replaces the intensity value of the center pixel with median value. However the filter approaches might blur the image, some fine details and edges of the test image will not be preserved. Due to its simplicity in implementation and also effectiveness in noise suppression, various changes have been done in the filter, such as Center *weighted median* filter and *weighted median* (WM) filter [2], [3]. The conventional median filter applies the median operation to each pixel completely, that is without considering whether it is noisy or noise-fee pixel. But still, filtering approaches is subjected and causes for the image degradation. In order to overcome the problems of these median filter, two switching scheme was introduced. The first switching scheme 1) Impulse detector – A detector analyses local characteristics of the 3x3 sliding window around each pixel using some considerations and marks the noise pixels in the corresponding local window. 2) The second switching scheme- Noise Filtering Process, only the marked pixels are processed rather than the whole area pixels of an image. The phenomenon of this scheme is so-called *switching median* filters [4] & [5]. In addition to median filter, there are various used to handle out impulsive noise. An alpha trimmed mean based method (ATMBM) was proposed by Luo [6]. In this method, impulse detection and in filtering process it replaces the noise pixel value by a continuous combination of its original pixel value and the median of its sliding window. In [7], Yu et al. proposed a rank-ordered relative differences (RORD-WMF) method to identify corrupted pixels based on ranking the pixel in the sliding window. Dong and Xu has proposed a new modified Directional Weighted median (DWM) [8] method. The decision tree is a simple but analysis the multiple variable process more easily [9]. It can break down a complex decisions into the collection of simpler decisions, thus give a solution which is often easier to analysed [10]. Based on the above concepts, a new decision tree based denoising method (DTBDM) is presented here.To contrast, the effects of removal of impulsive noise, the results of restored pixels are written as a part of input data. By doing so, this method include the pixel-intensity interaction to enhance its filtering capability in decreasing impulse noise, while preserving image details.

II. IMPULSE NOISE DETECTION

A. Impulse Noise Models

Gaussian noise is equally distributed over the signal. Impulsive noise is denoted by changing part of an image pixel with noisy values, this noise affects image pixel by pixel not the whole area of an image. Such noise is introduced during an acquisition process or due to transmission errors. Impulsive noise can be classified as fixed valued impulse noise and Variable type impulse noise. An image containing noise can be described as follows:

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

where x(i, j) denotes a corrupted image pixel, y(i, j) denotes a uncorrupted image pixel and η(i, j) denotes a corrupted pixel at the location (*i*, *j*).In fixed value impulse noise, corrupted pixels take either minimum or maximum values i.e. $\eta(i, j) \in \{N_{min}, N_{max}\}$, and for variable type impulse noise,(i.e.,RVIN) corrupted pixels take any value within the range minimum to maximum value i.e., $\eta_{i,j} \in [N_{min}, N_{max}]$,where N_{min} and N_{max} denote the lowest and the highest pixel values within the specified range respectively .

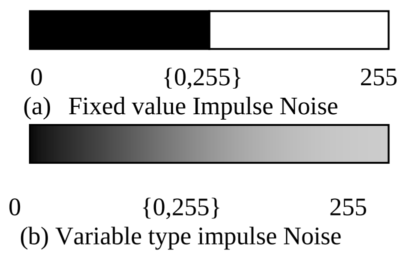

Fig. 1. Representation of Various Impulse Noise

Hence, it is little difficult to remove variable type impulse noise rather than fixed value impulse noise. For the preservation of fine image details and also suppression of noise is the main challenging phenomenon. The difference between fixed value and variable type impulse noise are represented in Fig. 1. In the case of fixed value impulse noise, the pixel is replaced with noise may be either $N_{min}(0)$ or $N_{max}(255)$, where as in variable type impulse noise situation it may range from N_{min} to N_{max}. Suppressing variable type impulse noise is more difficult than removing fixed-valued impulse noise. The differences in gray levels between a corrupted pixel and its uncorrupted neighbors are significant most of the times.

B. Noise Detection Scheme

Normally, two concerns are included in developing a determination process. First, it determines, its measure by using statistical parameter to capture and also to represent the local property of region. Second, a procedure to determine a threshold value for an unknown image. Based on two-state methods, the new impulse detectors that is attempt to indicate each image pixel as either corrupted or an uncorrupted pixel. The phenomenon of these two methods is to determine image pixels to be significant. One of the simplest and most inherent methods is to compare a image pixel's intensity with the median pixel intensity in its neighborhood. Another relative complex method such as the ACWM, DWM and DTBDM use more complex criteria to conclude whether a pixel is an impulsive one. However, this approach is simple or complex, each image pixel is decided under the same decision, without considering the property of each image pixel. Furthermore, these existing methods are resulted poor performance, when the noise density is high. Theoretically, a different decision rule is considered for different levels should be adopted. Hence, prior to making a decision, all pixels should be grouped based on the level of how impulsive-like. In statistics, there are many methods for detecting outliers. Among them, a conventional measure of the robust outlyingness of an observation with respect to a test is the ratio between its distance to the specific mean and the standard deviation (SD). Due to the properties of statistics, the impulse noise can be detected easily. In response to the feature aforementioned, a novel detection pattern mechanism for impulsive noise is proposed in this paper.

A new detection mechanism has been proposed based on the new statistics. The proposed detection mechanism describes the outlyingness of the pixels and divides the pixels into four clusters based on the ROR values. The simple absolute deviation to the median is used to identify the impulsive noise in each cluster. In fact, according to the principle of the proposed detection mechanism, different decision rules could be adopted in different clusters. Therefore, to choose a suitable decision rule of every cluster. The main characteristics of each decision rule is as follows,

(i) **Hierarchical:** The picture elements in the image are separated into four groups based on the value ROR, and they are independently detecting impulse noise in every group.

(ii) **Progressive:** The strategy, from-coarse-to-fine is adopted, and the new detection pattern mechanism contains two stages, i.e., the fine and coarse stages. The detection results become more accurate.

(iii) **Iterative:** The framework of iterations is adopted by our method.

(iv) **Anisotropic:** The decision rule with different threshold value is used in different group. In contrast, the ACWM and also other methods does not have these characteristics.

Therefore, a new detection pattern has been proposed that detects all the noisy pixels once in the block, and this method could be called as the block-wise pattern. For good performance, the capability of noise detection is very important. Here, the new detection method is compared with other methods like DTBDM. A new impulse detector should be able to detect most of the corrupted pixels as possible. If there are too many undetected noisy pixels, these pixels will show the presence of identifiable noise patches. Compared to other methods the proposed method can identify most of the noisy pixels. The results show that our method is more robust to the noise ratio than the other methods.

III. NON-LOCAL MEANS FILTERING (NLM)

Let us consider the model of the gaussian noise stands for the representation of the original image is the additive white gaussian noise with zero mean and variance, and it is the observed degraded image $\hat{y}$(i). The noise-free pixel at image can be derived as the weighted average of all gray values in the image (indexed in group) where weights a(i,j) denoted the similarity between the neighborhoods of each pair of pixels involved in the computation.

$$\alpha_i=\sum_{j\,\epsilon\,J} w_{i,j}\;\beta_{i,j} \tag{2}$$

where $w_{i,j}$ is weight, here α_i can be computed as weighted average of $\beta_{i,j}$.In the original NLM algorithm, the weights are calculated among the neighborhoods of the pixels, and that all pixels in every neighborhood are used. However, if the NLM method is directly used to the impulse noise, the weights would be wrong because the impulse noisy pixels are very different to their neighbors and do not contain any useful information unlike to the Gaussian noise. When applying NL-means to the impulse noise it is tough to calculate weights. In order to understand with this problem, a reference image and the detection result are obtained. The NLM filter can be easily extended to remove mixture of impulsive and gaussian noise.

The best solution would be to locally vary parameters, so that they are primely tuned to remove the particular amount and type of noise present in each section of the image. The proposed NLM algorithm,

(i)Choose the algorithm parameters, i.e., thresholds and window size (the actual size is 3 X 3); iterations and initial i=1.

(ii)Initialize the detection flag matrix as zeros, where "0s" and "1s" represent good and noisy pixels, respectively.

(iii)Calculate the ROR of the current pixel. If the ROR is in the fourth level, treat it as a good pixel, or calculate the absolute deviation between the current pixel and the median of its local window. Then, compare it with threshold according to its ROR value. If is larger than threshold, it is a noisy pixel, or it is a good pixel. Update the flag according to the result.

(iv)Get the Adaptive Center weighted median-based restored image according to the detection result. If the flag is 1, represent the pixel with the median of its local window, or do not change.

(v)If i<=mc, i=i+1 then go to step (ii) or the coarse and fine stage is complete.

A simpler yet still effective solution to restore an image corrupted by mixed noise. It is verified that ROR-NLM filter retains the original image with the ability to remove mixed noise. From the quantitative results and the visually quality, the proposed ROR-NLM has the ability to remove mixed noise, and it gets the best results.

IV. EXPERIMENTAL RESULTS

The proposed NLM method is compared with developed existing denoising methods, including the ACWM (Adaptive Center Weighted Median), DWM (Directional Weighted Median), and DTBDM (Decision Tree Based Denoising Method) and shown the resulted image and graph in Fig. 2, Fig. 3 and Fig. 4. A set of standard and real images are commonly used in the review of image denoising. The results of various denoising methods are described in Table II. From the Table II,the proposed NLM has achieved highly competitive denoising performance.

TABLE I
PSNR (dB) results for House image on different level of noise densities

Noise Density (%)	Median Filter	DWM	DTBDM	NLM
5	33.04	34.79	39.94	42.14
10	31.93	33.89	36.80	39.06
15	30.41	32.37	35.05	37.27
20	29.59	31.04	33.87	35.68
50	21.09	21.52	28.75	29.62
70	16.60	16.88	24.11	27.60
90	13.51	13.59	16.17	16.82

(a) Original Image (b)Noisy Image (c)Median

(d) DWM (e) DTBDM (f) Proposed

Fig. 2. Results of Different Methods in restoring 30 percent corrupted image "House"

TABLE II
Comparative Results in PSNR (dB) of Image Corrupted by 20 Percent Impulses

Images / Method	Lena	Boat	Peppers	House
Median	31.39	28.05	29.07	29.59
DWM	33.49	29.14	29.35	31.04
DTBDM	34.52	30.95	30.49	33.87
Proposed	**36.73**	**32.92**	**35.07**	**35.68**


(a)Original Image


(b)Noisy Image


(c) Median


(d) DWM


(e) DTBDM


(f) Proposed

Fig. 3. Results of Different Methods in restoring 50 percent corrupted image “Real”.

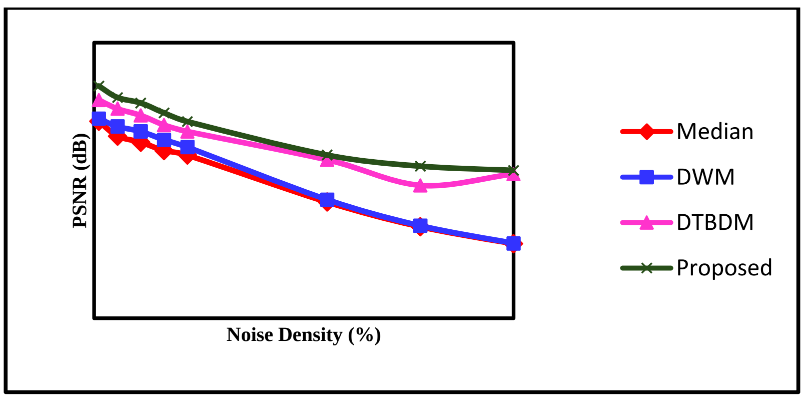

Fig. 4. Comparison graph of various denoising method

V. CONCLUSION

In this paper, a novel restoration method for image denoising method is proposed based on non-local means algorithm. The noise which is defined as the difference between degraded image and the original image, should be minimized for improvement in their performance on image restoration. To first, a novel detection mechanism, is proposed to detect both impulse and gaussian noise. Second, using NLM filtering for suppression of noise at all level of noise density. The reconstructed edges are much sharper and more image fine structures are recovered easily. Experimental results on image denoising, demonstrated with proposed work, can achieve higher performance than other principal denoising methods.

REFERENCES

[1] C.W. Ho, R.H. Chan, and M.Nikolova, “Salt-and-Pepper Noise removal by median-type noise detectors and detail-preserving Regularization,” IEEE Trans.Image Processing, vol. 14, no. 10, pp. 1479-1485, Oct.2005.
[2] Brownrigg D.R.K, “The Weighted Median Filter,”IEEE.Communication.ACM.vol.27,no. 8, pp. 807-818, Aug.1984.
[3] Y.-H. Lee and S.-j. Ko, “center weighted median filters and their applications to image Enhancement,” IEEE Trans.Circuits Systems, vol. 38, no. 9, pp. 984-993, Sept.1991.
[4] Y.Neuvo and T.Sun, “Detail-Preserving Median Based Filters in Image Processing.”Pattern Recognit.Lett. vol. 15,no. 4,pp.341 347,Apr.1994.
[5] D. Zhang and Z. Wang, “Progressive Switching median filter for the Removal of Impulse Noise From Highly Corrupted Images,” IEEE Trans. Circuits Systems II, Analog Digital Signal Processing, vol. 46, no. 1, pp. 78-80, Jan. 1999.
[6] W.Luo, “An Efficient detail preserving approach for removing impulse noise in images,”IEEE Signal Processing Letters, vol. 13, no.7, pp. 413-416, July 2006.

[7] H.Yu, L.Zhao, and H.Wang, "An Efficient Procedure for removing random-valued impulse noise in images,"IEEE Signal Processing Letters, vol. 15, pp. 922-925, 2008.

[8] S.Xu, and Y.Dong, "A new directional weighted median filter for removal of random –valued impulse noise,"IEEE Signal Processing Letters, vol. 14,no. 3,pp. 193-196,Mar. 2007.

[9] B.De Ville, Decision Trees for Business Intelligence and data mining.SAS Publishing, 2007.

[10] S.Rasoul Safavian and D.Landgrebe, "A Survey of Decision Tree Classifier Methodology,"IEEE Trans.Systems Man,cybernetics,vol.21,no.3,pp 660-674,May 1991.

[11] H.Hwang and R.A. Haddad,"Adaptive Median Filters: New Algorithms and Results," IEEE Trans.Image Processing, vol. 4, no. 4, pp. 499-502, April.1995.

[12] E. Abreu, M. Lightstone, S.K. Mitra and K. Arakawa,"A New Efficient Approach for the Removal of Impulse Noise For Highly Corrupted Images,"IEEE Trans.Image Processing, vol. 5, no. 6, pp. 1012-1025, June. 1996.

[13] H. –L. Eng and K. –K. Ma,"Noise Adaptive Soft Switching Median Filter," IEEE Trans.Image Processing, vol. 10,no. 2, pp.242-251,Feb. 2001.

[14] I. Aizenberg and C. Butakoff,"Effective Impulse Detector Based on Rank-Order Criteria," IEEE Signal Processing Letters,vol. 11,no. 3,pp. 363-366,March. 2004.

[15] P.E. Ng and K.K. Ma,"A Switching Median Filter with Boundary Discriminative Noise Detection for Extremely Corrupted Images,"IEEE Trans.Image Processing, vol. 15, no. 6, pp.1506-1516, June.2006.

[16] X. Zhang and Y. Xiong,"Impulse Noise Removal Using Directional Difference Based Noise Detector and Adaptive Weighted Mean Filter," IEEE Signal Processing Letters,vol. 16,no 4,pp. 295-298,April.2009.

[17] P. –Y. Chen,C. –Y. Lien, and H. –M. Chuang,"A Low-Cost VLSI Implementation for Efficient Removal of Impulse Noise,"IEEE Trans.Very Large Scale Integration Systems,vol. 18,no. 3,pp. 473-481,March. 2010.

[18] C.-Y.Lien, C. –C.Huang, P. –Y. Chen and Y.-F. Lin,"An Efficient Denoising Architecture for Removal of Impulse Noise in Images",IEEE Trans.Computers,vol. 62,no. 4,pp. 631-642,April.2013.

[19] A. Buades, B. Coll, and J. M. Morel, "A non-local algorithm for image denoising," in Proc. Int. Conf.Comput. Vis. Pattern Recognit., 2005,pp.60–65.

[20] Weisheng Dong, Lei Zhang, Guangming and Xin Li, "Nonlocally Centralized Sparse Representation for Image Restoration"IEEE Transactions on Image Processing, vol. 22, no. 4, pp. 1620-1630.April 2013.