

AN EFFICIENT DENOISING APPROACH FOR REMOVAL OF IMPULSE NOISE

Shiv Singh*

Dr.G.C.Lall*

Abstract

In this paper, an algorithm is presented for images which are highly corrupted by salt and pepper noise also called Impulse Noise. The proposed filtering algorithm consist of two phases. First phase identify the noisy pixels from corrupted image and then in second phase a filter is used to reconstruct the noisy pixel. The experimental result shows that the proposed filtering algorithm performs better than simple median filter for removing the noise and preserves the edges. Since the algorithm is simple and effective, it is suitable for many real time applications.

Key Words—Image denoising, image restoration, impulse noise, salt-and-pepper noise, PSNR, MSE.

* Haryana College of Tech. & Management, Kaithal.

I. INTRODUCTION

Noise is any undesired information that corrupts an image. Noise appears in an image from a variety of sources and is of different types. Impulse noise filtering is a very important pre-processing task in image processing where the salt & pepper like impulsive incidences of larger strength. 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 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].

II. 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 $m \times n$ monochrome images I and K , where one of the image is restores image and other is original image.

The MSE is defined as:

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

The PSNR is defined as:

$$\begin{aligned} PSNR &= 10 \log_{10} (MAX_I^2 / MSE) \\ &= 20 \log_{10} (MAX_I / MSE^{1/2}) \end{aligned} \quad (b)$$

Here MAX_I is the maximum pixel value of the image.

III. MEDIAN FILTER

Median filter, the most prominently used impulse noise removing filter, provides better removal of impulse noise from corrupted images by replacing the individual pixels of the image as the name suggests by the median value of the gray level of the pixels from a chosen neighbourhood.

The median of a set of values is such that half of its values in the set are below the median value and half of them are above it and so is the most acceptable value than any other image statistics value for replacing the impulse corrupted pixel of a noisy image for if there is an impulse in the set chosen to determine the median it will strictly lie at the ends of the set and the chance of

identifying an impulse as a median to replace the image pixel is very less. For a current image f which is noisy, the median filter is a sliding square window of odd size that moves over the entire image, replaces individual pixel of the image by the median of all the pixels of the window.

IV. 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.

A. 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:

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

Assume that $\text{Max}_{i,j}$ and $\text{Min}_{i,j}$ mean the maximum and minimum gray-scale values in the current working window $W_{i,j}$, respectively, and let $\text{Max}_{i,j}$ and $\text{Min}_{i,j}$ 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:

$$\begin{aligned} \text{Max}_{i,j} &= \text{Max}_{i,j-1}, & \text{if } \text{Max}_{i,j-1} \geq \text{Max}_{i,j} \\ &= \text{Max}_{i,j}, & \text{otherwise} \end{aligned} \quad (2)$$

$$\begin{aligned} \text{Min}_{i,j} &= \text{Min}_{i,j-1}, & \text{if } \text{Min}_{i,j-1} \geq \text{Min}_{i,j} \\ &= \text{Min}_{i,j}, & \text{otherwise} \end{aligned} \quad (3)$$

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

$$N_{\max} = \begin{cases} \text{Max}_{i,j}, & \text{if } \text{Max}_{i,j-1} = \text{Max}_{i,j} \\ 255, & \text{otherwise} \end{cases} \quad (4)$$

$$N_{\min} = \begin{cases} \text{Min}_{i,j}, & \text{if } \text{Min}_{i,j} = \text{Min}_{i,j-1} \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

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 $\text{Max}_{i,j}$ is equal to $\text{Max}_{i,j-1}$, it is very possible that the intensity value of “salt” noise in current image is identified. Hence, we set N_{\max} to $\text{Max}_{i,j}$. On the contrary, if $\text{Max}_{i,j}$ is not equal to $\text{Max}_{i,j-1}$, we cannot conclude that the value of $\text{Max}_{i,j}$ 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.

B. 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).

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

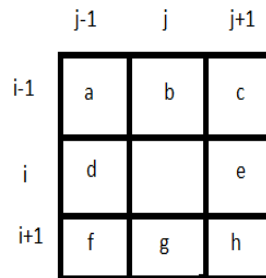


Fig.1.Those pixels around the current pixel

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

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 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:

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

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:

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

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.

V. EXPERIMENTAL RESULTS

In this section, we compare our method with an 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.

A wide range of noise ratios varied from 10 % to 90% with increments of 10% is 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 I 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 II, 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.

TABLE I

COMPARISONS OF RESTORATION RESULTS IN PSNR (DB) FOR A IMAGE CORRUPTED BY FIXED - VALUED IMPULSE NOISE

TABLE II

COMPARISONS OF RESTORATION RESULTS IN MSE (M) FOR A REFERENCE IMAGE CORRUPTED 10 TO 90% BY 10 TO 90% FIXED-VALUED IMPULSE NOISE

Noise Density	Decision Based Algorithm	Proposed 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

Noise Density	Decision Based Algorithm	Proposed Algorithm
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

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 Fig.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 Fig. 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.

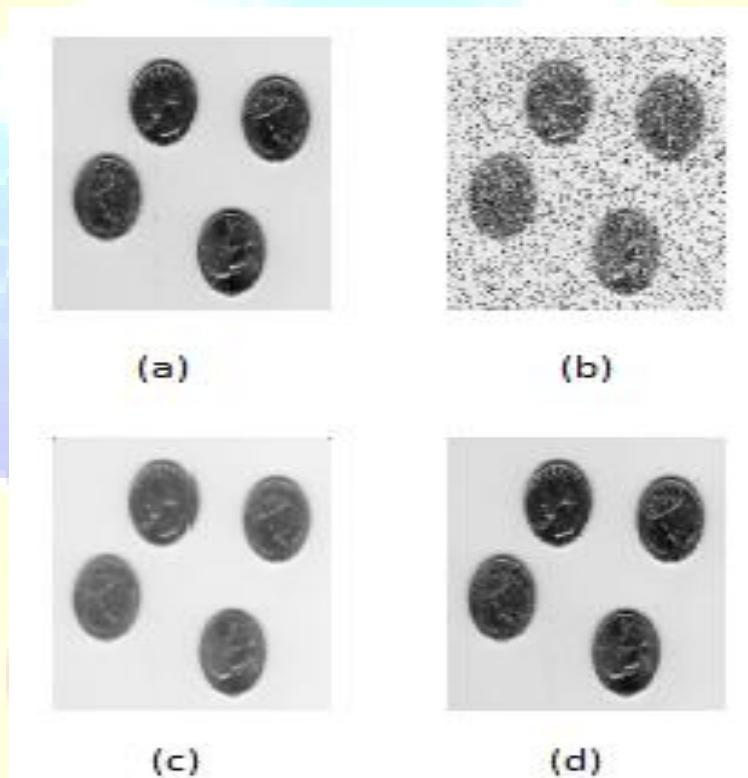


Fig.2 shows restoration results of two methods in restoring corrupted image.(a) Original noise-free image, (b) corrupted image with 20% impulse noise, (c) Decision based algorithm (d) Proposed algorithm.

VI. 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.

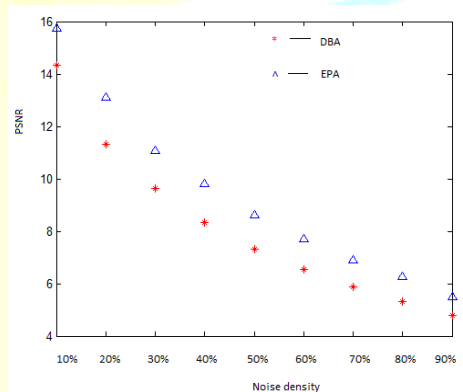


Fig.3 Comparison of restoration results in PSNR for Decision Based Algorithm and Proposed Algorithm

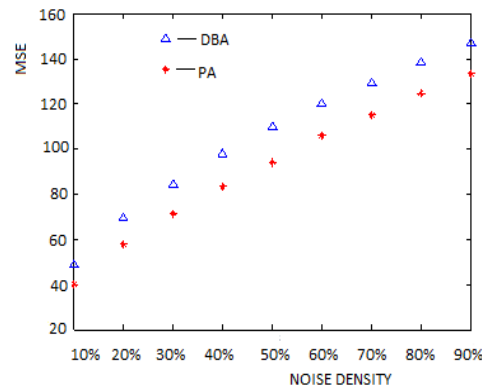


Fig.4 Comparison of restoration results in MSE for Decision Based Algorithm and Proposed Algorithm

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