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An Efficient Noise Removal Algorithm Based on the Noise Density

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Abstract- Gray scale and color images are affected by salt and pepper (impulse noise) which is encountered frequently in acquisition, transmission and processing of images. Proposed method achieves restoration of noisy image by usage of highly efficient filters which adapt based on the existing noise density in the image. The proposed algorithm involves two stages: noise density calculation of the corrupted image followed by noise detection and filtering. As noise density increases, the window size is increased which gives better results. The proposed algorithm replaces the pixels with values 0 and 255 with the median of the window considered if the window also includes pixel values other than 0 or 255. If the window considered contains pixels with values 0 and 255 only then they are replaced by the mean value of all elements present in the selected window. Since the proposed algorithm chooses the filter based on noise density, it works better than Median filter, Progressive Switched Median Filter (PSMF), Untrimmed Median Filter (UMF) and Adaptive Median Filter (AMF) considered individually. 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). 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 - Impulse noise, Median filter, untrimmed median filter, adaptive median Filter, progressive switched median filter.

INTRODUCTION

Salt and pepper noise is introduced in images during signal acquisition stage due to bit errors in transmission and also from dust particles in image acquisition source or over heated faulty components can cause this type of noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Noise removal is difficult task because images may be corrupted by different types of noises [1], such as additive, impulse or signal dependent noise. Linear filter can be used to remove additive noise in an image. However, linear filtering blur edges and it fails to minimize impulse noise. This drawback leads to the use of non-linear filtering in impulse noise reduction. The median filter was once the most popular nonlinear filter for removing salt & pepper noise because of its good denoising power and computational efficiency. However, when the noise level is over 50%, some details and edges of the original image are smeared by the filter. Different types of median filter have been used, e.g., the Adaptive Median filter [2] [3], the switching median filter (SMF), Decision Based Algorithm (DBA) [4], Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) [5] and High Density Bilateral Filter (HDBF) [6].

Adaptive Median Filter (AMF) performs well at low noise densities. But at high noise densities the window size has to be increased which may lead to blurring the image. To overcome the above drawback, Decision Based Algorithm (DBA) is proposed. 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. In order to avoid this drawback, Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is proposed. 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 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 for larger window size.

A Bilateral filter is also an efficient impulse noise denoising filter that uses weights based upon spatial and radiometric similarity. The bilateral filter has good results in removing noise while preserving image details. Also, this method is non-iterative, local and simple. The bilateral filter based upon the "detect and replace" methodology. Noise detection is based on the absolute difference between a current pixel and value and the reference median. The reference median is obtained from sorted quadrant median vector (SQMV).

The rest of the paper is structured as follows. A brief introduction of Modified Unsymmertric trimmed median filter and high density bilateral filter is given in Section II. The detailed description of the proposed algorithm with an example is presented in Section III. Simulation results with image are presented in Section IV. Finally conclusions are drawn in Section V.

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UNSYMMETRIC TRIMMED MEDIAN FILTER AND HIGH DENSITY BILATERAL FILTER

A. Trimmed filter is used to reject the noisy pixel from the selected 3×3 window in the corrupted image. Alpha Trimmed Mean Filtering (ATMF) is symmetric at either end in the trimming process. 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) [7] is used. 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.

B. The switching bilateral filter proposed by C. H. Lin et al, is a nonlinear filter which removes both Gaussian and impulse noise while preserving image details. This filter consist of two stages, in first stage to detect the type of noise then apply the filtering to the noisy pixel is a second stage. Let f(x, y) be the current processing pixel, and the neighborhood pixels are denoted as f(x+s,y+t). Here, s and t is varying from –N to N, N is the size of the selected window. The output of switching bilateral filter $\hat{f}(x, y)$ is defined as in (1)

$$f(x) = \frac{\sum_{s=-N}^{N}\sum_{t=-N}^{N} W_G(s,t) W_{SR}(s,t) f(x+s, y+t)}{\sum_{s=-N}^{N}\sum_{t=-N}^{N} W_G(s,t) W_{SR}(s,t)} \quad (1)$$

$$W_{SR}(s,t) = \exp\left(-\frac{(I = f(x+s, y+t))^2}{2\sigma_R^2}\right) \quad (2)$$

The computation of sorted quadrant reference median (SQMR) value is given in. In this method, the range filter (WSR) depends upon all the pixels in the selected window such as both noisy and noise free pixels given by (2). The computation of SQMR is more complex because it has to be computed for each and every processing pixel.

PROPOSED ALGORITHM

The proposed algorithm processes the corrupted image by first calculating the impulse Noise Density (ND). If the ND is lesser than or equal to 60% then HDBF filter is used for denoising. If the ND lies between 60-80%, MDBUTF filter with window size 5×5(K=2) is used for denoising. Then for above 80% ND for grayscale images MDBUTF filter with window size 7×7(K=3) is used and for color images DBM filter is used.

The algorithm consists of two phases. The first phase is used for calculating the noisy pixels (ND) in the corrupted image. In second phase, based on the calculated noise density the algorithm applies appropriate filter for noise removal.
The steps involved in phase 1 and 2 are specified as follows:

1. Calculating the total no of black ("0") and white ("255") pixels in the given corrupted image. Taking the sum of both and dividing by the total no of pixels in the images gives the Noise Density of the image. Noisy pixel is given by

$$N(i,j) = \begin{cases} 1, & 0 \text{ or } 255 \\ 0, & \text{else} \end{cases}$$

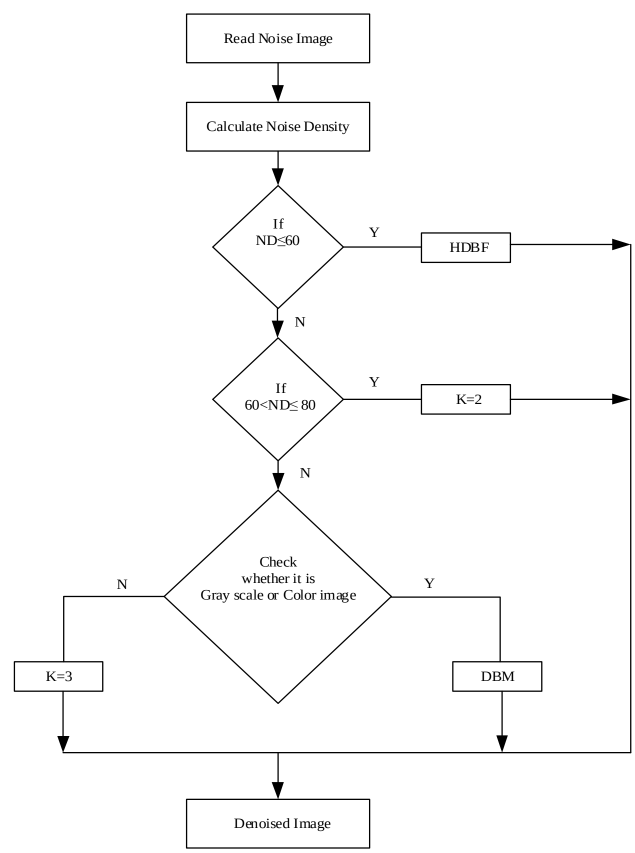
2. Based on the Noise Density appropriate filter is chosen. Table 1 shows the selection of window size for different noise densities for MDBUTM filter.

Table 1: Selection of Window size for a particular Noise Density

Noise Density	K value	Window Size W=(2K+1)
0-60%	1	3×3
60-80%	2	5×5
80-95%	3	7×7

For increasing noise density, the mask size should also be linearly increased for better noise identification. However increasing the mask size also imposes a blur effect on the restored image.

FLOW CHART



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Algorithm

Step 1: Calculate the ND for the given image.
Step 2: If the ND is <60% then apply HDBF filter.
Step 3: If the ND is 60<ND<80 the apply MDBUTF filter selecting 2-D window of size 5×5.
Step 4: Check for the grayscale or color image.
Case i) If it is grayscale image apply MDBUTF filter selecting 2-D window of size 7×7.
Case ii) If it is a color image apply DBM filter

RESULTS AND DISCUSSION

Simulation of proposed algorithm is carried out in various test images: 'Lena', 'Cameraman', and 'Barbara'. All the images with the size of 512 x 512 8 bit gray scale images are corrupted with salt and pepper noise with wide range of noise densities from 5% to 95%. The simulation is carried out in MATLAB 13a environment with Pentium Duo core-2.80GHz with 2GB of RAM. Qualitative and quantitative performance of proposed algorithm is on par with the existing algorithms. The qualitative measures taken into consideration are Peak Signal to Noise Ratio (PSNR), Image Enhancement Factor (IEF). MSE, PSNR and IEF as defined in (3), (4) and (5) respectively:

$$MSE = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(O(i,j)-\hat{Y}(i,j))^2}{M \times N} \qquad (3)$$

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \qquad (4)$$

$$IEF = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(N(i,j)-O(i,j))^2}{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(\hat{Y}(i,j)-O(i,j))^2} \qquad (5)$$

MSE stand for Mean Square Error, O(*i*,*j*) is the original image, $\hat{Y}(i,j)$ represents the denoised image, *N*(*i*, *j*) represents noisy image and *M* × *N* is the size of the image.

Table 2: Comparison of PSNR Values of Different Algorithms for Grayscale Lena Image at Different Noise Densities

				AMF	MDBUTMF			
NOISE DENSITY	PSM	DBMF	UTMF	K=4	K=1	K=2	K=3	HDBF
10	33.41	39.08	37.9	36.49	40.3668	37.3924	35.0767	41.18
20	29.77	34.6	34.72	34.01	36.7831	33.0335	32.1473	37.37
30	26.87	31.9	32.5	31.75	34.4978	29.3876	31.0624	34.78
40	23.93	29.69	30.92	30.01	32.3007	28.3704	29.7211	32.77
50	20.67	27.41	28.91	28.04	30.0849	28.8758	28.5719	30.25
60	16.33	25.52	26.12	26.43	26.7719	28.3103	27.5738	26.96
70	9.58	23.37	22.48	23.57	22.8147	26.9688	26.3312	22.96
80	7.7	20.68	18.31	18.69	18.341	24.1224	25.1207	18.59
90	6.19	17.21	14.36	11.8	14.3603	15.9048	21.8932	14.28

Graph 1: shows the comparison of PSNR and Noise Densities for different filters of Grayscale Lena image.

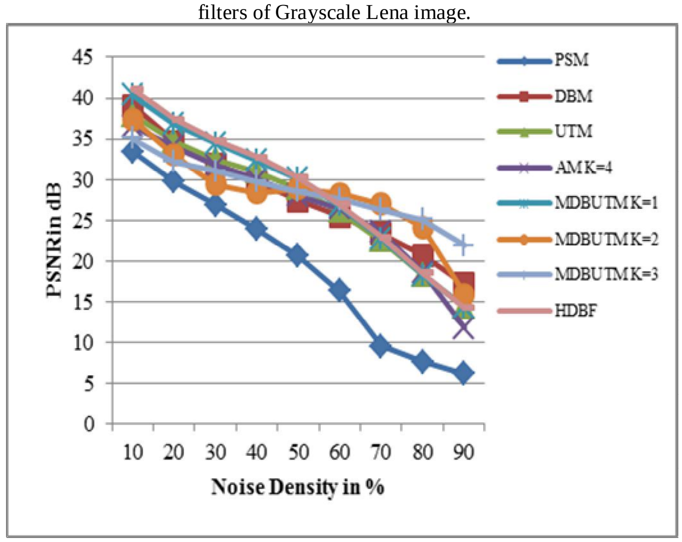

Table 3: Comparison of IEF Values of Different Algorithms for Grayscale Lena Image at Different Noise Densities

				AMF	MDBUTMF			
NOISE DENSITY	PSM	DBMF	UTMF	K=4	K=1	K=2	K=3	HDBF
10	67.98	251.68	192.81	139.28	338.2905	172.3433	101.6414	411.4
20	59.48	181.83	185.82	156.58	300.713	125.4348	102.9879	340.4
30	45.83	145.36	166.9	140.27	264.0978	81.8281	120.5151	283.55
40	30.99	116.15	154.56	125.57	211.7423	85.926	117.2722	237.35
50	18.17	86.37	122.14	99.84	159.9214	121.7746	112.515	164.37
60	8.06	67.03	76.99	82.65	89.4082	127.4881	107.2297	92.99
70	1.99	47.59	38.87	49.74	41.917	109.3783	94.4373	43.42
80	1.47	29.33	16.98	18.57	17.1169	64.8627	81.3416	18.07
90	1.17	14.83	7.68	4.27	7.6874	11.006	43.4266	7.58

Graph 2: shows the comparison of IEF and Noise Densities for different filters of Grayscale Lena image.

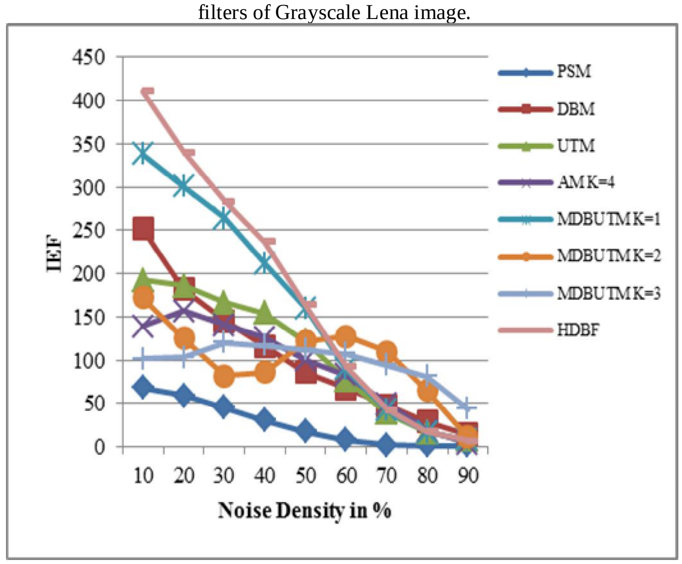

Fig 1: Results of different algorithms for Lena image. (a) Output of PSM. (b) Output of DBM. (c) Output of UTM. (d) Output of AM K=4. (e) Output of MDBUTM K=1. (f) Output of MDBUTM K=2. (g) Output of MDBUTM K=3. (h) Output of HDBF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 70% noise densities, respectively

Fig 2: Results of different algorithms for Lena image. (a) Output of PSM. (b) Output of DBM. (c) Output of UTM. (d) Output of AM K=4. (e) Output of MDBUTM K=1. (f) Output of MDBUTM K=2. (g) Output of MDBUTM K=3. (h) Output of HDBF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 85% noise densities, respectively

Fig 3: Results of different algorithms for Color Lena image. (a) Output of PSM. (b) Output of DBM. (c) Output of UTM. (d) Output of AM K=4. (e) Output of MDBUTM K=1. (f) Output of MDBUTM K=2. (g) Output of MDBUTM K=3. (h) Output of HDBF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 70% noise densities, respectively

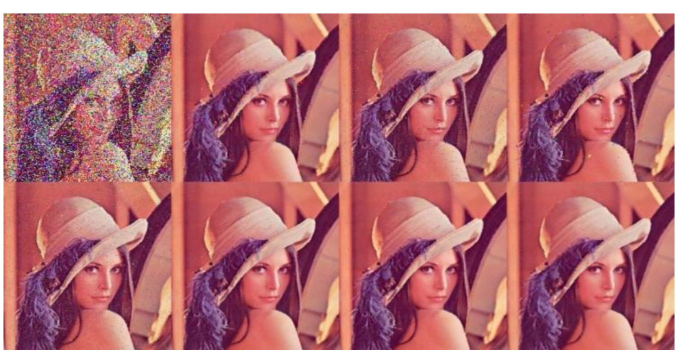

Fig 4: Results of different algorithms for Color Lena image. (a) Output of PSM. (b) Output of DBM. (c) Output of UTM. (d) Output of AM K=4. (e) Output of MDBUTM K=1. (f) Output of MDBUTM K=2. (g) Output of MDBUTM K=3. (h) Output of HDBF. Row 1 and Row 2 show processed results of various algorithms for image corrupted by 85% noise densities, respectively

Among the commonly tested 8-bit grayscale and color images Lena, Baboon and Cameraman are selected for simulations. In the simulations, images are corrupted by "salt" (with value 255) and "pepper" (with value 0) noise. The algorithm is tested for a range of noise levels from 5% to 95% with increments of 5%. Table 2 shows the proposed algorithm being compared with the existing algorithms with respect to PSNR and IEF with varying noise densities. Table 3 shows IEF values for Lena grayscale image. Fig 1 and Fig 2 shows results of images corrupted with 70% and 85% noise densities respectively. Fig 3 and Fig 4 shows that the performance of the proposed algorithm is better compared to the existing algorithm. Graphs of PSNR and IEF against noise densities for Lena image is shown are plotted Graph 1 and 2. In all tables, the first column represents the noise densities. Subsequent columns represent the processed images for PSMF [8], DBA, UTM, AMF, MDBUTMF and HDBF. From the tables and graphs, 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.

CONCLUSION

In this paper we have discussed image denoising at low and medium noise density by the use of High Density Bilateral Filter. At higher noise densities DBM is used. MDBUTM filter is also used at high noise densities with increased window size. The performance of the algorithm has been tested under a wide range (from 5% to 95%) of noise densities on both gray-scale and color images. Results reveal that the proposed algorithm exhibits better performance in comparison with other existing algorithms in terms of MSE, PSNR and IEF. Even at high noise density levels, proposed algorithm gives better results both visually and quantitatively. The proposed algorithm is effective for salt and pepper noise removal in images at high noise densities. This image restoration of images finds applications in a number of different areas such as medical diagnostics, archaeology, satellite imaging, etc.

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