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Performance Analysis of Various Impulse Noise Reduction Techniques in Images

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Abstract−Image filtering algorithms are applied on images to remove salt-and-pepper noise that are either present in the image during capturing or injected in to the image during transmission. In this context, two denoising algorithms are compared and performances of the filters are compared using the Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and computational time.

Index Terms−Impulse Noise, Image Denoising, Image Restoration, PSNR, MSE.

I. INTRODUCTION

Images are often corrupted by Impulse noise, also known as salt and pepper noise. Image and video signals might be corrupted by impulse noise in the process of signal acquisition and transmission, so variety of denoising techniques has been proposed. It is well known that linear filtering techniques fail when the noise is non-additive and are not effective in removing impulse noise. This has led the researchers to the use of nonlinear signal processing techniques. Classes of widely used nonlinear digital filters are median filters. Median filters are known for their capability to remove impulse noise as well as preserve edges. The main drawback of a standard median filter (SMF) is that it is effective only for low noise densities. At high noise densities, SMFs often exhibit blurring for large window sizes and insufficient noise suppression for small window sizes [2], [3].

Most of the median filters operate uniformly across the image and thus tend to modify both noise and noise-free pixels. Consequently, the effective removal of impulse often leads to images with blurred and distorted features.

To overcome this problem a new Decision Based algorithm has been proposed by K.S. Srinivasan and D.Ebenezer in which corrupted pixels are replaced by either the median pixel or neighborhood pixel in contrast to AMF [1] and other existing algorithms that use only median values for replacement of corrupted pixels. At higher noise densities, the median value may also be a noisy pixel in which case neighborhood pixels are used for replacement. In addition, the new Decision based algorithm (DBA) uses simple fixed length window of size 3*3, and hence, it requires significantly lower processing time compared to other algorithms.

In [4], a two-phase scheme for salt-and-pepper noise removal is proposed. It identifies the noisy pixels with an adaptive median filter and then restores them by an edge-preserving method. Based on their idea, an efficient edge-preserving algorithm for impulse noise removal is proposed by Pei-Yin Chen and Chih-Yuan Lien . It uses a noise detector to detect the pixels corrupted by impulse noise. After detection, we employ an effective edge-preserving filter to preserve the edge features rather than reconstruct the noisy pixel values with standard median filter. The experimental results demonstrate that EPA can obtain better performances in terms of both quantitative evaluation and visual quality than those state-of-the-art impulse denoising methods [5]–[7].

I. FILTERING METHODS

A. Decision Based Algorithm

The DBA processes the corrupted image by first detecting the impulse noise. The detection of noisy and noise-free pixels is decided by checking whether the value of a processed pixel lies between the maximum and minimum values that occur inside the selected window. This is because the impulse noise pixels can take the maximum and minimum values in the dynamic range (0, 255) [4]. If the value of the pixel processed is within the range, then it is an uncorrupted pixel and left unchanged. If the value does not lie within this range, then it is a noisy pixel and is replaced by the median value of the window or by its neighborhood values. Following are the steps for DBA:

Step 1) A 2-D window "S_{XY} " of size 3*3 is selected. Assume the pixel to be processed is P(X, Y).

Step 2) The pixel values inside the window are sorted, and, P_{min}, P_{max} and P_{med} are determined as follows.

a) The rows of the window are arranged in ascending order.

b) The columns of the window are arranged in ascending order.

c) The right diagonal of the window is now arranged in ascending order. Now the first element of the window is the minimum value P_{min}, the last element of the window is the maximum value P_{max} , and the middle element of the window is the median value P_{med} .

Step 3) Case 1) The P(X,Y) is an uncorrupted pixel if P_{min}<P(X,Y)< P_{max}, P_{min}>0, and P_{max}<255; the pixel being processed is left unchanged. Otherwise, P(X,Y) is a corrupted pixel.

Case 2) If P(X,Y) is a corrupted pixel, it is replaced by its median value if P_{min}<P_{med}< P_{max} and 0<P_{med}<255..

Case 3) If P_{min}<P_{med}< P_{max} is not satisfied or 255<P_{med}=0, then $_{Pmed}$ is a noisy pixel. In this case, the P(X,Y) is replaced
by the value of neighborhood pixel value.

Step 4) Steps 1 to 3 are repeated until the processing is completed for the entire image.

B. Edge Preserving Algorithm

The algorithm is composed of two components: efficient impulse detector and edge preserving filter. The former determines which pixels are corrupted by fixed-valued impulse noise. The latter reconstructs the noisy pixels by observing the spatial correlation and preserving the edges efficiently. The proposed edge-preserving image filter adopts a directional

Correlation-dependent filtering technique based on observing the sample correlations of six different directions. For each noisy pixel, the image filter detects edges in six directions first and estimates the intensity value of the pixel accordingly.

III. EXPERIMENTAL RESULTS

In this section, we compare the results of existing denoising approaches for removal of fixed-valued impulse noise. To verify the characteristics and performances of various denoising algorithms, a variety of simulations are carried out on the 512*512 8-bit gray-scale image(*bridge.jpg*) as shown in fig.1.

Fig.1 Original image (bridge.jpg)

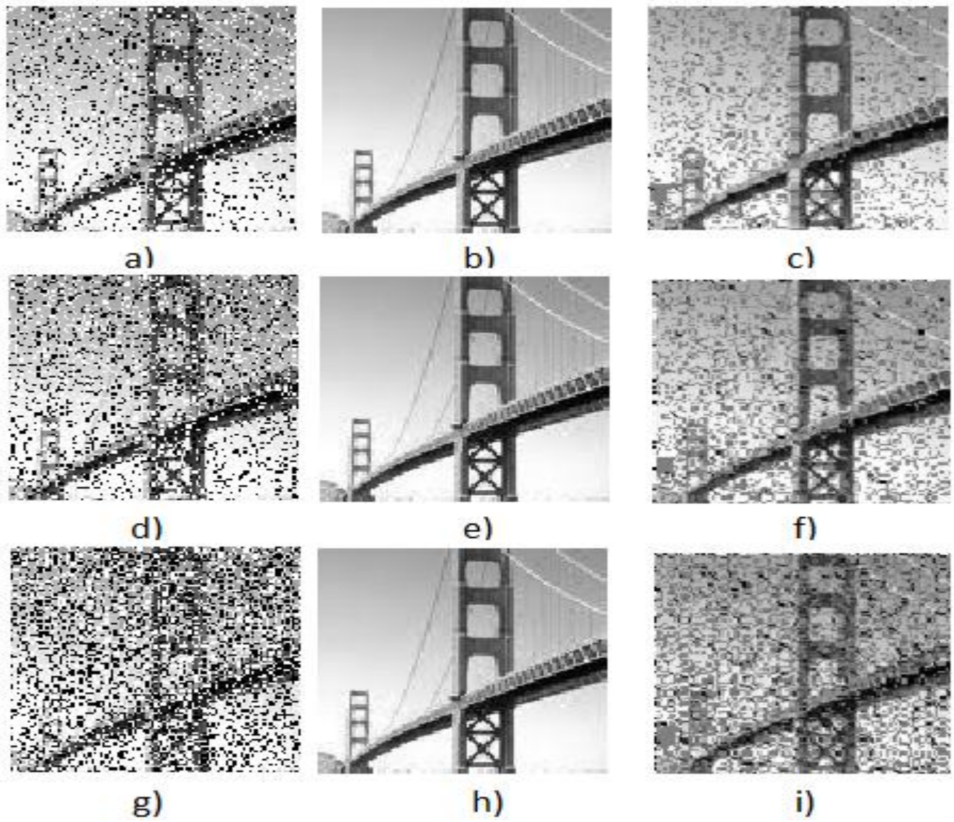

Fig.2. Restoration results of Decision based and Edge preserving algorithm. (a) Corrupted bridge image with 20% salt-and-pepper noise (b) Decision based algorithm (11.71dB). (c) Edge preserving algorithm (12.80 dB). (d) Corrupted bridge image with 30% salt-and-pepper noise. (e) Decision based algorithm (9.75dB). (f) Edge preserving algorithm (10.93 dB). (g) Corrupted bridge image with 50% salt-and-pepper noise (h) Decision based algorithm (7.45dB). (f) Edge preserving algorithm (8.57dB)

In the simulations, image is corrupted by salt-and-pepper noise, where 255 represent the "salt" noise and 0 represents the "pepper" noise with equal probability. A wide range of noise ratios varied from 10% to 90% with increments of 10% are tested. Two recent denoising methods are compared in this section in terms of objective testing (quantitative evaluation) and subjective testing (visual quality): 1) Decision based algorithm, 2) Edge preserving Algorithm.

We employ the peak signal-to-noise ratio (PSNR) to illustrate the quantitative quality of the reconstructed image for various methods. Table I lists the restoration results in terms of PSNR (dB), MSE and computational time of different approaches for image "*bridge.jpg*" corrupted by fixed valued impulse noise with various noise ratios. It is easy to see that edge preserving algorithm provides better result in terms of PSNR.
The comparison of restoration results in PSNR for the reference image corrupted with various impulse noise ratios are shown in Fig. 2. Apparently, the performance of DBA is better but edges are not preserved. However EPA method is good in terms of PSNR but it will take so much time to process the algorithm. Table I list the performance analysis of DBA and EPA in terms of PSNR, MSE and Computational time.

IV. CONCLUSION

The developed algorithms are tested using 512*512, 8-bits/pixel image *bridge* (Gray). The performance of the various algorithms are tested for different values of noise densities and compared with each other. Each time the test image is corrupted by salt and pepper noise of different density ranging from 10 to 90% with an increment of 10% and it will be applied to various algorithms. In addition to the visual quality, the performance of the existing algorithms is quantitatively measured by the following parameters such as peak signal-to-noise ratio (PSNR), Mean square error (MSE) and computational time. All the algorithms are implemented in MATLAB 7.5. The quantitative performances in terms of PSNR, MSE and computational time for various algorithms are given in Table I.

TABLE I

COMPARISON OF RESTORATION RESULTS IN PSNR (DB), MSE AND COMPUTATIONAL TIME (SECONDS) FOR IMAGE "BRIDGE.JPG"

Noise Density	PSNR(dB)		MSE		Time(seconds)	
	DBA	EPA	DBA	EPA	DBA	EPA
10%	14.74	15.07	46.68	44.95	0.54	57.08
20%	11.71	12.80	66.21	60.80	0.57	57.80
30%	9.75	10.93	82.90	72.38	0.55	66.62
40%	8.59	9.62	94.84	84.15	0.54	60.73
50%	7.45	8.57	108.04	95.00	0.54	62.63
60%	6.71	7.67	117.63	105.37	0.55	66.42
70%	6.09	6.98	126.38	114.16	0.55	67.64
80%	5.50	6.16	135.30	125.16	0.55	71.70
90%	5.08	5.61	141.92	133.16	0.54	76.22

Comparison graph of DBA and EPA in terms of PSNR, MSE and Computational time are shown are given in fig. 3,4 and 5.

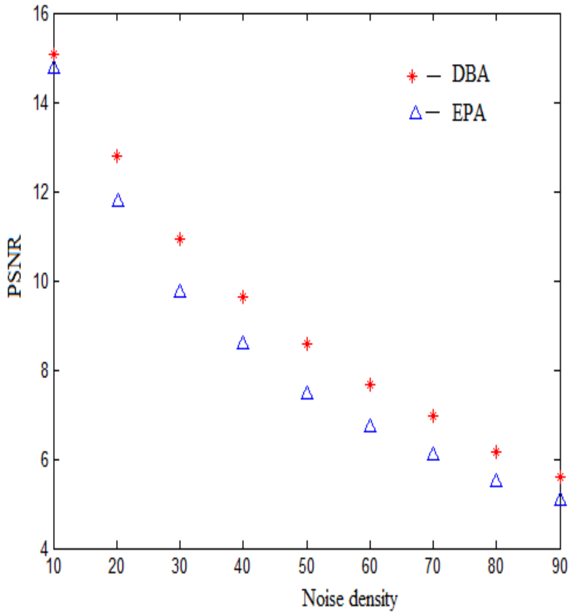

Figure 3. Comparison graph of PSNR for *bridge.jpg* image

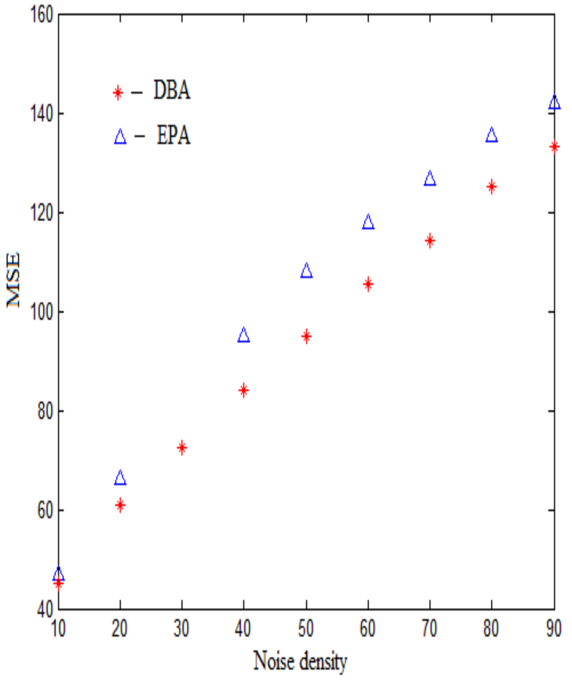

Figure 4. Comparison graph of MSE for *bridge.jpg* image

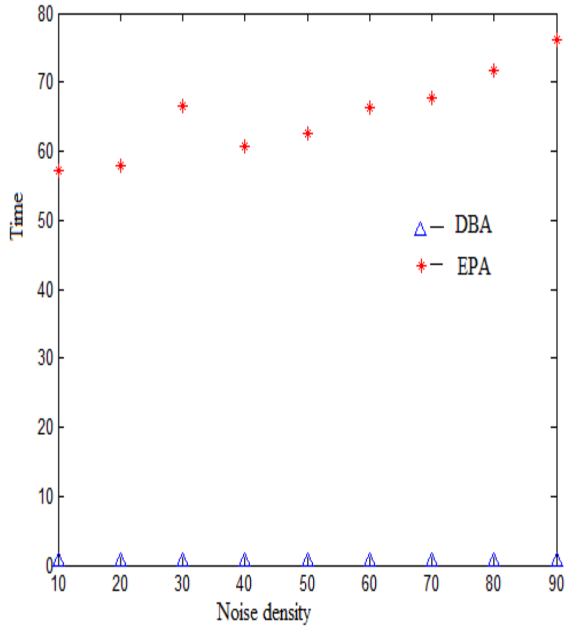

Figure 5. Comparison graph of Computational time for *bridge.jpg* image

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