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Nonlinear Transformation Based Detection And Directional Mean Filter to Remove Random Valued Impulse Noise

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Abstract: *In this paper, a novel two stage algorithm for the removal of random valued impulse noise from the images is presented. In the first stage the noise pixels are detected by using an exponential nonlinear function. The transformation of the pixels increases the gap between noisy and noise free candidates which leads to an efficient detection. In the second stage, the directional differences between the pixels in the four main directions are calculated. The mean values of the pixels which lie in the direction of minimum difference are calculated and the noisy pixel values are replaced with the mean value of the pixels lying in the direction of minimum difference. Experimental results show that proposed method is superior to the conventional methods in peak signal to noise ratio.*

Index terms: *Impulse noise, mean, peak signal to noise ratio.*

I. Introduction

Noise Suppression from images is one of the most important concerns in digital image processing. The impulse noise is one kind of the most ubiquitous noise, which comes from transmission errors, malfunctioning pixel elements in the camera sensors, faulty memory locations, and timing errors in analog-to-digital conversion An important characteristic of this type of noise is that only part of the pixels are corrupted and the rest are noise-free. The amount of impulse noise is usually quantified by the percentage of pixels which are corrupted.Fixed valued impulse noise takes the values 0 and 255 where as the random valued impulse noise takes the values in the dynamic range of [0,255]. Various methods have been proposed in the literature for the removal of impulse noise.

One of the most popular methods is the median filter [2], which can suppress noise with high computational efficiency. However, since every pixel in the image is replaced by the median value in its neighborhood, the median filter often removes desirable details in the image and also blurs the image too. The weighted median filter and the center-weighted median filter [6] were proposed as remedy to improve the median filter by giving more weight to some selected pixels in the filtering window. Although these two filters can preserve more details than the median filter, they are still implemented uniformly across the image without considering whether the current pixel is noise-free or not. ROAD [5] mechanism provides a measure of how close a pixel value to its four most similar neighbors. But when the noise level is high it introduces blurring in the image.

Recently, directional weighted median filter [11] and has been reported in the literature to overcome the above draw backs and to improve the filtering performance in terms of noise removal and detail preservation. But the main drawback of these filters is that it uses large number of iterations for better noise removal and hence it takes large computation time.

PWMAD[6] is a robust estimator of variance, MAD (median of the absolute deviations from the median), is modified and used to efficiently separate noisy pixels from the image details. The median of the absolute deviations from the median-MAD is used to estimate the presence of image details, thus providing their efficient separation from noisy image pixels. An iterative pixel-wise modification of MAD (PWMAD) provides reliable removal of arbitrarily distributed impulse noise

The ACMF[8] devises a novel adaptive operator, which forms estimates based on the differences between the current pixel and the outputs of center-weighted median filters with varied center weights. It employs the switching scheme based on the impulse detection mechanisms. It utilizes the center-weighted median ilter that have varied center weights to define a more general operator, which realizes the impulse detection by using the differences defined between the outputs of CWM filters and the current pixel of concern. The ultimate output is switched between the median and the current pixel itself.

A new directional weighted median filter[2] for the removal of random-valued impulse noise algorithm uses a new impulse detector, which is based onthe differences between the current pixel and its neighbours aligned with fourmain directions. After impulse detection, it does not simply replace noisy pixels identified by outputs of median filter but continue to use the information of the four directions to weight the pixels in the window in order to preserve the details as removing noise. It is an iterative method. This method repeats 8 to 10 times.

The methods which filters all the pixels irrespective of the corruption tends to blur the image, hence the techniques which follow the two stage process of detection of noise pixels and filtering of noise pixels are employed to achieve better performance in terms of peak signal to noise ratio.In order to overcome the difficulties in this paper, a two stage algorithm removal of impulse noise is proposed. The proposed method is simple and outperforms the existing methods in terms of the peak signal to noise ratio.

II. Principles Of Algorithm

The algorithm is a two stage algorithm. In the first stage the detection of noise pixels is done by widening the gap between the noise pixel and other pixels in the window. In the second stage detected pixels are subjected to the directional mean filtering process.

III. Two Stage Algorithm For Removal Of Impulse Noise.

Consider X to be a random valued noise corrupted image of size MxN and X(i,j) denote the grey level at the pixel location (i,j). The pixels in the detection window 'P' of size 3x3 is denoted as

P= $[X_{i-1,j+1}, X_{i,j+1}, X_{i+1,j+1}, X_{i-1,j}$
$X_{i,j}, X_{i+1,j}, X_{i-1,j-1}, X_{i,j-1}, X_{i+1,j-1}]$

In the first stage the noise corrupted pixels are detected using the absolute deviation between the mean value and the centre pixel value and by comparing with threshold value. In the second stage, the detected noise pixels are replaced with the mean value of the pixels lying in the direction of the minimum difference.

A. Noise detection

Step 1: A 3x3 sliding window (p) was chosen from the noise corrupted image, and it runs from the top most left corner to the bottom most right corner, covering the entire size of the image. The centre pixel of the 3x3 window was treated as the test pixel.

Step 2: Usually the pixels located in the neighbourhood of a test pixel are correlated to each other and they process almost similar characteristics if the test pixel under consideration is noise free. The normalizedabsolute difference between the centre pixel value and its corresponding neighbours in the chosen 3X3 window is calculated.

ND = abs(p-p(i,j))/255

Step 3: The exponential nonlinear function is applied inorder to transform the pixel values within the filter window in a progressive manner. This operation widens the gap between noisy pixel and the other Pixels within the window.

NLF = exp(k*ND)-1

The values of k are varied in steps of 10 in each iteration. The initial value of k is assigned to 10.

Step 4: The summatiom of least 'm' values from NLF are calculated .

$$\text{Sum} = \sum_{i=1}^{m} NLF(i)$$

Where m = 6 for the 3x3 window and 12 for 5x5 window under consideration.

Step 5: The threshold value 'T' is choosen adaptively for each window under consideration.

T = MAD(P);

Where MAD is the median of absolute deviation from the median of the window under consideration.

Step 6: The pixel under consideration is treated as noisy pixel if the absolute deviation is greater than the threshold value otherwise the pixel is treated as noise free.

Step 7: Steps 3 to 6 are repeated until entire pixels in the noisy image 'X' are covered. The number of iterations varies from 2 to 6 depending on the noise density.

Step 8: Binary noise mask 'N' is created on the basis of step 6.

$$\mathrm{N(i,j)} = \begin{cases} 1, & \text{if d} < T \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

Step 9: Noise free pixels are sited directly to output image and Noisy pixels are subjected to filtering process.

B. Filtering stage:

In this stage the "noise pixels" marked with N(i,j) = 0 is replaced by an estimated correction term.

Step 1: Consider a 3x3 window, starting from the top-most left corner of the impulse noise corrupted image X.

Step 2: The absolute differences between the current pixel and its neighbors in the four main directions (i.e.) horizontal, vertical and direction along two diagonals are calculated.

$$Dk(i, j) = |X(i+u, j+v) - X(i-u, j-v)| \quad (6)$$

where, (k, u, v) = {(1, 1, 1), (2, 0, 1), (3,−1, 1), (4,−1, 0)}

Step 3: The direction along which the pixels giving the minimum difference value is calculated (i.e.) Min { D_1, D_2, D_3, D_4}.

Step 4: The median value of the pixels in the step 3 was calculated.

Step 5: Finally, the correction term to restore a detected “noise pixel” was obtained from the step 4 is replaced with the noise pixel value. The above steps 1 to 5 are repeated for all the pixels in the image.

IV. Illustration

To illustrate the proposed algorithm a 3x3 image segment from a lena image corrupted by 55% of random valued impulse noise is taken.

Original segment Noisy segment

$$I = \begin{bmatrix} 151\ 156\ 157 \\ 156\ 156\ 157 \\ 151\ 156\ 157 \end{bmatrix} X = \begin{bmatrix} 82\ 156\ 186 \\ 156\ 218\ 157 \\ 31\ \ 58\ \ 157 \end{bmatrix}$$

A. Detection Stage

The normalized absolute difference between centre pixel value and its corresponding neighboursin X is given as:

$$\text{ND} = \begin{bmatrix} 0.533 & 0.243 & 0.1255 \\ 0.243 & 0 & 0.2392 \\ 0.7333 & 0.6275 & 0.2392 \end{bmatrix}$$

Calculation of the exponential nonlinear function is gives the values as

NLF = sort (Exp(10*ND)-1)

NLF = [0 2.5 9.9 9.9 10.4 10.4 206.1 206.1 528.9 529.5]

Summation of least six values of NLF are

Sum = 0+2.5+9.9+9.9+10.4+10.4 = 43.1

Calculation of Threshold value

Median(X) = 156.

Median (abs(X-Xmedian) = median(0 0 1 1 30 62 74 98 125)=30.

Since sum > t , the centre pixel in the noisy segment is treated as Noise candidate. Hence the corresponding element in the binary noise segment is N(i,j) = 0.

Binary Noise segment N = $\begin{bmatrix} 0\ 1\ 0 \\ 1\ 0\ 1 \\ 0\ 0\ 1 \end{bmatrix}$

B. *Filtering Stage*

By using the binary segment N , only the noise candidates are filtered.

calculation of mean of the pixels lying in the direction of minimum difference.

$$|82 - 157| = 75$$
$$|156 - 58| = 98$$
$$|186 - 31| = 155$$
$$|156 - 157| = 1 \ \rightarrow \text{minimum}$$

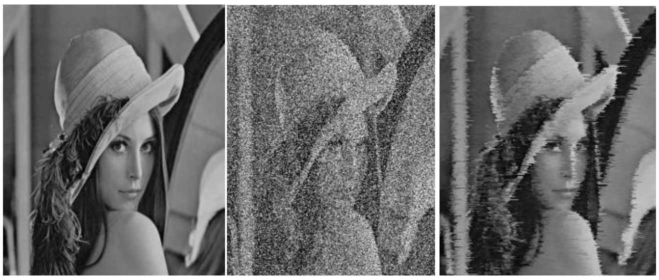
So mean of 156,157 is 156.5

The centre pixel in the noisy segment is replaced with the resultant value. The resultant segment is

$$\text{R} = \begin{bmatrix} 82 & 156 & 186 \\ 156 & 156.5 & 157 \\ 31 & 58 & 157 \end{bmatrix}$$

V. Results And Discussion

In this section, the feasibility of the proposed algorithm is compared to the other filters based on the quantitative measures. The PSNR (dB) evaluation scheme is used to access the strength of the filtered image, taken into consideration so as to measure the computational efficiency of the filter which was being implemented. In order to validate the proposed algorithm, Lena 512 ×512, Barbara 512x512, bridge 512x512 , 8- bit images are used in the analysis of the proposed algorithm.

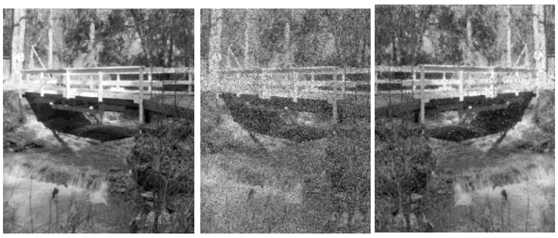


(a) (b) (c)

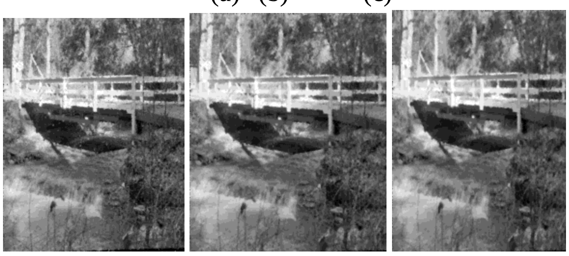
(d) (f) (g)

(h)

Figure 1: (a) original image (b) corrupted image (RVIN 50%) Restored image using (c) median filter (d) DWF (e) CWMF (f) CEF (g) proposed algorithm.



(a) (b) (c)



(e) (f) (g)

(h)

Figure 2: (a) original image (b) corrupted image (RVIN 40%) Restored image using (c) median filter (d) DWF(e) CWMF (f) CEF (g) proposed algorithm.

(a) (b) (c) (d)

(e) (f) (g)

(h)

Figure 3: (a) original image (b) corrupted image (RVIN 40%) Restored image using (c) median filter (d) DWF (e) CWMF (f) CEF(g) proposed algorithm.

TABLE 1
COMPARATIVE PSNR VALUES OF VARIOUS NOISE FILTERS ON NOISY LENA IMAGE.

Noise density	**Median**	**DWF**	**CWMF**	**CEF**	**PA**
10	36.6	38.2	38.01	40.2	43.09
20	32.5	37.15	34.98	37.6	38.02
30	27.7	34.87	33.1	35.3	36.64
40	23.5	32.62	31.4	33.5	34.12
50	20	30.26	28.2	30.5	32.48
60	17.4	26.74	24.01	27.5	30.64

Restoration results are quantitatively measured by peak signal-to noise ratio (PSNR), Table 1 shows the comparison of PSNR values of proposed technique with existing techniques for 512x512 Lena image. It can be seen that our proposed filter provides the best results in PSNR. In particular, when the noise ratio is larger than 30%, the proposed algorithm produces PSNR values that are one decibel higher than the closest competing filters. By experimental results, the performance of the proposed algorithm is better than the competing filters in terms of the peak signal to noise ratio. It also removes most of the noise while preserving the edge details very well, and even thin lines.The algorithm has been implemented on the MATLAB platform, version 7.5 in core2duo processor with 2 GB RAM.

VI. Conclusion

The proposed algorithm deals with the removal of random valued impulsive Noise. Impulsive noise being contaminated in some pixels based on probability densities. The detector utilises a threshold value to compare with a predefined parameter. Fixed threshold is not suitable and do not work well under different noise conditions as well as for different images. In this algorithm, adaptive threshold determination strategy based on given noisy image statistics was proposed. Various statistical parameters i.e. (μ,σ^2) are also used to predict the threshold value. The proposed filter is an impulsive noise removal scheme using the directional pixel wise difference method, replacing the corrupted pixel with the median value of pixels lying in the direction of minimum directional difference. The restored image, by this scheme exhibits the desirable properties of edge and detail preservation.

Extensive simulations and comparisons are done with competent schemes. It is observed, in general, that the proposed schemes are better in terms of peak signal to noise ratio suppressing impulsive noise at different noise densities than their counterparts.

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