Image Denoising and Deblurring Using Non-Local Means Algorithm in Monochrome Images

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ABSTRACT – Image deblurring and denoising are the fundamental problems generally arise in the field of image processing with several applications. This paper presents both areas of image restoration. Image deblurring and denoising methods are most commonly designed for removal of both impulsive noise and Gaussian noise. Impulsive 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. Impulsive noise can be categories into two i.e., Salt and Pepper Noise and Random Valued Impulsive Noise. Image deblurring methods are most commonly designed for Gaussian noise. The proposed work concentrates on removal of both Impulsive noise and Gaussian noise from images. Removal of impulsive noise is carried out using a non-linear filter that involves two phases, i.e. detecting the noise and also followed by filtering. Hence we proposed an efficient filter method for suppressing the noise in an image. The numerical results will confirm that proposed methods yields the better performance, in the terms of PSNR (Peak Signal to Noise Ratio).

Keywords

Salt and Pepper noise, Random Valued Impuse noise, image denoising, image deblurring, Gaussian noise, non-local means, non -linear filters.

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 contamination 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, have very good visuality in applications like mobile phone, television, digital cameras etc., the acquired image signal 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 the impulse 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 processes 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.

PROPOSED DENOISING ALGORITHM

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 .

0 {0,255} 255
(a) Fixed value Impulse Noise

0 {0,255} 255
(b) Variable type impulse Noise

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.

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. The existing denoising methods use many different approach to determine whether a given image pixel is a noisy one in this sense. 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 density of is high. In fact, the level of impulse noise in an image is different. Some pixels look more like corrupted pixels, and some do not look like corrupted pixels. Theoretically, for separate levels, independent decision rules should be adopted. Hence, prior to making a decision, all pixels should be grouped based on the level of how impulsive-like. Then, in different group, adopt different decision rules. In statistics, there are various methods for detecting outliers. Among them, a conventional measure of the outlyingness of an observation with respect to a sample is the ratio between its distance to the sample mean and standard deviation (SD). Due to the statistics, the impulse noise can be detected easily. In response to the aspects aforementioned, a novel detection paper mechanism for impulse noise is proposed in this paper. The flowchart of denoising algorithm is shown in Fig. 2.

A new detection mechanism has been proposed based on the new statistics. Most of the existing detection methods are often realized by comparing certain number of local neighborhood statistics to the same number of corresponding thresholds. However, all these existing detection methods mentioned above, deal with every pixel under the same rule without considering the outlyingness differences among the pixels. 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 median filter analysis and the detection method in DWM are used to get better results. Detecting one by one pixel can get good results, but the efficiency may be low. 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 lead to the presence of noticeable 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.

Non-Local Means Filtering (NLM)

Basically, the NL-means filter estimates an uncorrupted intensity as average weighted for all pixel in the image, and the weighted value are proportional to the similarity between the neighbor pixel value being processed and the surrounding pixels of neighbor pixels. However, these nonlocal means filtering method are very efficient in preserving image details when denoising. This filtering method also to remove combination of impulse and Gaussian noise. The best solution could be to locally varying parameters, so that they are primely tuned to remove the particular amount and various noises present in each part of the image.

DEBLURRING ALGORITHM

Image deblurring is the exercise of processing the whole image to view it a better representation of the section. In this process of restoring the original sharp image a mathematical model of the blurring is used. So, first a mathematical model is devised that relates, the

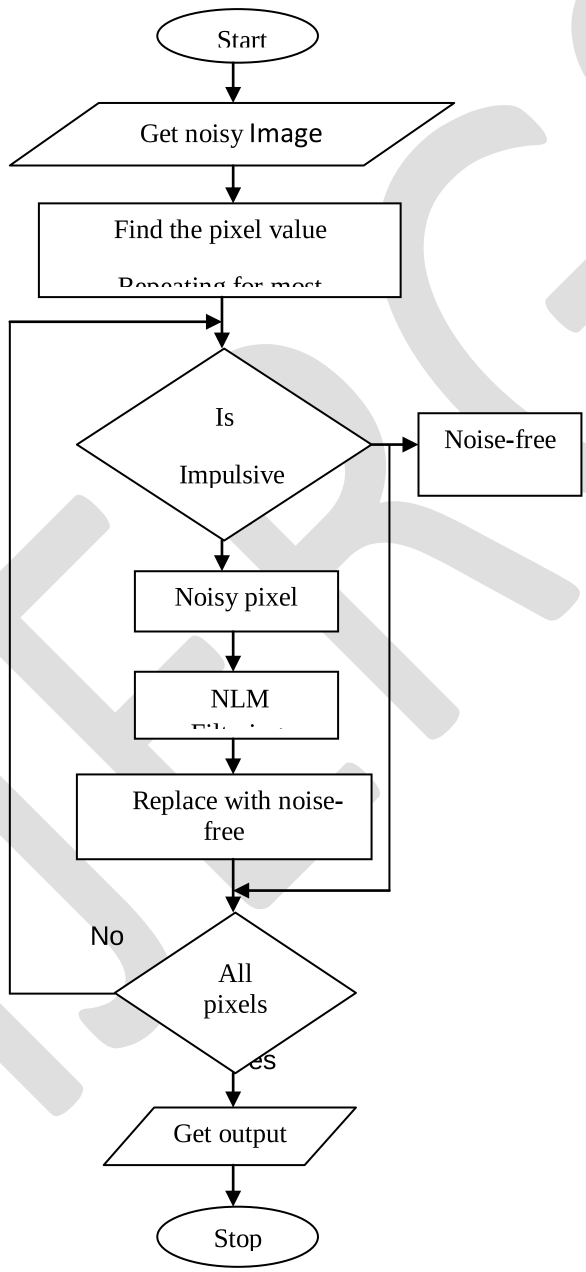


Fig. 2. Flowchart of denoising algorithm

given blurred image to the unknown true image. Image Deblurring techniques are sensitive to noise, yet a small amount of noise, which is unavoidable in low-light conditions, can disintegrate the quality of gaussian blur kernel estimation dramatically. Iteratively deblur and denoised, a blurry and noisy image. However, directly applying image denoising methods often slightly damages the blur information that is removed from the original image, leading to kernel estimation. A new method is proposed for handling noise in image deblurring based on new theoretical and practical insights. The key observation is that applying an iterative filtering process, so that the noise level in an image get greatly reduces, while preserving the blur information in the statiscally independent direction to the filter. A non-local self similarity constraint is combine with non-locally centralized sparse representation (NCSR) is proposed. The proposed image deblurring methods are effective in restoring image structures from blurred image data. However, they tend to over smooth the local image details. This drawback is overcome by combining iterative shrinkage regularization with a NL self-similarity constraint, which helps to sharpen image edges and restore the fine details. Experimental results validate the performance of the proposed approach in both evaluation indexes and visual quality. As mentioned in Table II and Table III, that our algorithm achieves higher performance quality results than existing methods on blurry and noisy images.

EXPERIMENTAL RESULTS

Image Denoising

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. 3,Fig. 4 ,Fig.5 and Fig.6. 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 cameraman image on different
level of noise densities

Noise Density (%)	**Median Filter**	**DWM**	**DTBDM**	**NLM**
5	26.85	27.08	36.21	38.26
10	26.21	26.59	32.89	34.19
15	25.73	25.76	31.35	32.01
20	24.57	25.15	30.18	30.47
50	18.19	18.33	24.28	29.62
70	14.32	14.53	20.89	26.17
90	11.73	11.75	14.52	23.39

Image Deblurring

The deblurring methods is applied to the simulated blurred images and compare the proposed method with BM3D and shown the resulted image in Fig. 6. In the simulated image deblurring, two generally used blur kernels are 9×9 uniform blur kernel and 2D Gaussian function (nontruncated) with standard deviation is used for simulations. The results of various deblurring methods are reported in Table IV. From Table IV, the proposed method has achieved highly competitive deblurring performance.

TABLE II

Comparative Results in PSNR (dB) of Image Corrupted by 5 Percent Impulses

Images / Method	Lena	Boat	Peppers	House
Median	34.67	25.82	25.24	31.25
DWM	35.93	30.31	27.99	34.92
DTBDM	36.32	35.71	31.37	40.05
Proposed	**40.17**	**38.82**	**38.12**	**42.14**

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

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

Fig. 3. Results of Different Methods in restoring 15 percent corrupted image “Boat”.

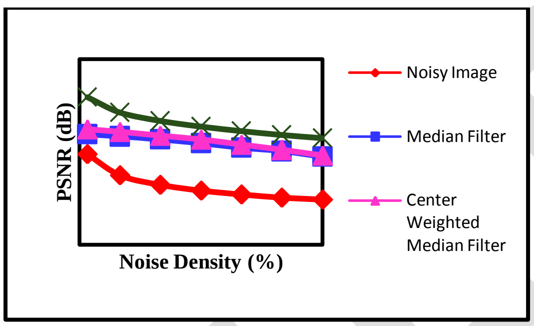
(a)Original Image (b)Noisy Image (c) Median

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

Fig. 4. Results of Different Methods in restoring 10 percent corrupted image “Real”.

TABLE III
PSNR (dB) results for lena image on different
level of noise densities.(Filtering Without Detection)

Noise Density	PSNR(dB)			
	Noisy Image	**Median Filter**	**CWM Filter**	**AM Filter**
1	29.31	35.62	37.38	**47.70**
5	22.34	34.93	36.49	**42.68**
10	19.31	33.97	35.25	**39.88**
15	17.49	32.82	33.97	**38.11**
20	16.25	31.39	32.39	**36.73**
25	15.27	30.18	30.60	**35.39**
30	14.48	28.39	28.89	**34.38**



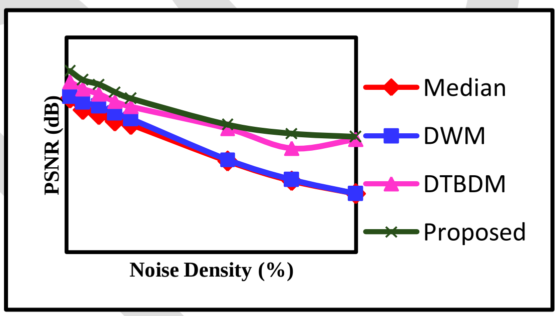


Fig. 5.Comparison graph of various denoising method

(a) Original Image

(b) Noisy Image

(c) Median

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

Fig. 6. Results of Different Methods in restoring 50 percent corrupted image "House".

TABLE IV

Comparative Results in PSNR (dB) of deblurring methods

Images / Method	Lena	Boat	Peppers	House
Noisy	20.17	23.33	20.14	20.14
BM3D	30.09	28.73	30.16	32.86
Proposed	32.05	29.09	31.96	34.24

(a) Original Image (b) Blur image (c)BM3D (d)Proposed

Fig. 7.Results of different deblurring performance comparison on "house.

(a) Original Image (b) Blur image (c) BM3D (d) Proposed

Fig. 8.Results of different deblurring performance comparison on "Peppers".

CONCLUSION

In this paper, a novel restoration method is presented for both image denoising and image deblurring. 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 denoising method is proposed for suppression of noise at all level of noise density. Second,, in deblurring method ,a new combine constraint of non-local similarity and Non-locally centralized Sparse Representation is proposed for achieving higher performance. The reconstructed edges are much sharper and more image fine structures are recovered easily. Experimental results on image denoising, and deblurring demonstrated with proposed work, can achieve higher performance than other principal denoising and deblurring methods.

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