Removal of High Density Impulse Noise from Color Images Using an Adaptive Fuzzy Filter

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***Abstract*—Low density impulse noise can be successfully denoised by traditional median filter. But the performance badly deteriorates if the noise density is high. Recently fuzzy-based adaptive median filter has been introduced to handle high density noise in grayscale images. To make it more generalized in this paper we develop an adaptive fuzzy median filter to remove impulse noise from color images. Here we use fuzzy filter with fully adaptive and automatically adjustable threshold value on each component of RGB color space to remove the noise. Finally concatenation is applied to RGB components for restoring the original image. Experimental result confirms the superiority of the proposed method compared to the state-of-the-art median filtering approaches in terms of both denoising and detail preservation.**

Keywords-impulse noise, adaptive fuzzy median filter, threshold value, peak signal to noise ratio, mean square error.

I. INTRODUCTION

Impulse noise is the main source of image degradation which occurs during acquisition, transmission or due to faulty memory locations in hardware. In the corrupted image some of the pixels of original image are replaced with new pixels having luminance value equal to minimum or maximum allowable dynamic range (e.g. 0 or 255). The noise density varies depending on various factors such as reflective surfaces, atmospheric variations, communication channels and so on. Noise reduction is an important step in many applications (e.g. pattern recognition, edge detection, data compression, image segmentation, feature extraction etc.), since the performances of subsequent image processing tasks are strictly dependent on the success of noise removal operation [1]. However, suppressing the impulse noise from corrupted color image is a difficult task in image processing field, as the restoration filter distort useful information while removing noise.

Compared to the grayscale image each pixel in color image is represented by three values that can be considered as a vector in 3D space e.g. RGB color space [2]. Once linear filter was a primary tool in the development of image processing applications but its performance is poor in the presence of noise. Later non-linear filters were developed to improve the limitation of linear filters. Median filter is the most common non-linear filter that can be applied for each color space to remove impulse noise. Different median filters were proposed, such as standard median filter [3], adaptive median filter [4], hybrid median filter [5], decision based median filter [6], [7], vector median filter [8], weighted median filter [9], switching median filter [10], rank ordered median filter [11] etc. But the main drawback of these filters is that the noisy pixels are replaced by some median value in their vicinity without taking into account the local features such as possible presence of edges. Hence if the noise density is high the performances of the filters are low for detail preservation. Robust estimation algorithm [12], diagonal sorting algorithm [13], adaptive variational method [14], integrated fuzzy additive and impulse noise reduction method [15] were proposed to remove high density noise. But the main disadvantage of these methods is that the quality of the restored image degrades as the noise level increases over 50%.

Recently fuzzy based adaptive filtering technique is introduced as an attractive alternative. Thus, for achieving better result, previously we used fuzzy-based median filtering, which is applicable to grayscale images in removing impulse noise [16]. To overcome this limitation, in this paper we focused on denoising color images using fuzzy based median filter that avoid the drawbacks of standard median filter and its variants in removing high density impulse noise with fine detail preservation.

The remainder of this paper is organized as follows. The methodology is described in section II. Section III contains simulation results and discussions. Finally conclusions are drawn in section IV.

II. METHODOLOGY

We divided the total noise reduction process in two steps, such as primary processing and noise reduction stage.

A. Primary processing

When we convert RGB image into grayscale we lost a lot of information, Hence, it is difficult to get back RGB image from the gray image. In the primary processing, at first we make three images by pre-allocating the original image pixels with zeros and then put R, G and B components separately to each image.

B. *Noise Reduction Stage*

For each RGB component the noise reduction stage is divided into three distinct steps [16]:

1. *Noise extimation*: Considering the information of neighbouring pixel we can estimate noise of the corrupted image. The primary step is to determine the central pixel $J(i,j)$ of a 3×3 or 5×5 filter windows lies in the trimming range or not. If not consider the pixel as corrupted to some extend and need to replace. At first a 3×3 filter is used by defining minimum and maximum grayscale values in the window as g_{min} and g_{max}, respectively. Then the number of pixels within the window are counted as K , *if* $\lfloor J\ (i + n, j + m) / 4 \rfloor$ is not equal to $\lfloor g_{max}/4 \rfloor$ or $\lfloor g_{min}/4 \rfloor$, where m,n € [-1,+1]. If K=0, repeat the above process for window size 5×5 and m,n € [-2,+2]. If K>0, the center pixel $J(i,j)$ is not in trimming range, then the estimated value of this pixel will be the median value K pixels. Otherwise, if K=0, the pixel is in trimming range and the estimated value is equal to the average value of four neighboring pixels.

2. *Calculation of the degree of corruption:* Based on the degree of corruption we need to calculate fuzzy membership value. Fuzzy membership value for each corrupted pixel can be determined using the following equation [6]:

$$\mu[w(i,j)] = max\ \ (1 - \frac{D}{E(i,j)}|J(i,j) - E(i,j)|) \qquad (1)$$

$$\mathrm{D} = median \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} |J(i,j) - E(i,j)| \qquad (2)$$

Where, fuzzy membership value $\mu[w(i,j)]$ € [0,1] and $E(i,j)$ is the estimated value of each pixel.

The membership value $\mu[w(i,j)]$ determines the extend of corruption by impulse noise of pixel (i,j). If the difference between the intensity value of noisy pixel and the estimated value equals to zero then the pixel is noise free and membership value will equal to 1. Otherwise, the pixel is considered as corrupted one and the membership value will be determined using the above equation.

3. *Image restoration:* Filter based on the above membership values generate the following output,

$$Y(i,j) = E(i,j) + \mu[w(i,j)] \times [J(i,j) - E(i,j)]) \qquad (3)$$

Where noise free pixels remain unaltered and noisy pixels replaced by weighted average of $J(i,j)$ and $E(i,j)$.

Finally, concatenation of R, G, B components (image) is applied to all denoised color components to produce desire output image.

III. Simulation Reports and Results

The algorithm is tested on various noisy color images and compared with standard filters namely standard median filter (SMF) [3], adaptive median filter (AMF) [4], hybrid median filter (HMF) [5], decision based median filter (DBMF) [6], [7], robust estimation algorithm (REA) [12]. Images of size 512×512 pixels have been used in our simulation. The test images are corrupted by salt and pepper (impulse) noise of different density ranging from 10% to 97%. In addition to image quality, the performance of the developed method and other standard methods are quantitatively measured by the parameters such as Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE).

A. *Performance Characteristics*

Peak Signal to Noise Ration (PSNR):

$$PSNR = 10log_{10}\left(\frac{255^2}{MSE}\right)\ dB \qquad (4)$$

Where MSE is the mean square error, and is defined as,

$$MSE = \frac{\sum_X \sum_y (I(x,y) - Y(x,y))^2}{MN} \qquad (5)$$

Where I is the original corrupted color image and Y is the restored image of size M×N pixels.

B. *Comparison of PSNR and MSE*

We have compared the performance of our method with the existing methods using the standard "Lena" image. Fig.1 and Fig.2 illustrate the comparison graphs of PSNR values obtained after applying different filters (SMF, AMF, HMF, DBMF, REA and the proposed method) on the corrupted image, where injected salt and pepper noise ranging from 10% to 97%. The lowest value of MSE and the highest value of PSNR of the proposed method confirm that it performs better for removing high density impulse noise from color images.

Fig.3 shows the visual (qualitative) comparative results in restoring the original image from high density additive impulse noise using 'Lena' image. We also show the visual results (in Fig. 4 to Fig. 7) using other images for different noise levels. Both quantitative and qualitative measures confirm the effectiveness of our proposed method compared to the state-of-the-art filtering methods. The present method is more generalized as it removes high density impulse noise from color as well as grayscale images, where as the previous adaptive fuzzy filter [16] was designed for only grayscale image.

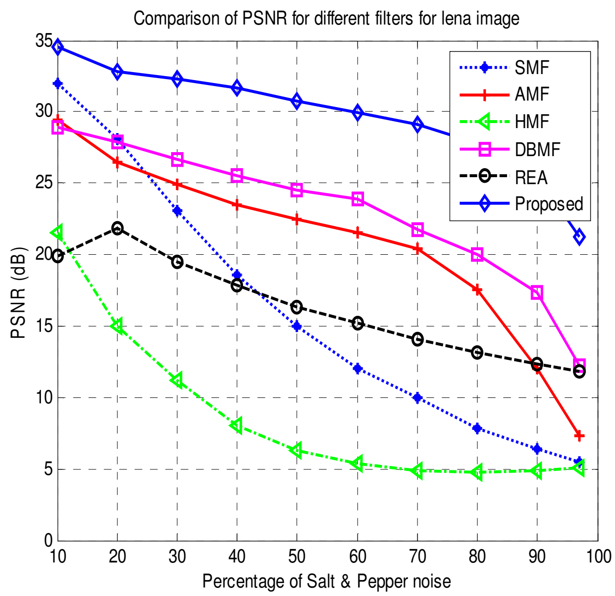


Figure 1. Comparison of PSNRs for the restores "Lena" image obtained after applying different filters at different noise densities.

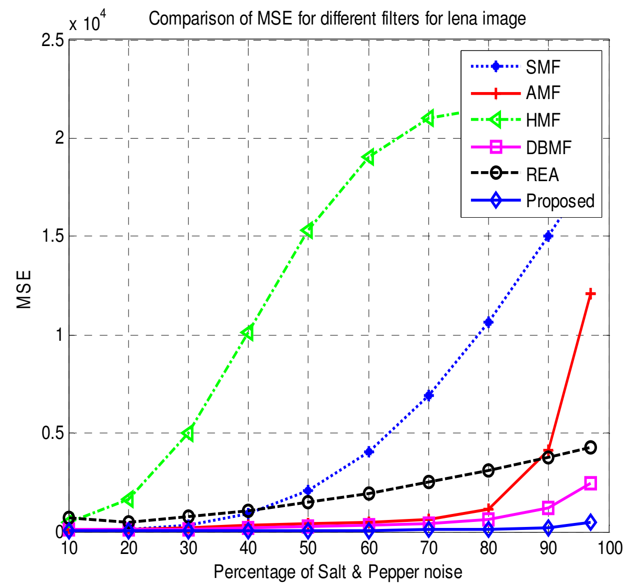


Figure 2. Comparison of MSEs for the restores "Lena" image obtained after applying different filters at different noise densities.

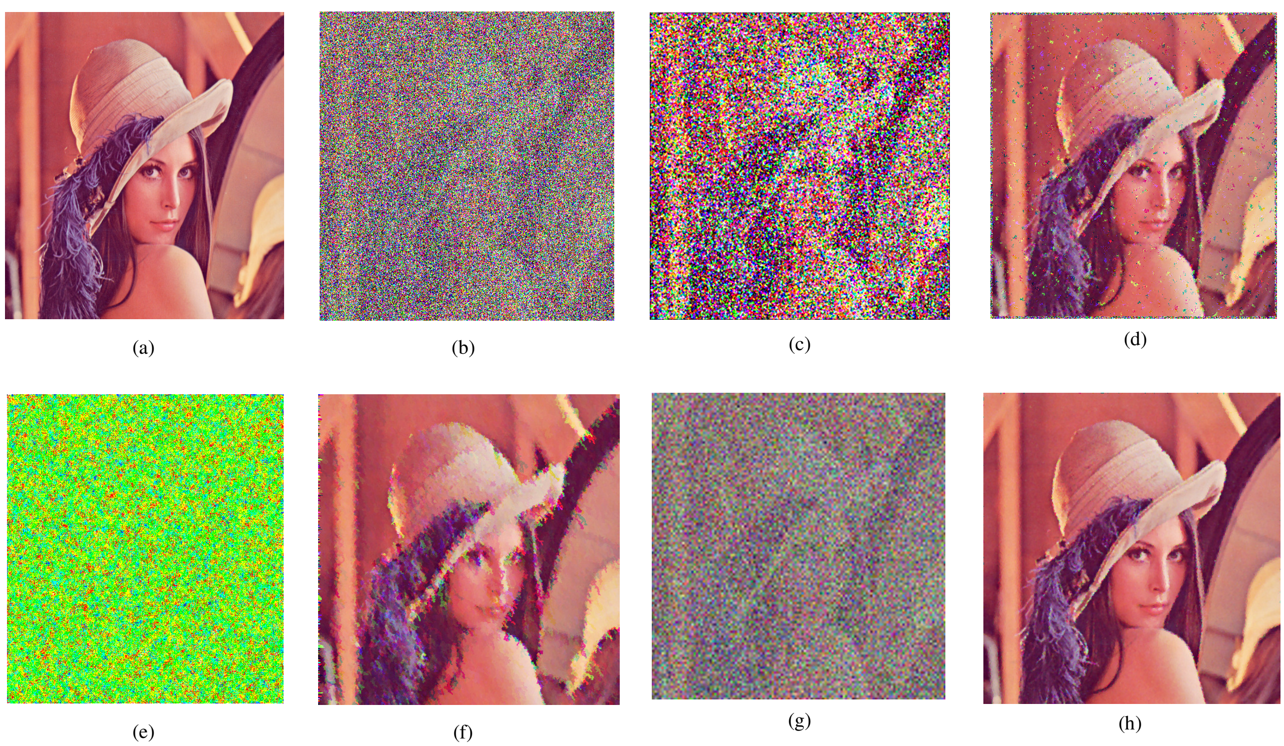
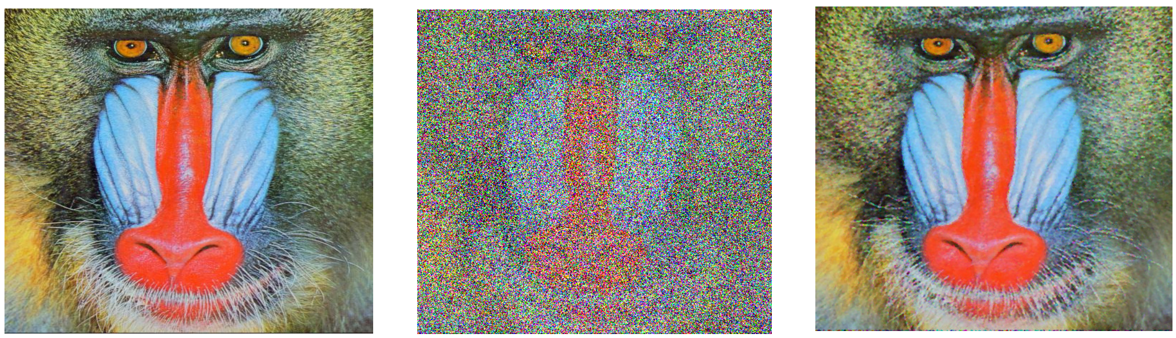


Figure 3. Restoration results of different filters : (a) original color image; (b) corrupted image by 80% salt and pepper noise; (c) SMF (MSE: 10655.07, PSNR : 7.86dB); (d) AMF (MSE : 1150.67, PSNR : 17.52 dB); (e) HMF (MSE : 21517.70, PSNR : 4.80dB); (f) DBMF (MSE : 653.43, PSNR : 19.98dB); (g) REA (MSE 3090.12:, PSNR : 13.23dB); (h) proposed filter (MSE : 108.92, PSNR : 27.76dB).

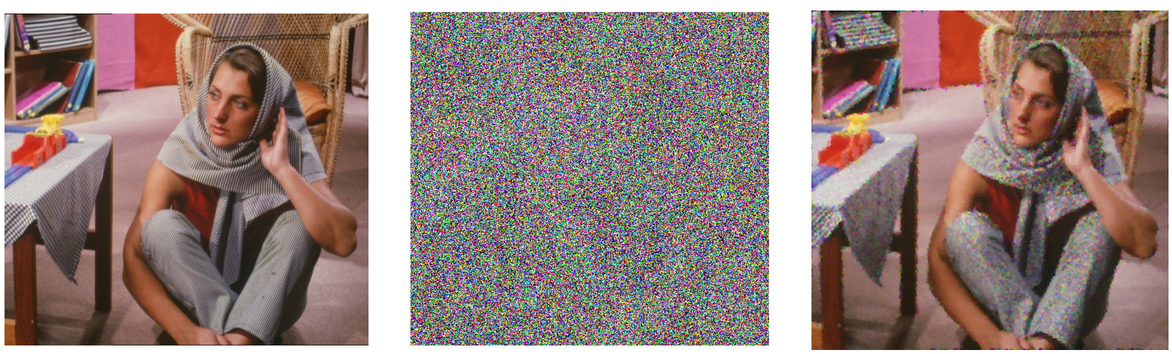
(a) (b) (c)

Figure 4. Result obtained by our method for the noise level 60% (a) Original image (b) Corrupted image (c) Denoised image.



(a) (b) (c)

Figure 5. Result obtained by our method for the noise level 70% (a) Original image (b) Corrupted image (c) Denoised image.



(a) (b) (c)

Figure 6. Results obtained by our method for the noise level 90% (a) Original image (b) Corrupted image (c) Denoised image.

(a) (b) (c)

Figure 7. Results obtained by our method for the noise level 97% (a) Original image (b) Corrupted image (c) Denoised image.

For implementing our proposed method we have used Matlab Version R2009b with Windows 7 operating system, Intel core i5 2430M processor with 6 GB RAM. Table I shows the computation time statistics.

TABLE I. COMPUTATION TIME (SECONDS) OF THE PROPOSED METHOD

RGB Color Space	Primary process	Noise Filtering	Total Computation time
RED Space	0.009217 (s)	13.772862 (s)	36.526413 (s)
GREEN Space	0.003609 (s)	11.425624 (s)	
BLUE Space	0.003664 (s)	11.311437 (s)	

Two minor limitations of our method are: (i) for low density noise removal the performance of our method is slightly lower than AMF and (ii) noise detection phase is a bit time consuming.

IV. CONCLUSION

Noise reduction and detail preservation are two most important factors in modern image enhancement filters, specially for color images. In this paper, we proposed a noise removal technique using adaptive fuzzy filter that has been tested under a wide range (from 10% to 97%) of noise densities on color images. Experimental results show that proposed method exhibits better performance in comparison with other existing filtering methods in terms of both qualitative (visual) and quantitative (MSE and PSNR figures) points of view. Our future work will focused on computation time improvement as well as removal other high density noises.

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