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Salt and Pepper Noise Detection and removal by Modified Decision based Unsymmetrical Trimmed Median Filter for Image Restoration

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ABSTRACT

In this paper, six different image filtering algorithms are compared based on their ability to reconstruct noise affected images. The purpose of these algorithms is to remove noise from a signal that might occur through the transmission of an image. A new algorithm, the Spatial Median Filter, is introduced and compared with current image smoothing techniques. Experimental results demonstrate that the proposed algorithm is comparable to these techniques.. This proposed algorithm shows better results than the Standard Median Filter (MF), Decision Based Algorithm (DBA), Modified Decision Based Algorithm (MDBA), and Progressive Switched Median Filter (PSMF). The proposed algorithm is tested against different grayscale and color images and it gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF).

Keywords: Median Filter, Salt and Pepper Noise, Unsymmetrical Trimmed Median Filter.

1. INTRODUCTION

Impulse noise in images is present due to bit errors in transmission or introduced during the signal acquisition stage. There are two types of impulse noise, they are salt and pepper noise and random valued noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Several nonlinear filters have been proposed for restoration of images contaminated by salt and pepper noise. Among these standard median filter has been established as reliable method to remove the salt and pepper noise without damaging the edge details. However, the major drawback of standard Median Filter (MF) is that the filter is effective only at low noise densities [1]. When the noise level is over 50% the edge details of the original image will not be preserved by standard median filter.

Adaptive Median Filter (AMF) [2] perform well at low noise densities. But at high noise densities the window size has to be increased which may lead to blurring the image. In switching median filter [3], [4] the decision is based on a pre-defined threshold value. The major drawback of this method is that defining a robust decision is difficult. Also these filters will not take into account the local features as a result of which details and edges may not be recovered satisfactorily, especially when the noise level is high.

To overcome the above drawback, Decision Based Algorithm (DBA) is proposed [5]. In this, image is denoised by using a 3 3 window. If the processing pixel value is 0 or 255 it is processed or else it is left unchanged. At high noise density the median value will be 0 or 255 which is noisy. In such case, neighboring pixel is used for replacement. This repeated replacement of neighboring pixel produces streaking effect [6]. In order to avoid this drawback, Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is proposed [7]. At high noise densities, if the selected window contains all 0's or 255's or both then, trimmed median value cannot be obtained. So this algorithm does not give better results at very high noise density that is at 80% to 90%. The proposed Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) algorithm removes this drawback at high noise density and gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF) values than the existing algorithm.

The rest of the paper is structured as follows. A brief introduction of unsymmertric trimmed median filter is given in Section 2. Section 3 describes about the proposed algorithm and different cases of proposed algorithm. The detailed description of the proposed algorithm with an example is presented in Section 4. Simulation results with different images are presented in Section 5. Finally conclusions are drawn in Section 6.

2. SPATIAL MEDIAN FILTER

When transferring an image, sometimes transmission problems cause a signal to spike, resulting in one of the three point scalars transmitting an incorrect value. This type of transmission error is called “salt and pepper” noise due to the bright and dark spots that appear on the image as a result f the noise. The ratio of incorrectly transmitted points to the total number of points is referred to as the noise composition of the image. The goal of a noise removal filter is to take a corrupted image as input and produce an estimation of the original with no foreknowledge of the noise composition of the image.

In images containing noise, there are two challenges. The first challenge is determining noisy points. The second challenge is to determine how to adjust these points. In the VMF, a point in the signal is compared with the points surrounding it as defined by a filter mask. Each point in the mask filter is treated as a vector representing a point in a three-dimensional space. Among these points, the summed vector distance from each point to every other point within the filter is computed. The point in the signal with the smallest vector distance among these points is the minimum vector median.The point in space that has the smallest distance to every other point is considered to be the best representative of the set. The original VMF approach does not consider if the current point is original data or not.

If a point has a small summed vector distance, yet is not the minimum vector median, it is replaced anyway. The advantage of replacing every point achieves a uniform smoothing across the image. The disadvantage to replacing every point is that original data is sometimes overwritten. A good smoothing filter should simplify the image while retaining most of the original image shape and retain the edges. A benefit of a smoothed image is a better size ratio when the image needs to be compressed. The Spatial Median Filter (SMF) is a new noise removal filter. The SMF and the VMF follow a similar algorithm and it will be shown that they produce comparable results. To improve the quality of the results of the SMF, a new parameter will be introduced and experimental data demonstrate the amount of improvement.

The SMF is a uniform smoothing algorithm with the purpose of removing noise and fine points of image data while maintaining edges around larger shapes. The SMF is based on the spatial median quintile function developed by P. Chaudhuri in 1996, which is a $L1$ norm metric that measures the difference between two vectors [4]. R. Serfling noticed that a spatial depth could be derived by taking an invariant of the spatial median [5]. The Serfling paper first gave the notion that any two vectors of a set could be compared based on their “centrality” using the Spatial Median. Y. Vardi and C. Zhang have improved the spatial median by deriving a faster estimation formula [6]. The spatial depth between a point and set of points is defined by,

$$S_{depth}(X,x_1,\dots,x_N) = 1 - \frac{1}{N-1}\left\| \sum_{i=1}^{N} \frac{X-x_i}{\|X-x_i\|} \right\| \quad (6)$$

The following is the basic algorithm for determining the Spatial Median of a set of points, $x1, ...,xN$: Let $r1, r2, ..., rN$ represent $x1,x2, ...,xN$ in rank order such that

$$\begin{aligned} & S_{depth}(r_1,x_1,\dots x_N) \\ \geq\ & S_{depth}(r_2,x_1,\dots x_N) \\ \geq\ & \dots \\ \geq\ & S_{depth}(r_N,x_1,\dots x_N) \end{aligned} \quad (7)$$

and let rc represent the center pixel under the mask. Then,

$$SMF(x_1,\dots,x_N) = r_1 \quad (8)$$

The SMF is an unbiased smoothing algorithm and will replace every point that is not the maximum spatial depth among its set of mask neighbors. The Modified Spatial Median Filter attempts to address these concerns.

3. UNSYMMETRIC TRIMMED MEDIAN FILTER

The idea behind a trimmed filter is to reject the noisy pixel from the selected 3 3window.Alpha Trimmed Mean Filtering (ATMF) is a symmetrical filter where the trimming is symmetric at either end. In this procedure, even the uncorrupted pixels are also trimmed. This leads to loss of image details and blurring of the image. In order to overcome this drawback, an Unsymmetric Trimmed Median Filter (UTMF) is proposed. In this UTMF, the selected 3 3 window elements are arranged in either increasing or decreasing order. Then the pixel values 0’s and 255’s in the image (i.e., the pixel values responsible for the salt and pepper noise) are removed from the image. Then the median value of the remaining pixels is taken. This median value is used to replace the noisy pixel. This filter is called trimmed median filter because the pixel values 0’s and 255’s are removed from the selected window. This procedure removes noise in better way than the ATMF.

4. PROPOSED ALGORITHM

The proposed Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) algorithm processes the Corrupted images by first detecting the impulse noise. The processing pixel is checked whether it is noisy or noisy free. That is, if the processing pixel lies between maximum and minimum gray level values then it is noise free pixel, it is left unchanged.

If the processing pixel takes the maximum or minimum gray level then it is noisy pixel which is processed by MDBUTMF. The steps of the MDBUTMF Each and every pixel of the image is checked for the presence of salt and pepper noise. Different cases are illustrated in this Section. If the processing pixel is noisy and all other pixel values are either 0's or 255's is illustrated in Case i). are elucidated as follows.

ALGORITHM

Step 1: Select 2-D window of size 3 × 3. Assume that the pixel being processed is P_{ij}.

Step 2: If $0 < P_{ij} < 255$ then P_{ij} is an uncorrupted pixel and its value is left unchanged. This is illustrated in Case iii) of Section IV.

Step 3: If $P_{ij} = 0$ or $P_{ij} = 255$ then P_{ij} is a corrupted pixel then two cases are possible as given in Case i) and ii).

Case i): If the selected window contain all the elements as 0's and 255's. Then replace P_{ij} with the mean of the element of window.

Case ii): If the selected window contains not all elements as 0's and 255's. Then eliminate 255's and 0's and find the median value of the remaining elements. Replace P_{ij} with the median value.

Step 4: Repeat steps 1 to 3 until all the pixels in the entire image are processed.

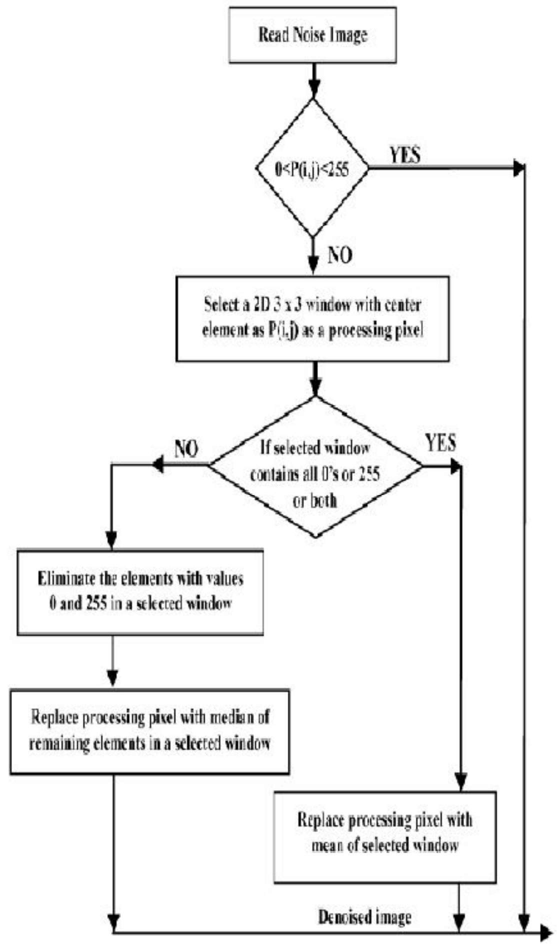

Fig. 1. Flow chart of MDBUTMF.

If the processing pixel is noisy pixel that is 0 or 255 is illustrated in Case ii). If the processing pixel is not noisy pixel and its value lies between 0 and 255 is illustrated in Case iii). *Case i):* If the selected window contains salt/pepper noise as processing pixel (i.e., 255/0 pixel value) and neighboring pixel values contains all pixels that adds salt and pepper noise to the image:

5. SIMULATION RESULTS

The performance of the proposed algorithm is tested with different grayscale and color images. The noise density (intensity) is varied from 10% to 90%. Denoising performances are quantitatively measured by the PSNR and IEF as defined in (1) and (3), respectively:

$$PSNR\ in\ dB = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (1)$$

$$MSE = \frac{\sum_i \sum_j \left(Y(i,j) - \hat{Y}(i,j)\right)^2}{M \times N} \quad (2)$$

$$IEF = \frac{\sum_i \sum_j \left(\eta(i,j) - Y(i,j)\right)^2}{\sum_i \sum_j \left(\hat{Y}(i,j) - Y(i,j)\right)^2} \quad (3)$$

where MSE stands for mean square error, IEF stands for image enhancement factor, is size of the image, Y represents the original image, denotes the denoised image, represents the noisy image. The PSNR and IEF values of the proposed algorithm are compared against the existing algorithms by varying the noise density from 10% to 90% and are shown in Table I and Table II. From the Tables I and II, it is observed that the performance of the proposed algorithm (MDBUTMF) is better than the existing algorithms at both low and high noise densities. A plot of PSNR and IEF against noise densities for Lena image is shown in Fig. 2. The qualitative analysis of the proposed algorithm against the existing algorithms at different noise densities for Baboon image is shown in Fig. 3. In this figure, the first column represents the processed image using MF at 80% and 90% noise densities. Subsequent columns represent the processed images for AMF, PSMF, DBA, MDBA and MDBUTMF. The proposed algorithm is tested against images namely Cameraman, Baboon and Lena. The images are corrupted by 70% “Salt and Pepper” noise. The PSNR values of these images using different algorithms are given in Table III. From the table, it is clear that the MDBUTMF gives better PSNR values irrespective of the nature of the input image.

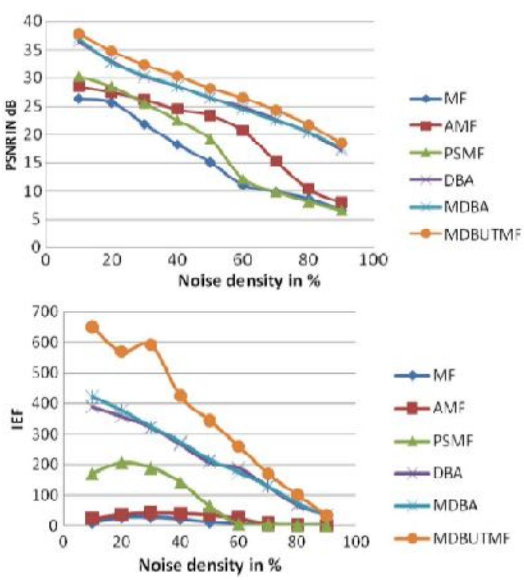

Fig. 2. Comparison graph of PSNR and IEF at different noise densities for Lena image.

The MDBUTMF is also used to process the color images that are corrupted by salt and pepper noise. The color image taken into account is Baboon. In Fig. 3, the first column represents the processed image using MF at 80% and 90% noise densities. Subsequent columns represent the processed images for PSMF, DBA, MDBA and MDBUTMF. From the figure, it is possible to observe that the quality of the restored image using proposed algorithm is better than the quality of the restored image using existing algorithms.

Fig. 3. Results of different algorithms for Baboon image. (a) Output of MF. (b) Output of AMF. (c) Output of PSMF. (d) Output of DBA. (e) Output of MDBA. (f) Output of MDBUTMF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 80% and 90% noise densities, respectively.

6. CONCLUSION

In this letter, a new algorithm (MDBUTMF) is proposed which gives better performance in comparison with MF, AMF and other existing noise removal algorithms in terms of PSNR and IEF. The performance of the algorithm has been tested at low, medium and high noise densities on both gray-scale and color images. Even at high noise density levels the MDBUTMF gives better results in comparison with other existing algorithms. Both visual and quantitative results are demonstrated. The proposed algorithm is effective for salt and pepper noise removal in images at high noise densities.

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