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Restoration of High Density Salt and Pepper Noisy Gray & Color Videos using MDBUTMF

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***Abstract*— In the Transmission of Videos over channel, Video frames are corrupted by salt and pepper noise (Impulse Noise), due to faulty communication systems. The objective of this paper is to implement a better filtering technique that makes the noisy video frames to noise free video frames. Median filters are the best known non-linear digital filters based on order statistics to solve the present problem. Median filters are known for their capability to remove salt and pepper noise and preserves the shape. The noise detection process to discriminate between uncorrupted pixels and the corrupted pixels prior to applying non-linear filtering is highly desirable to protect the signal details of uncorrupted pixels. In this paper we proposed A Modified Decision Based Unsymmetrical Trimmed Median filter (MDBUTM) algorithm for the restoration of gray scale, and color video frames that are highly corrupted by salt and pepper noise. This proposed algorithm shows better results than the Standard Median Filter (SMF), Decision Based Algorithm (DBA), Modified Decision Based Algorithm (MDBA), and Progressive Switched Median Filter (PSMF). We tested the algorithm against different gray and color video frames and it gives better results with high PSNR and IEF.**

***Keywords*—Median Filter, Salt and Pepper noise, Midpoint Filter, Shear Sort, Un-symmetric Trimmed Median Filter.**

I. INTRODUCTION

Video frames are often corrupted by impulse noise. In general, the impulse noise in video frames is present due to bit errors in transmission or introduced during the signal acquisition stage. Based on the noise values, the impulse noise is classified in to two; they are salt and pepper noise and random valued noise. Salt and Pepper noise is easier to restore but, the random valued noise is more difficult to restore. Salt and Pepper noise can corrupt the frame where the corrupted pixel takes either maximum or minimum gray level. Many different non-linear filters have been proposed for restoration of salt and pepper noisy video frames. Among all the methods for removal of impulse noise, the median filter [6,7] is used widely because of its effective noise suppression capability and high computational efficiency [8]. Non-linear digital filters, based on order statistics are median filters (MF). Median filters are well known for their capability to remove impulse noise without damaging the edge information.

However, the major drawback of standard Median Filter (SMF) is that the filter is effective only at low noise densities [1]. At high noise densities, SMF often exhibits blurring for large window sizes and insufficient noise suppression for small window sizes. When the noise level is over 60% the edge details of the original frame will not be preserved by the standard median filter (SMF). However, most of the median filters are operates uniformly across the video frames and it modifies both noise and noise-free pixels, causes information loss. Ideally, the filtering should be applied only to corrupted pixels but not to uncorrupted pixels. Adaptive median filter (AMF) [2] works well at very low noise densities. Noise detection process to discriminate between uncorrupted pixels and the corrupted pixels prior to applying non-linear filtering is highly desirable Adaptive Median Filter is a decision based or switching filter that differentiates the noisy pixels and performs the filtering operation on them leaving all other pixels unchanged. These filters will not take into account the local features as a result of which details and edges may not be recovered satisfactorily, especially for high noise level cases. By providing enough large size windows, detection of impulse noise at high noise levels using AMF is reliable for simple background video frames.

Decision based algorithm (DBA) is proposed to overcome this problem [3]. In this, selected video frame is de-noised by using a 3x3 window. The detection of noise and noise free pixels is decided by checking the value of a processed pixel element lies between the maximum and minimum values that occur inside the selected window [9,10]. If the processing pixel value is 0 or 255 it is processed otherwise it is left unchanged. In addition, the DBA uses simple fixed length window of size 3x3, and hence it requires lower processing time while compared to AMF. But, at high noise density levels the median value may also be noisy. In this case, neighbouring pixel is used for replacement. This repeated replacement of neighbouring pixels produces streaking effect [4]. Hence, details and edges are not recovered satisfactorily, especially when the noise level is high.

In order to avoid this drawback, Decision Based Un-symmetric Trimmed Median Filter (DBUTMF) is proposed [5].

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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 densities i.e. at >80%. Hence we proposed Modified Decision Based Un-symmetric Trimmed Median Filter (MDBUTMF) algorithm to overcome the problem with DBUTMF. We tested the algorithm on simple background, complex background video frames and it gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF). Implementation of MDBUTMF requires a brief knowledge on sorting algorithms.

The remaining paper is organized six sections. A brief introduction of sorting algorithms is given in section II. Section III describes the concept of Un-symmetric Trimmed Median Filter (UTMF). Section IV introduces the algorithm of existing Decision Based Un-symmetric Trimmed Median Filter (DBUTMF). Section V gives the detailed algorithm of proposed method MDBUTMF. Simulation results of different video frames are presented in section VI. Finally conclusions and future scopes are discussed in section VII.

II. Brief Review On Sorting Algorithms

A. Shear Sorting Algorithm

Sorting is the most important operation used to find the median of a window. There are different sorting algorithms such as binary sort, bubble sort, merge sort, quick sort etc. In the proposed algorithm shear sorting technique is used since it is based on parallel architecture. In general the parallel architectures help to reduce the number of logic cells required for its implementation.

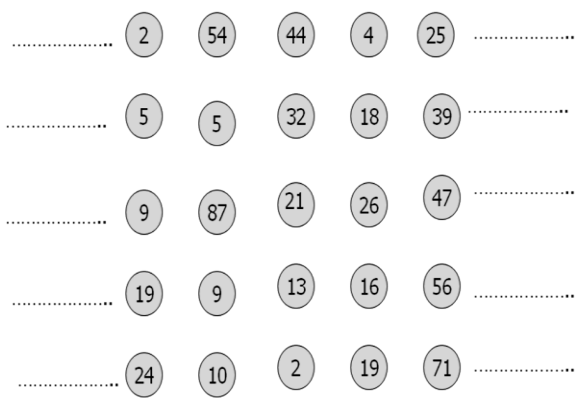

Fig. 1 Numbers that are to be sorted arranged in group of five

The general procedure of sort can be understood from the fig1-3. (Sort each of the group in *O*(n) time. Finding the median of each group for a given set (……..2,5,9,19,24,54,5,87,9,10,44,32,21,13,24,18,26,16, 19,25,39,47,56,71,91,61,44,28………) having **n** elements)

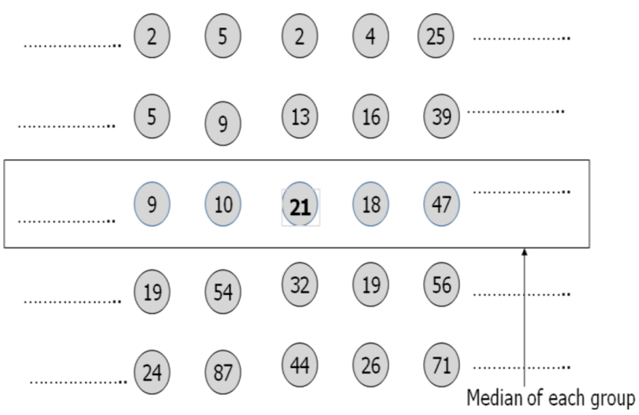

Fig. 2 Median of each group shown in the middle

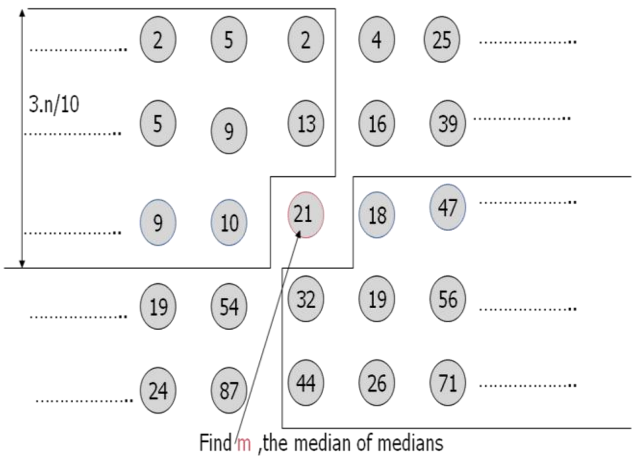

Fig. 3 Median of Medians of all groups shown in the middle

The above figures show the general procedure of median calculation using sorting technique. The illustration of shear sorting is shown in figure. 4-7. In the odd phases (1, 3, 5) even rows are sorted in descending order and rows are sorted out in ascending order. In the even phases columns are sorted out independently in ascending order.

13	17	12
18	11	19
15	14	16

Fig. 4 Matrix before Sorting (Original)

12	13	17	→
19	18	11	←
14	15	16	→

Fig. 5 Row Sorting (Step-1)

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12	13	11	↓
14	15	16	
19	18	17	

Fig. 6 Column Sorting (Step – 2)

11	12	13	→
16	15	14	←
17	18	19	→

Fig. 7 Row Sorting (Step-3)

B. Modified Shear Sorting Algorithm

In order to improve the computational efficiency Shear Sorting algorithm is modified as follows:

Step 1: A 2-D window of size 3x3 is selected.
The pixel to be processed is **þ**(x,y).

Step 2: The pixel value inside the window are sorted, And þ_{min}, þ_{max} and þ_{med} determined as follows:

i) The rows of the window are arranged in ascending order.
ii) The columns of the window are arranged in ascending order.
iii) The right diagonal of the window is now arranged in ascending order.

Step 3:

Case i: The **þ(x,y)** is an uncorrupted pixel if $\text{þ}_{min} < \text{þ}(x,y) < \text{þ}_{max}$, $\text{þ}_{min} > 0$ and $\text{þ}_{max} < 255$, the pixel being processed is left unchanged. Otherwise **þ(x,y)** is a corrupted pixel.

Case ii: If **þ(x,y) is** a corrupted pixel, it is replaced by its median value if $\text{þ}_{min}<\text{þ}_{med}<\text{þ}_{max}$ and $0< \text{þ}_{med} <255$.

Case iii: If $\text{þ}_{min}<\text{þ}_{med}<\text{þ}_{max}$ is not satisfied or $255< \text{þ}_{med}=0$, then þ_{med} is noisy pixel. In this case, the **þ(x,y)** is replaced by the value of neighbourhood pixel value.

Step 4: Above steps are repeated until the process is completed for the entire video frames.

III. UN-SYMMETRIC TRIMMED MEDIAN FILTER (UTMF)

Median filters are widely used for smoothing operations in signal, speech and image processing. This filter operation is performed on an NxN image matrix ***I***[1...N, 1...N] using a *W*x*W* window where *W*=2w+1 is an odd number. The result of median filtering is an NxN matrix. The median for a 2-D frame is defined as:

*MEDIAN*2D[i,j]= **median**{ I[a,b] | *nbhd*(a,i,w,N) and *nbhd*(b,j,w,N) }

Where,

$$nbhd\,(p,q,r,s) = \begin{cases} \textbf{True;}\ (p-q) \bmod s \leqslant r \text{ or } (q-p) \bmod s \leqslant r \\ \textbf{False;}\ \text{otherwise} \end{cases}$$

A trimmed filter rejects the noise pixel from the selected 3x3 window. Alpha Trimmed Median Filter (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 video frame details and blurring of the video frames. In order to overcome this problem, an Un-symmetric Trimmed Median Filter (UTMF) is proposed. In UTMF, the selected 3x3 window elements are arranged in either increasing or decreasing order. Then the pixel values 0's and 255's which are causing salt and pepper noise, are removed from the video frame. The median value is then calculated for the remaining pixels. This median value is used to replace the noisy pixels. The pixel values 0's and 255's are removed from the selected window hence, we are calling it as trimmed median filter. This UTMF gives better noise removal than ATMF.

IV. DECISION BASED UN-SYMMETRIC TRIMMED MEDIAN FILTER (DBUTMF)

Decision Based Algorithm (DBA) is a recently proposed algorithm to remove salt and pepper noise. In DBA each pixel is processed for de-noising using a 3x3 window. During processing if a pixel is '0' or '255' then it is processed else it is left unchanged. In DBA the corrupted pixel is replaced by the median of the window. At higher noise densities the median itself will be noisy, and the processing pixel will be replaced by the neighbourhood processed pixel. This repeated replacement of neighbourhood pixels produces streaking effect. In DBUTMF, the corrupted pixels are identified and processed. The DBUTMF algorithm checks whether the left and right extreme values of the sorted array obtained from the 3x3 window are impulse values. The corrupted processing pixel is replaced by a median value of the pixels in 3x3 windows after trimming impulse values. The corrupted pixel is replaced by the median of the resulting array.

A. Implementation of DBUTMF

The video sequence is first converted in to frames and frames in to images, Then DBUTMF algorithm is applied to the images which are separated from frames. After the filtering process, the frames are converted back to the original video. The below figure 8 shows the process flow.

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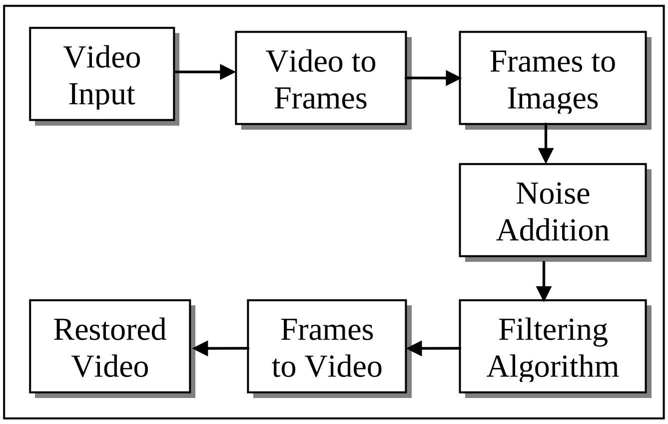

Fig. 8 Process flow block diagram of DBUTMF

B. DBUTMF Algorithm

1. Video to Frames: The noisy video sequence containing Impulse noise (Salt and Pepper noise) is converted into frames at 24 f/s rate.
2. Frames to Images: Frames are then converted in to .JPEG images to pass through the Filtering process to remove the Impulse noise presented.
3. Filtering: The impulse noise from the noisy images is removed using DBUTMF algorithm.
4. Frames to Movie: After removal of impulse noise from all noisy images, the frames are converted back in to original video. The following figure 9 shows the flow chart of DBUTMF.

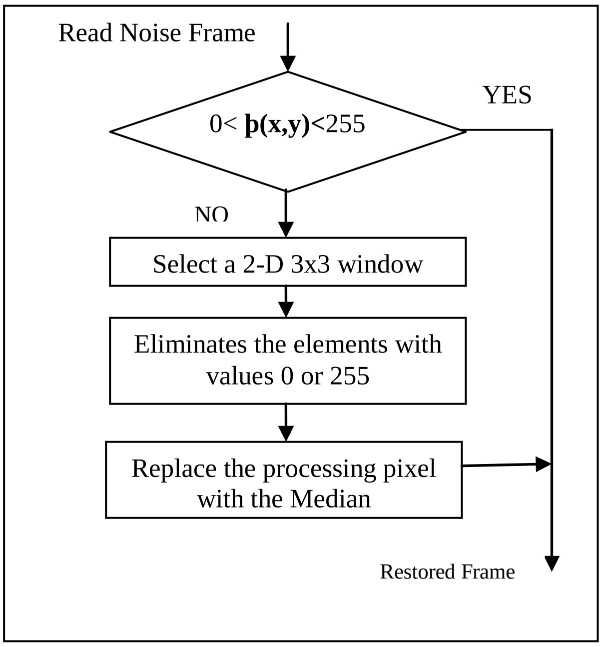

Fig. 9 DBUTMF Algorithm Flow Chart

V. Modified Decision Based Un-Symmetric Trimmed Median Filter (MDBUTMF)

The proposed Modified Decision Based Un-symmetric Trimmed Median Filter (MDBUTMF) algorithm processes the corrupted video frame by first detecting the impulse noise. The processing pixel is checked whether it is noisy or noise-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.

Each and every pixel of the frame 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). If the processing pixel is noisy pixel that is 0 or 255 is illustrated in case (ii). If the processing pixel is not noisy and its value lies between 0 and 255 is illustrated in case (iii).

Case (i): If the selected window contains salt and pepper noise as processing pixel and neighbouring pixel values contains all pixels that adds salt and pepper noise to the video frame.

$$\left\{\begin{matrix} 0 & 255 & 0 \\ & \langle 255 \rangle & 255 \\ 255 & 0 & 255 \end{matrix}\right\}$$

Where "255" is processing pixel.

Since all the elements surrounding **þ(x,y)** are 0's and 255's. If one takes the median value it will be either 0 or 255 which is again noisy. To solve this problem, the mean of the selected window is found and the processing pixel is replaced by the mean value. Here the mean value is 170. Replace the processing pixel by 170.

Case (ii): If the selected window contains salt and pepper noise as processing pixel and neighbouring pixel values contains some pixels that adds salt and pepper noise to the video frame.

$$\left\{\begin{matrix} 78 & 90 & 0 \\ 120 & \langle 0 \rangle & 255 \\ 97 & 255 & 73 \end{matrix}\right\}$$

Where "0" is the processing pixel.

Salt and pepper noise is now eliminated from the selected window. That is elimination of 0's and 255's. The 1-D array of the above matrix is [78 90 0 120 0 255 97 255 73]. After elimination of 0's and 255's the pixel values in the selected window will be [78 90 120 97 73]. Here the median value is 90. Hence replace the processing pixel **þ(x,y)** by 90.

Case (iii): If the selected window contains a noise free pixel as a processing pixel, it does not require further processing. For example, if the processing pixel is 90 then it is noise free pixel.

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$$\begin{Bmatrix} 43 & 67 & 70 \\ 55 & \langle 90 \rangle & 79 \\ 85 & 81 & 66 \end{Bmatrix}$$

Where "90" is the processing pixel.

Since 90 is a noise free pixel it does not require further processing.

VI. Simulation Reports And Results

The developed algorithm is tested on various simple and complex impulse noisy gray/color videos and compared with standard filters namely standard median filter (SMF), Adaptive median filter (AMF), decision based algorithm and decision based un-symmetric median filter (DBUTMF). Each time the test frame 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 filters. In addition to image quality, the performance of the developed algorithm and other standard algorithms are quantitatively measured by the parameters such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Image Enhancement Factor (IEF).

A. Performance Characteristics

Peak Signal to Noise Ratio (PSNR):

$$PSNR = 10\,\mathbf{log}_{10}(255^2 / MSE)\ \text{dB.} \quad \text{---- (1)}$$

Where *MSE* is the mean square error, and is defined as follows

$$MSE = \frac{\sum_x \sum_y \left(Y(x,y) - \hat{Y}(x,y) \right)^2}{MN} \quad \text{---- (2)}$$

Where $Y(x,y)$ is the original video frame of size M x N.

The Image Enhancement Factor is a measure of Image quality, and is defined as

$$IEF = \frac{\sum_x \sum_y \left(\xi(x,y) - Y(x,y) \right)^2}{\sum_x \sum_y \left(\hat{Y}(x,y) - Y(x,y) \right)^2} \quad \text{----(3)}$$

B. Comparison of PSNR and IEF values

TABLE I
Comparison of PSNR values of various algorithms for Video Frame one shown in Fig. 10

Noise %	PSNR in dB					
	MF	AMF	PSMF	DBA	DBUTMF	MDBUTMF
10	28.33	30.50	32.42	38.24	38.95	39.93
20	27.86	29.40	30.39	34.69	34.64	36.98
30	23.87	28.26	27.56	32.16	32.44	33.66
40	20.22	26.50	24.59	30.59	30.56	32.42
50	17.06	25.39	21.23	28.54	28.66	30.25
60	13.21	22.50	14.22	26.93	26.83	28.43
70	11.93	17.25	11.84	24.64	24.48	26.30
80	10.68	12.31	10.02	22.32	22.45	23.14
90	8.85	9.96	8.57	19.15	19.65	20.50

TABLE III
Comparison of IEF values of various algorithms for Video Frame one shown in Fig. 10

Noise	Image Enhancement Factor (IEF)					
	MF	AMF	PSMF	DBA	DBUTMF	MDBUTMF
10	12.58	25.25	173.52	395.69	425.29	650.99
20	30.27	39.79	209.35	360.98	379.56	570.56
30	32.09	45.68	195.96	325.79	345.63	594.26
40	25.37	43.69	153.33	268.49	281.22	436.25
50	15.79	39.41	65.89	212.87	222.22	349.24
60	9.31	27.31	8.31	193.86	179.29	283.46
70	5.21	9.79	5.38	130.44	131.55	173.56
80	5.12	5.62	4.26	70.46	76.52	104.24
90	2.32	2.31	2.35	35.89	35.35	36.67

The PSNR and IEF values of the proposed algorithm for the video frame1 at different noise densities are compared against the existing algorithms. From the Table I and Table II it is observed that the proposed algorithm gives the better PSNR and good IEF among all remaining algorithms. The qualitative analysis of the proposed algorithm against the existing algorithms at different noise densities is shown in fig.12. The MDBUTMF can be used for processing both gray and color videos at different noise density levels effectively.

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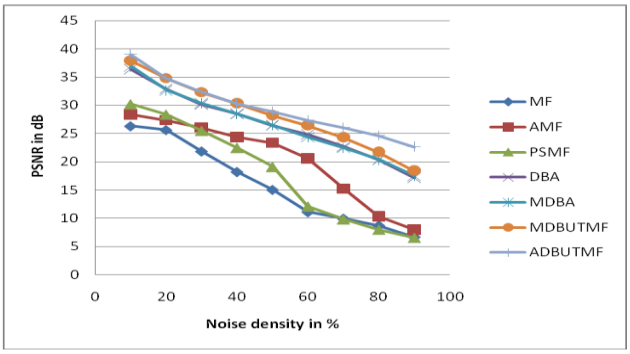

Fig. 10 PSNR of various algorithms Vs. Noise density

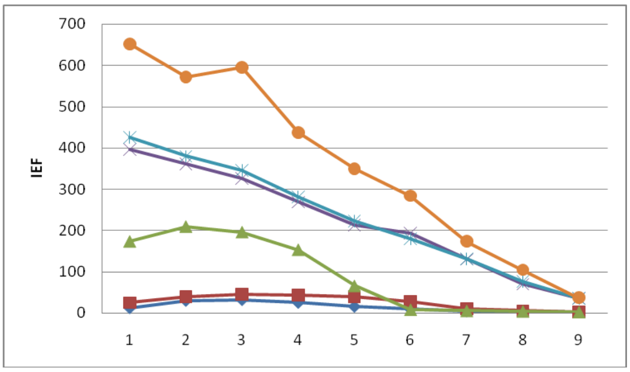

Fig. 11 IEF of various algorithms Vs. Noise density

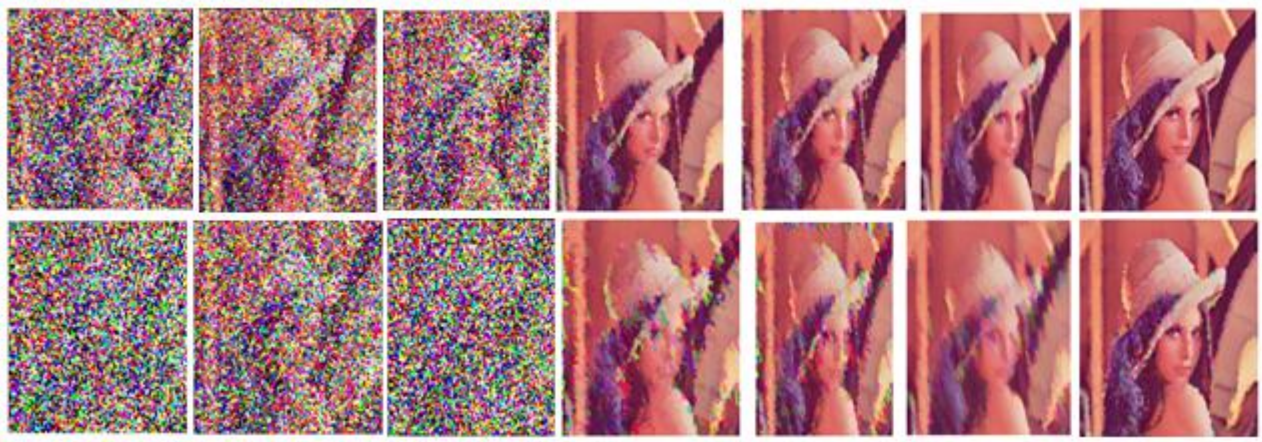

Figure 12. Results of different algorithms for color Lena images. (a) Output of MF. (b) Output of AMF (c) Output of PSMF. (d) Output of DBA. (e) Output of MDBA. (f) Output of MDBUTMF. (g) Output of PA. Row 1 and Row 2 show processed results of various algorithms for color image corrupted by 80% and 90% noise densities.

The above figure shows the performance of different algorithms, and it shows the ability of each algorithm for removing Salt and Pepper noise (impulse noise).

VII. Conclusions

An efficient algorithm to remove high density salt and pepper noise is proposed. The modified shear sorting algorithm reduces the computational time required for finding mean. This increases the efficiency of the system. The algorithm removes impulse noise even at higher noise densities and preserves the edges and frame details. Both visual and quantitative results are demonstrated.

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