

Direction Information Concerned Algorithm for Removing Gaussian Noise in Images

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Abstract—In this paper an efficient algorithm is proposed to remove additive white Gaussian noise(AWGN) with edge preservation. A function is used to separate the filtering mask to two sets according to the direction information. Then, we calculate the mean and standard deviation of the pixels in each set. In order to preserve the details, we also compare standard deviations between the two sets to find out smaller one. Corrupted pixel is replaced by the mean of the filtering window's median value and the smaller set's mean value that the rate of change is faster than the other one. Experiment results show that the proposed algorithm outperforms with significant improvement in image quality than the conventional algorithms. The proposed method removes the Gaussian noise very effectively.

Index Terms— Additive white Gaussian noise, direction information, set, standard deviation.

I. INTRODUCTION

IT is well known that the quality of digital image is degraded by various noises originating from imaging system severely. An image gets corrupted with additive white Gaussian noise(AWGN) during acquisition, transmission, reception, and retrieval processes. As a result, there is degradation in the visual quality of an image. Image denoising is usually required to be performed before display or further processing like segmentation, feature extraction, texture analysis[1].

The purpose of denoising is to remove the noise while retaining the edges and other detailed features as much as possible. But, good smoothing causes blurring of edges whereas retaining edges suppresses noise insignificantly. That is, noise suppression and edge preservation are two objectives of just opposite nature. Thus, it has been a great challenge to scientists and engineers since many years to develop very efficient image denoising schemes for suppressing the noise while preserving the edges and fine details as far as possible [1][2].

Traditionally, AWGN is suppressed using linear spatial-domain filters such as Mean filter(MF), Gaussian

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filter(GF)[2]. Linear techniques possess mathematical simplicity but have the disadvantage of yielding blurring effect. They also do not perform well in the presence of signal-dependant noise. Non-linear filters are then developed to avoid the aforementioned disadvantages. Standard Median(SM) filter is quite popular nonlinear denoising filter because it provides excellent noise reduction capabilities with considerably less blurring than linear smoothening filters of same size[3]. However, the SM filter tends to modify not only noise pixels but also noise-free pixels. This will result the elimination of fine details such as thin lines and corner or distortion in the images. In order to avoid distorting details, many other median filters were found, such as Center Weighted Median(CWM) filter and Hybrid Median(HM) filter[1]-[3]. But they effectively removes low density Gaussian noise with edges are better preserved. In all these methods complexity of the algorithm is high[4]-[8].

In this paper we proposed a simple and efficient method to remove low to high density Gaussian noise with edges are better preserved. The proposed algorithm is used to separate the filtering mask to two sets according to the direction information. Then, we calculate the mean and standard deviation of the pixels in each set. In order to preserve the details, we also compare standard deviations between the two sets to find out smaller one. Corrupted pixel is replaced by the mean of the filtering window's median value and the smaller set's mean value that the rate of change is faster than the other one.

The outline of this paper is Section II reviews some conventional algorithms. Section III introduces the proposed algorithm for removing the Gaussian noise, Section IV discusses the experiments and the comparison results of the proposed algorithm with the other conventional algorithms. Finally we make a brief conclusion in Section V.

II. CONVENTIONAL ALGORITHM

A. Mean filter

MF is a straightforward spatial-domain technique for image restoration. MF is denoted as (1)[4].

$$Y(i, j) = \frac{1}{Z \times Z} \sum_{i,j}^Z X(i+s, j+t) \quad (1)$$

$Z \in W, \quad Z = 2N + 1$

Here, W is mask size, and it can be defined as (2).

$$W = \{(s, t) | -N \leq s \leq N, -N \leq t \leq N\} \quad (2)$$

Here, (s, t) is the position of the pixels in the mask and the mask size is $(2N+1) \times (2N+1)$.

B. Gaussian filter

The two-dimensional digital Gaussian filter can be expressed as:

$$G(x, y) = \frac{1}{\sqrt{2\pi}\sigma} \exp(-x^2 + y^2 / 2\sigma^2) \quad (3)$$

Where σ^2 is the variance of Gaussian filter, and the size of the filter kernel $1 (-1 \leq x, y \leq 1)$ is often determined by omitting values lower than five percent of the maximum value of the kernel. The one-dimensional Gaussian filter is expressed as:

$$G(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp(-x^2 / 2\sigma^2) \quad (4)$$

When the Gaussian filter is used for noise suppression, a large filter variance is effective in smoothing out noise, but at the same time it distorts those parts of the image where there are abrupt changes in pixel pixels. The Gaussian filter also gives rise to edge position displacement, the vanishing of edges, and phantom edges.

C. Standard median filter

SM filter is the most important and popular nonlinear filter which exploits the rank-order information of pixel intensities within a filtering window and replaces the center pixel with the median value [5]. However, the SM filter tends to modify not only noise pixels but also noise-free pixels. This will result the elimination of fine details such as thin lines and corner or distortion in the images.

D. Hybrid median filter

A square-shaped mask can erode the corners of rectangular objects, while a cross-shaped neighborhood mask will leave corners intact. This observation has lead to the development of a hybrid median filter, which is a multiple-step pixels-ranking algorithm. For the two direction, 3×3 hybrid median filter included in the tutorial, the median pixels values of the neighbors forming a "x" shape are computed, as illustrated in Fig. 1.

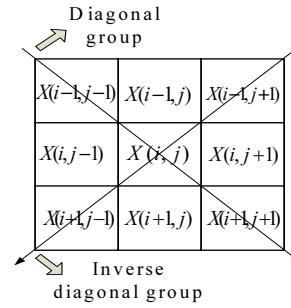


Fig. 1. Hybrid median mask.

These two pixels values, along with the pixels value of the central pixel of the neighborhood, are then placed in ascending order. The median value of the three resulting pixels then defines the pixels level of the filtered pixel. With repeated application, the hybrid median filter does not excessively smooth image details, and typically provides superior visual quality in the filtered image.

E. Center weighted median filter

CWM filter, which gives more weight to the center pixel and other pixels in the window are given weight for 1. The output $Y(i, j)$ of the CWM filter is given by

$$Y(i, j) = \text{med} \{X(i+s, j+t), 2K \forall X(i, j) \mid (s, t) \in W\} \quad (5)$$

Here, $2K$ is the value of weight which is given to the center pixel in the filtering window[5].

III. PROPOSED METHOD

In order to remove Gaussian noise efficiently and preserve the edges and fine details, in this paper first sort the pixels inside the processing window(in this paper uses 3×3 window) and found out the median value mid , then separate into two sets denoted by h and h' according to the direction information as Fig. 2.

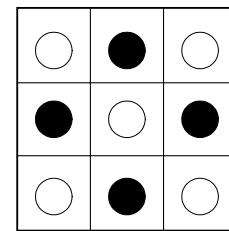


Fig. 2. Two sets of the mask.

In Fig. 2 the black dots are the pixels that involved in the set h and the white dots are the pixels which are contained in the set h' . Where h and h' can be defined as follows:

$$h = \begin{Bmatrix} X(i-1, j) & X(i, j-1) \\ X(i, j+1) & X(i+1, j) \end{Bmatrix} \quad (6)$$

$$h' = \begin{Bmatrix} X(i-1, j-1) & X(i-1, j+1) & X(i, j) \\ X(i+1, j-1) & X(i+1, j+1) & X(i, j) \end{Bmatrix} \quad (7)$$

Next, we calculated the standard deviation and the mean of each set, we define σ_{s1} and M_1 are the standard deviation and the mean of the set h . σ_{s2} and M_2 stand for the standard deviation and average of set h' . After defining these parameters, we compared σ_{s1} to σ_{s2} .

A. If $\sigma_{s1} \geq \sigma_{s2}$, the differences between these pixels which are in the set h are larger than the ones in the set h' . Then we try to smooth the set h as follows:

$$D_{s1} = \frac{mid + P_{s1}}{2} \quad (8)$$

Here, P_{s1} is the median value of the set h , the expression of P_{s1} is as follows:

$$P_{s1} = \text{median}\{h\} \quad (9)$$

Then the output after filtering is

$$Y(i, j) = \frac{M_1 + D_{s1}}{2} \quad (10)$$

B. If $\sigma_{s1} < \sigma_{s2}$, the rate of change in set h' is larger than set h , then we also try to smooth the pixels in the set h' use the mean of two median values that mid and the median value of the set h' .

$$D_{s2} = \frac{mid + P_{s2}}{2} \quad (11)$$

Here, P_{s2} is the median value of the set h' and it is defined as formula (12).

$$P_{s2} = \text{median}\{h'\} \quad (12)$$

So, in this case the value of the output after filtering is formulated as (13).

$$Y(i, j) = \frac{M_2 + D_{s2}}{2} \quad (13)$$

Because we process the noise pixel according to the result of comparing the standard deviations, proposed

method can remove AWGN while keeping detail information.

The structure of the proposed algorithm is shown Fig. 3.

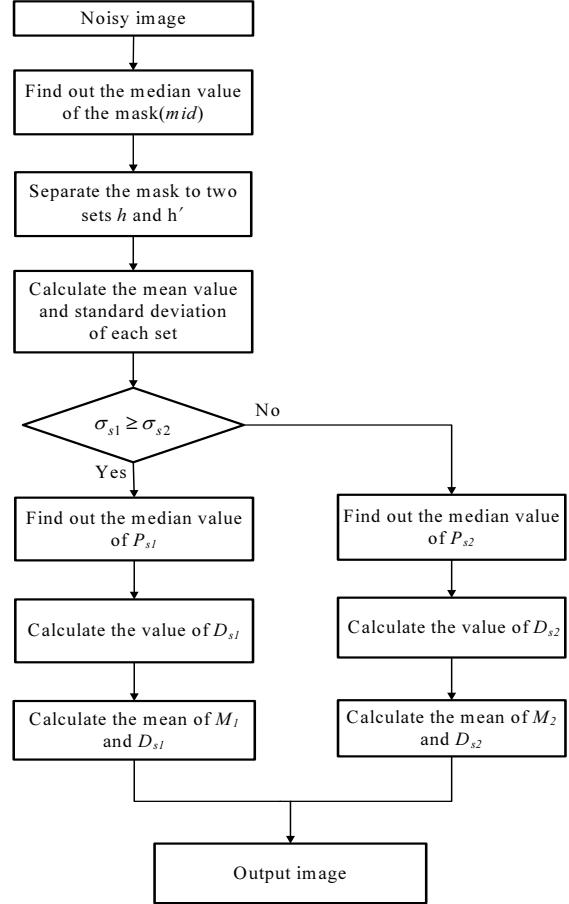


Fig. 3. Structure of the proposed algorithm.

IV. EXPERIMENT RESULT ANALYSES

In order to study the performance of the proposed algorithm, we compared the proposed algorithm with the Gaussian filter(GM), hybrid median(HM) filter, standard median(SM) filter, mean filter(MF), center weighted median(CWM) filter on a 8-bit gray image Barbara which size is 512×512 . In addition to the visual quality, the performance is quantitatively measured by the peak signal to noise ratio (PSNR).

$$\text{PSNR} = 10 \log_{10} \left(\frac{255^2 \times R \times C}{\sum_{i,j} O(i, j) - Y(i, j)} \right) \quad (14)$$

Where R and C are the total number of pixels in the horizontal and vertical dimensions of the images. $O(i, j)$

is the pixel value of original image, $Y(i, j)$ is filtered image's pixels, respectively.

Fig. 4 shows the result of the simulation for subjective visual quality comparison, where the standard deviation of the noise added to the original image is 20. In order to compare the result more clearly, we also plotted the profiles for line 250 of each restored image which are processed by different algorithms.

In the Fig. 4, (a) is the original test image, (b) is the noisy image that corrupted by AWGN with $\sigma = 20$. (c) ~ (h) show the result of restoration by GF(3×3), HM (3×3) filter, SM(3×3) filter, MF(3×3), CWM(3×3 , C=3) and the proposed filter respectively.

As shown in Fig. 4, the GF and HM filter remain a lot of Gaussian noise in the image.

The SM filter and MF can remove Gaussian noise effectively, but they damage the image's detail seriously. However, CWM filter performs better than the other conventional methods, the profile indicates that it also cannot preserve the edge well. As expected, the proposed filter is able to produce the most appealing visual results by successfully suppressing noise at the same time preserving image fine details.

PSNR values expressed in decibel of different filters are plotted against standard deviation of AWGN which are shown in Fig. 5 for Barbara image, respectively. From Fig. 5, proposed method performs better than conventional algorithms, especially at high density noise environment.

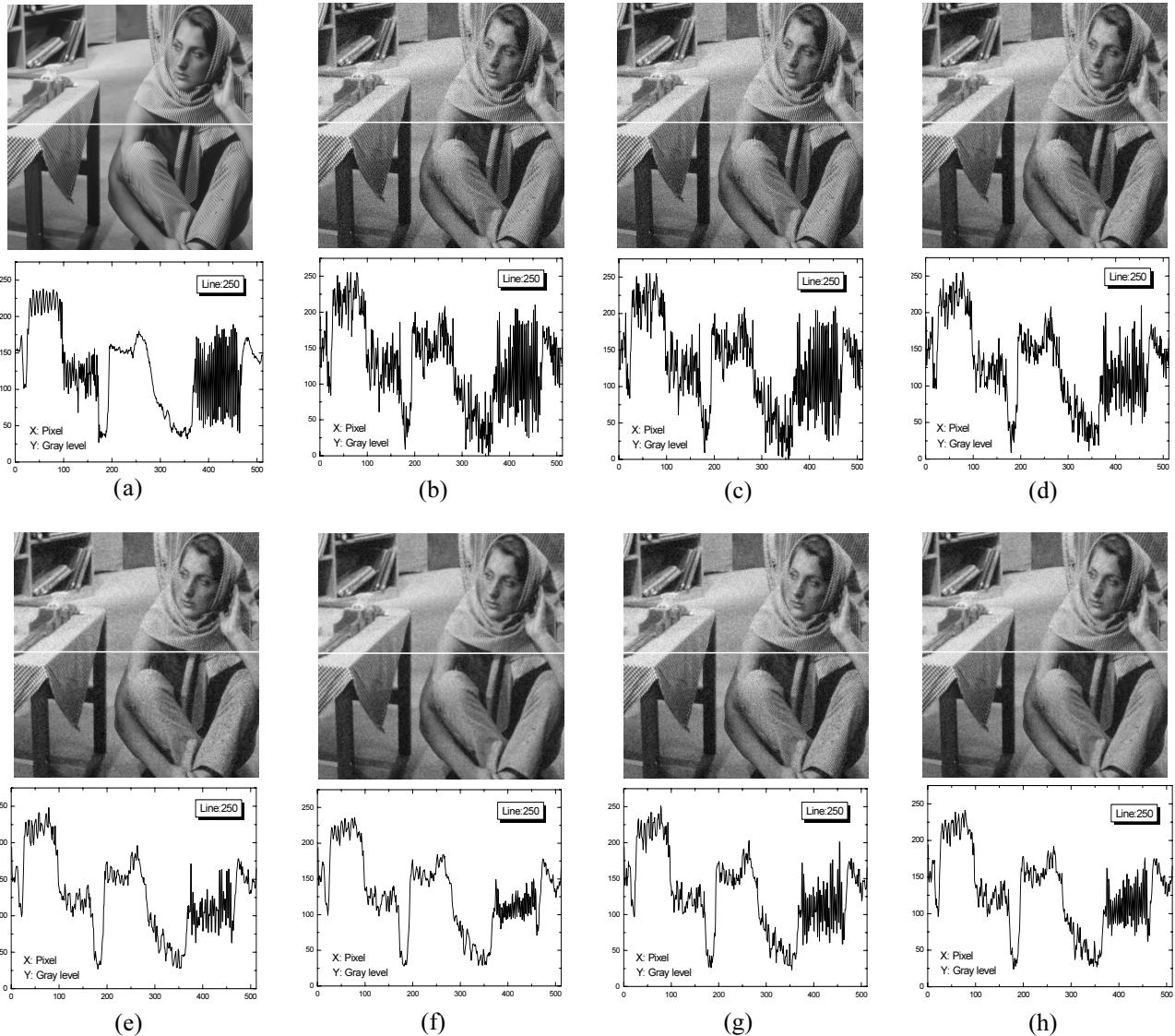


Fig. 4. Simulation result of Barbara image.

- (a) Test image
- (b) Noisy image
- (c) GF(3×3)
- (d) HM(3×3) filter
- (e) SM($3 \times 3, C=3$) filter
- (f) MF(3×3)
- (g) CWM(3×3) filter
- (h) Proposed filter

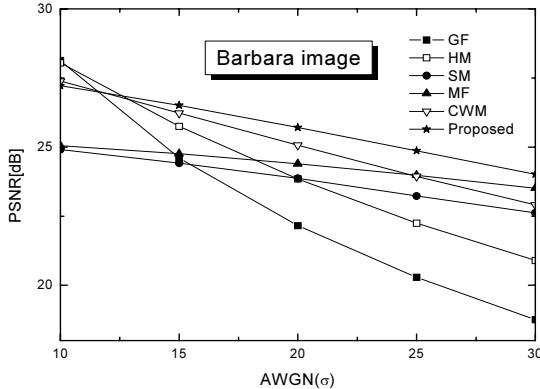


Fig. 5. Comparison results in PSNR for the Barbara image at different noise standard deviation.

Table I shows the PSNR values of restored images with $\sigma = 10, 15, 20, 25$ or 30 for Barbara image. From Table 1, it is apparent that our proposed algorithm has outperformed other filters implemented in terms of PSNR. For instance, When test image Barbara corrupted by AWGN with standard deviation $\sigma = 25$, the PSNR value after filtering by GF, HM, SM, MF and CWM filters are 20.29dB, 22.25dB, 23.23dB, 23.98dB, 23.94dB, but the after processing by proposed method the PSNR value is 24.87dB.

TABLE I
PERFORMANCE COMPARISON FOR RESTORING
BARBARA IMAGE

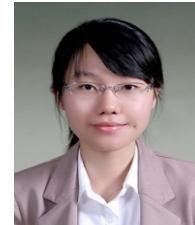
σ	Method[dB]					
	GF 3×3	HM 3×3	SM 3×3	MF 3×3	CWM 3×3	Proposed
10	28.13	28.05	24.91	25.05	27.39	27.22
15	24.61	25.75	24.42	24.76	26.23	26.51
20	22.16	23.85	23.87	24.40	25.07	25.71
25	20.29	22.25	23.23	23.98	23.94	24.87
30	18.76	20.90	22.62	23.51	22.91	24.02

V. CONCLUSIONS

In this paper, an efficient algorithm is presented for suppression of AWGN with the edge preservation. The proposed method chooses suppression method of the Gaussian noise according to these sets which separated by direction information. The effectiveness of this method is evaluated in a performance comparison to the other methods. The experimental results demonstrate that our proposed method performs much better than conventional methods qualitatively. So the proposed method not only has good capability in AWGN suppression but also reserve image details.

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