A Study on a Liner Filter for Restoration of Images Corrupted by Mixed Noises

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ABSTRACT

Both impluse noise and AWGN (additive white Gaussian noise) are easily corrupted into images, during signal transmission and acquisition. Thus, an algorithm for removing both noises is represented in this paper. An impulse noise detection step can effectively separate impulse noise with AWGN, then in the noise filtering step, by using several parameters, not only impulse noise but also AWGN can be reduced. The value of those parameters are automatically changeable when the standard deviation of AWGN, the impulse noise density, and the spatial distances between pixels are different. Results of computer simulations show that the proposed approach performs better than other conventional filters.

Keywords
impulse noise, AWGN, image restoration

Ⅰ. Introduction

Digital image processing has been greatly progressed besides the development of interrelated theories and researches. Data transformation from analog to digital is very important, and digital images are often corrupted by impulse noise and additive white Gaussian noise (AWGN) during signal acquisition and transmission. The most fundamental problem in image processing is how preserving uncorrupted pixels when removing noisy pixels simultaneously. The noise removal algorithms are also applied differently, according to the types of noise. For AWGN and impulse noise are mostly representative in all noise models, a great many researches have been studied to remove them from degraded images.

Impulse noise is characterized by replacing original image's pixel values with extremely high or low values. Impulse noise is easily introduced into images during signal transmissions. The most fundamental algorithm for impulse noise removal is the median filter. Moreover, for good edge preserving performance, many algorithms based on median filter have been studied actively, and the adaptive switching median filter (ASM) not only removes impulse noise very well but also preserves detail information efficiently at the same time [1]-[3].

Generally, AWGN is systematically superposed into images during signal acquisition. Besides, AWGN is characterized by adding to each image pixel a value from a zero-mean Gaussian distribution during image acquisition. Ideally, removing AWGN would involve smoothing inside the distinct regions of an image without degrading the sharpness of their edges. And the mean filter, which is based on calculating the mean value of pixels in filtering mask as the output value to replace the centre pixel, is a representative method in removing AWGN [4].

Although images are usually corrupted by impulse noise and AWGN, there hasn't been much work carried out on building filters that can effectively remove them both. Though mean filter or median filter is applicable in complex noise environment, in case of impulse noise with large noise density and AWGN with large standard deviation, the removal image is badly degraded in feature. So the Trilateral filter was proposed in order to overcome this problem. According to more detailed calculation and separation of weight value parameters, the

Trilateral filter method presents excellent noise removal characteristics. However, in regions of high local noise density corruption, the effectiveness of impulse noise still is deteriorated.

An image restoration algorithm using variety weighted parameters was proposed in this paper. We detected the impulse noise using a threshold value, earned by calculating the intensity differences between pixels nearby with each other in localized window, then used the result to estimate the variation value of AWGN. The proposed method removed complex noise with parameters of weight values by calculating the intensity difference and the spatial distance between pixels in filtering mask. We used a test image corrupted by AWGN as well as impulse noise with various densities for simulation, and also used PSNR to evaluate restoration performance.

II. Conventional Filters

1. Mean filter

Mean filter is the most basic linear type method for removing AWGN, denoted as (1). The method replaces center pixel value by calculating mean value as output value [3].

$$y_{i,j} = \frac{1}{w \times w} \sum x_{k,l}, \qquad (k,l) \in \Omega^{w}_{k,l} \tag{1}$$

Where, $x_{k,l}$, $y_{i,j}$, (i,j), and (k,l) are denoted as input value, output value and spatial coordinates of center pixel and adjacent pixels in filtering mask. Besides $w \times w$ and $\Omega^{w}_{k,l}$ are represented as the mask size and the region of the pixels within the mask in (2).

$$\Omega^{w}_{k,l} = \left\{ k,l \;\middle|\; \begin{array}{l} i-(w-1)/2 \le k \le i+(w-1)/2 \\ j-(w-1)/2 \le l \le j+(w-1)/2 \end{array} \right\} \tag{2}$$

2. Median filter

A delegated nonlinear filter which is named as median filter, can be denoted in equation (3). All pixels in the mask are arranged into ascending order, then median value is chosen as the output value [1].

$$y_{i,j} = \text{median}\{x_{k,l}\}, \qquad (k,l) \in \Omega^{w}_{k,l} \tag{3}$$

3. ASM filter

The adaptive switching median (ASM) filter, after estimating by the noise detection step only removes noisy pixels, and filtering mask size can be adaptively changeable. The method can decrease the degradation phenomenon by remaining uncorrupted pixels [2].

$$y_{i,j} = \begin{cases} m_{i,j}, & \text{if} \quad f_{i,j} = 1,\ M > (w \times w)/2 \\ x_{i,j}, & \text{otherwise} \end{cases} \tag{4}$$

Where, $f_{i,j} = 1$ means the current pixel is a impulse noise while $f_{i,j} = 0$ means it is an uncorrupted pixel. And $m_{i,j}$ and M are represented as the median value and the number of uncorrupted pixels in the mask.

III. Proposed Algorithm

The remaining noise or the degradation phenomenon occurs in complex noise environment by using the same weight parameter. Therefore, in this paper, through the noise detection step the location of impulse noise in image was exactly confirmed, and during the noise filtering step complex noise was removed by adding different weight values to each pixel in the filtering mask.

1. Impulse noise detection

In case that the location of impulse noise would be exactly detect from noisy image, an more improved noise removal result can be earned through noise filtering step. So, in this paper, after ascending pixels in mask region, the difference value between sorted pixels is used to detect the location of impulse noise.

The noisy image corrupted by both impulse noise and AWGN is denoted in equation (5).

$$x_{i,j} = \begin{cases} 0, & \text{with probability} \quad p \\ 255, & \text{with probability} \quad p \\ x^{0}_{i,j} + n_{i,j}, & \text{with probability} \quad 1-2p \end{cases} \tag{5}$$

From above, (i,j), $x^{0}_{i,j}$, $x_{i,j}$, $n_{i,j}$, and p are expressed as the space coordinates, the value of original pixel, the value of noisy pixel, the amplitude of AWGN, and the probability of the impulse noise respectively. By making the pixels in the mask in an ascending order, the sequence $\hat{x}$ is established as equation (6).

$$\hat{x} = \{X[1], X[2], \cdots, X[N]\}, \quad (N = w \times w) \tag{6}$$

Where, $X[n]$ represents as n-th biggest pixel in sequence $\hat{x}$ and the intensity difference between each pair of adjacent pixels in $\hat{x}$ is expressed as equation (7).

$$D[n]=X[n+1]-X[n],\qquad (1\le n\le N-1) \tag{7}$$

To figure out the boundaries by finding the maximum intensity differences in two clusters divided by median value are defined as in equation (8).

$$\begin{aligned} b_1&=\max\{D[n_1]\}, && (1\le n_1\le (N-1)/2)\\ b_2&=\max\{D[n_2]\}, && ((N+1)/2\le n_2\le N-1) \end{aligned} \tag{8}$$

Where, b_1 is the maximum difference value smaller than the region of median value while b_2 is the maximum difference value larger than the region of median value. If the current pixel belongs to the cluster $b_1\le x_{i,j}<b_2$, it would be considered as uncorrupted pixel if $f_{i,j}=0$. When it belongs in either of this two clusters $0\le x_{i,j}<b_1$ or $b_2\le x_{i,j}\le 255$, it would be considered as a noise candidate.

2. Noise filtering

The proposed method, using the standard deviation estimated in the region without impulse noise pixels, removed complex noise, the combination of the impulse weight value, the AWGN weight value and the spatial distance weight value.

Other pixels except for impulse noise are regarded as AWGN in the noisy image, and the standard of AWGN is expressed as (9).

$$\hat{\sigma}_G=\sqrt{\frac{\pi}{2}}\,\frac{\sum_{i,j=1}^{m,n}|(u*L)_{i,j}|\,W_I(x_{i,j})}{\sum_{i,j=1}^{m,n}W_I(x_{i,j})}, \tag{9}$$

$$\text{where}\quad L=\begin{bmatrix}-1&-1&-1\\-1&8&-1\\-1&-1&-1\end{bmatrix}$$

Where, L is the Laplacian filter, $*$ represents the convolution, and (m,n) is the size of whole image. Besides, $W_I(x_{i,j})$ is the impulse weight value corresponding to the spatial coordinates (i,j) of image. In case that $f_{i,j}=1$, the impulse weight value would be $W_I(x_{i,j})=0$, else it would be $W_I(x_{i,j})=1$.

From (9), $2\hat{\sigma}_G$ is denoted as the threshold value about AWGN and the AWGN weight value $W_G(x_{i,j},x_{k,l})$ between center pixel and its neighboring pixels is defined as (10).

$$W_G(x_{i,j},x_{k,l})=\exp\left(-\frac{|x_{i,j}-x_{k,l}|}{2(2\hat{\sigma}_G)^2}\right) \tag{10}$$

And the spatial distance weight value $W_S(x_{i,j},x_{k,l})$ between center pixel and its neighboring pixels in mask is denoted as (11).

$$W_S(x_{i,j},x_{k,l})=\exp\left(-\frac{(i-k)^2+(j-l)^2}{2\sigma_S^2}\right) \tag{11}$$

Where σ_S is the threshold about spatial distance. And $\sigma_S=0.5$ when current pixel is an impulse noise as $f_{i,j}=1$, else $\sigma_S=5$.

In this paper, by the spatial distance weight value W_S, the impulse weight value W_I and the AWGN weight value W_G, the total weight value W applied between the center pixel and its neighboring pixels was proposed as in (12).

$$\begin{aligned} &W(x_{i,j},x_{k,l})=\\ &\qquad W_S(x_{i,j},x_{k,l})\,W_G(x_{i,j},x_{k,l})\,W_I(x_{i,j}) \end{aligned} \tag{12}$$

Where, different weight value was applied to different pixel in the mask, by the spatial distance between pixels and the type of noise superposed on the center pixel and its neighboring pixels. Which means, the weight value is being decreased while the spatial distance between pixels increases, large weight value is applied to AWGN while small weight value is applied to impulse noise.

At last, the image would be restored in both impulse noise and AWGN environment by using equation (13).

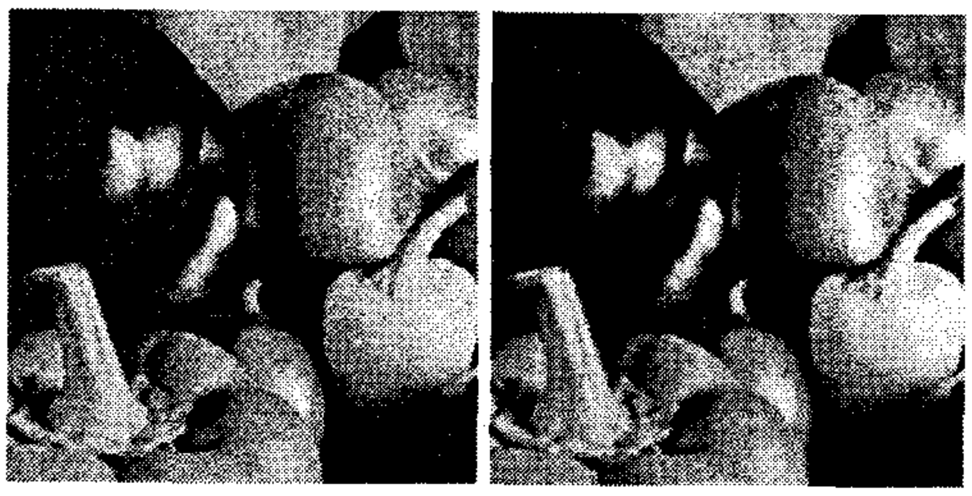
$$y_{i,j}=\frac{\sum_{k,l\in\Omega_{k,l}^{w}}W(x_{i,j},x_{k,l})\,x_{k,l}}{\sum_{k,l\in\Omega_{k,l}^{w}}W(x_{i,j},x_{k,l})} \tag{13}$$

Ⅳ. Simulation Results

We used the 512×512 "Peppers" image, corrupted complexly by impulse noise with density of 20% and AWGN with the standard deviation of 10 for the simulation. Besides, the

(a) Original image (b) Noisy image

(c) Mean filter (d) Median filter



(e) ASM filter (f) Proposed method

Fig. 1. Restoration results of noisy image (impulse noise $p = 20\%$, AWGN $\sigma = 10$).

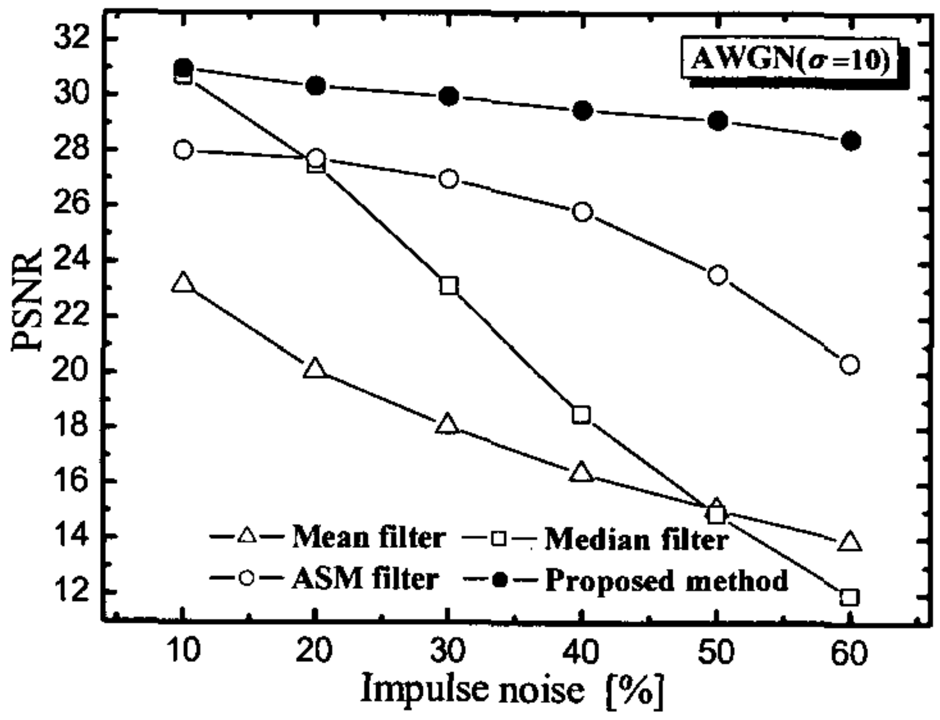


Fig. 2. PSNR with variation of impulse noise.

peak signal to noise ratio (PSNR) is also provided to evaluate restoration performance. The proposed method was compared with conventional algorithms. Moreover, parts of enlarging restoration images were represented to confirm the noise removal effect visually.

The restoration result of "Peppers" image is shown in Fig. 1. Where (a) is the original image while (b) is the corrupted image by impulse noise with the density of 20% and AWGN with the standard deviation of 10. And (c) to (f) are the restoration results by the median filter, the mean filter, the ASM filter and the proposed method respectively. From the figure, the blurring phenomenon occurs in edge region because conventional methods did not remove AWGN and impulse noise separately. On the other hand, the proposed method showed a excellent visual result, by removing the noise separately while preserving the edge region of image simultaneously. And Fig. 2 is to compare the noise removal results by changing the impulse noise density with 10% to 60% while fixing the standard deviation of AWGN with 20. The proposed method shows better PSNR performance than other methods in any noisy standard deviation.

V. Conclusion

An image restoration method for separating and removing AWGN and impulse noise was proposed in this paper. weighted values in mask are established more exactly by detecting the spatial location of impulse noise and calculating the standard deviation of AWGN.

From the simulation result, the proposed method separated and removed impulse noise as well as AWGN while preserving edge regions simultaneously, and also showed a better PSNR result. It is believed that the proposed method would be widely used in many image processing fields.

References

[1] D. R. K. Brownrigg, "The weighted median filter", Commun. ACM, vol. 27, no. 8, pp. 807-818, Aug. 1984.

[2] T. Sun and Y. Neuvo, "Detail-preserving median based filters in image processing", Pattern Recognit. Lett., vol. 15, pp. 341-347, Apr. 1994.

[3] A. Restrepo and A. C. Bovik, "Adaptive trimmed mean filters for image restoration", IEEE Trans. Signal Process., vol. 36, pp. 1326-1337, Aug. 1988.

[4] R. Garnett, T. Huegerich, C. Chui and W. He, "A universal noise removal algorithm with an impulse detector", IEEE Transt. Image Process., vol. 14, pp. 1747-1754, Nov. 2005.