

A New Method for Removal of Salt and Pepper Noise through Advanced Decision Based Unsymmetric Median Filter

A.Srinagesh^{#1}, BRLKDheeraj^{*2}, Dr.G.P.Saradhi Varma^{*3}

¹CSE Department, RVR & JC College of Engineering, Guntur, INDIA

²Associate System Engineer, TCS, Hyderabad, INDIA

³IT Department, SRKR Engineering College, Bhimavaram, INDIA

Abstract— A new method using a highly efficient filter algorithm for the restoration of images that are very highly corrupted by high density salt and pepper noise is proposed in this paper. The proposed method restores the image by processing the values of the pixels having 0 or 255 and copying the processed result in new image's corresponding pixel. Initially the new resulting image is to be assigned with noisy image. When all the pixel values in the selected window are 0's and 255's, the pixel value of the new image is replaced by the median of the pixel values that are processed before the present pixel gets processed. The proposed algorithm provides much better results than the Median Filter (MF), Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) which shows better results than Decision Based Algorithm (DBA), Modified Decision Based Algorithm (MDBA) and Progressive Switched Median Filter (PSMF). The Proposed method of noise removal is tested against color and gray images and it provides better Peak-Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF) particularly at high noise densities.

Keywords— Image Processing, Pre-Processing, Noise Removal, Filtering.

I. INTRODUCTION

Small amount of noise can damage the image to a great extent. High density Impulse noise gets immersed into the images due to bit errors in the transmission of signal and interference while transmitting the image. There are two types of impulse noise. They are salt and pepper noise and random valued noise. There are several methods to remove salt and pepper noise in the image. Among all those methods Standard Median Filter has been established a reliable method. However the Median Filter is reliable only at low noise density and the Median Filter can only remove noise if the noisy pixels occupy less than half of the neighborhood pixels. In Decision Based Algorithm (DBA), image is denoised by using 3x3 window. If the pixel value is 0 or 255, then it is processed or else it is left unchanged. If all the pixel values of the 3x3 window are 0's and 255's then the replacing value will also become 0 or 255. In such case, the neighboring pixel is used for replacement. This repeated replacement produces streaking effect in the image. In order to avoid this drawback, Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is proposed. When all the pixel values in the 3x3 window are 0's or 255's, trimmed median will not obtain. So the pixel value is replaced by the mean of the pixel values of that 3x3

window. This provides better Peak-Signal-to-Noise Ratio (PSNR) than Decision Based Algorithm (DBA). The main drawback of the Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) is its consideration of processed pixels in calculating the median even the window consists of uncorrupted pixels. The trimmed median of the entire 3x3 window will not provide the noisy pixel value as accurate as the trimmed median of uncorrupted pixels of the same 3x3 window. To overcome this drawback we proposed ADBUTMF in which the 3x3 window that is processed is always taken from the noisy image and the processed value is copied in the new image's corresponding pixel. If the 3x3 window contains all 0's or 255's, it is replaced with the median value of the pixel values that get processed that is, in a 3x3 window, three elements of the first row and the first element of second row are considered and the median of those four values is placed as the processed value. This gives better results than the Decision Based Unsymmetric Trimmed Median Filter (DBUTMF). The proposed method gives much better results even in the high noise density that is of 80% to 90%.

The rest of the paper is structured as follows. A brief description of the literature reviewed is given in section II. Noise removal techniques like Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) and Advanced Decision Based Unsymmetric Trimmed Median Filter (ADBUTMF) algorithms are defined in Section III A and B. Introduction to the proposed method is described in Section III C. The detailed description of the proposed algorithm with example is defined in Section III D. Simulation results of different images are provided in Section IV. Finally conclusions are provided in Section V.

II. LITERATURE SURVEY

Digital Images are often corrupted by impulse noise, also known as salt and pepper noise. A standard signal processing requirement is to remove randomly occurring impulses without disturbing edges [1, 2]. The impulse noise pixels can take the maximum and minimum values in the dynamic range (0, 255) if a pixel value is with 255 then regarded as "Salt" and if pixel value is 0 regarded as "Pepper" combining the Salt-and-Pepper Noise. In order to remove the noise from an image we need to identify the noise-free and noisy pixels from an image. If the value of the pixel to be processed while removing the noise from an image if 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. In selecting a noise reduction algorithm [3], we need to consider the following factors:

- (i) The available computer power of a system and available time.
- (ii) Whether sacrificing some real detail is acceptable if it allows more noise to be removed.
- (iii) The characteristics of the noise and the detail in the image, to better make those decisions.

Salt-and-Pepper noise or Impulsive noise distorts the information content. This effect is more prominent in an image which is corrupted with individual noisy pixels or with images whose brightness differs significantly from that of a neighbourhood. In this type of noise effect [4], the image is corrupted with white and/or black pixels. Noise can occur in still images or video sequences of DTV in various steps such as image acquisition, recording, and transmission [5]. The standard television broadcast signals are often contaminated with impulse noise arising from various sources such as household electrical appliances and atmospheric disturbances [6]. In order to get images and video sequences of high quality in digital cameras and DTV, it is very important to eliminate impulse noise in the images. For further uses of these images needs the noise is to be removed from those corrupted images [8].

A. EFFECT OF NOISE IN DIGITAL IMAGES

All images contain some visual noise. The presence of noise gives an image a mottled, grainy, textured, or snowy appearance [9]. No imaging method is free of noise, but noise is much more prevalent in certain types of imaging procedures than in others. The presence of noise in an image hides the image features, blurs the image content, degrades the quality of an image and will have impact on object visibility by giving undesirable appearance [10]. Noise introduces some problems in digital cameras, In low light, correct exposure requires the use of long shutter speeds, higher gain (or sensitivity), or both. On most cameras, longer shutter speeds lead to increased salt-and-pepper noise due to photodiode leakage currents [11]. At the cost of a doubling of read noise variance, this salt-and-pepper noise can be mostly eliminated by dark frame subtraction. The relative effect of both read noise and shot noise increase as the exposed is reduced, corresponding to increased ISO sensitivity, since fewer photons are counted (shot noise) and since more amplification of the signal is necessary [2]. The size of the image sensor, or effective light collection area per pixel sensor, is the largest determinant of signal levels that determine signal-to-noise ratio and hence apparent noise levels. The sensitivity of a given image at the same noise level scales roughly with the sensor area.

B. IMPULSE NOISE OR SALT-AND-PEPPER NOISE

Images are often corrupted by impulse noise, also known as salt and pepper noise [12]. A standard signal processing requirement is to remove randomly occurring impulses without disturbing edges. The impulse noise

pixels can take the maximum and minimum values in the dynamic range (0, 255) if a pixel value is with 255 then regarded as “Salt” and if pixel value is 0 regarded as “Pepper” combining the Salt-and-Pepper noise means it represents randomly occurring white and black pixels in an image [13]. An Image can be corrupted by Impulse Noise during transmission or reception. A pixel which is being corrupted by an impulse noise has gray level value either zero i.e. black dot or 255 i.e. pure white dot on the image. Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise [14]. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by dead pixels, analog-to-digital converter errors, bit errors in transmission, etc [15]. The following figure shows original image along with some percentage of pixels corrupted by Salt-and Pepper noise.

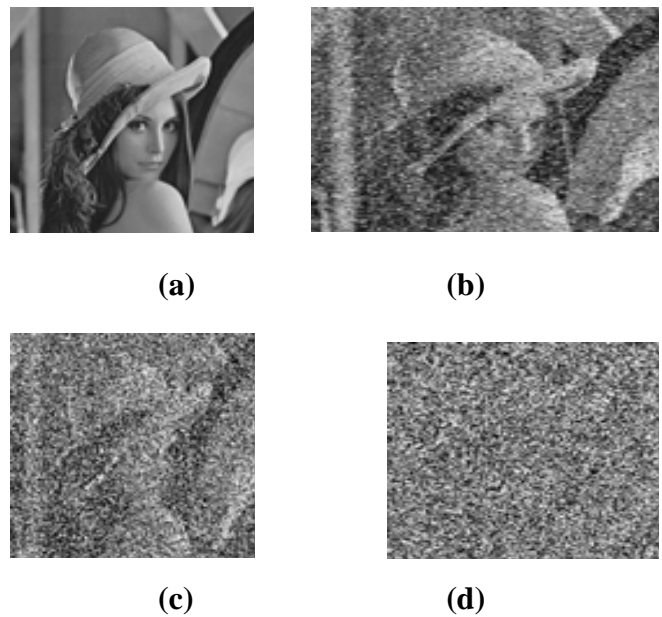


Fig: 1 (a) Original image (b) 30% Impulse Noise (c) 60% Impulse Noise (d) 90% Impulse Noise

For further uses of these images needs the noise is to be removed from those corrupted images. This can be achieved by applying Image-denoising methods [3]. The predominant use of Image denoising methods is to suppress the image noise. This method uses a small neighborhood of a pixel in an input image to produce a new brightness value in the output image. A New Fast and Efficient Decision-Based Algorithm for Removal of High-Density Impulse Noises from highly corrupted images were proposed by K. S. Srinivasan and D. Ebenezer [14].

Many image denoising methods have been proposed to carry out the impulse noise suppression. Some of them employ the standard median filter or its modifications to implement the denoising process. However, these approaches might blur the image since both noisy and noise-free pixels are modified.

To avoid the damage on noise-free pixels, many image filters with an impulse detector are proposed in the

literature [15]. The main advantage of these methods is that they employ an impulse detector to locate and filter the noisy pixels without processing the noise-free pixels. Many recent denoising techniques use a fixed-size local window for processing and perform image denoising simply and efficiently. A new impulse detector (NID) for switching median filter used the minimum absolute value of four convolutions which are obtained by using one-dimensional Laplacian operators to detect noisy pixels. The differential rank impulse detector (DRID) implemented the impulse detector based on a comparison of signal samples within a narrow rank window by both rank and absolute value. An alpha-trimmed mean-based method (ATMBM) uses the alpha-trimmed mean in impulse detection and replaced the noisy pixel value by a linear combination of its original value and the median of its local window. The decision-based algorithm (DBA) was presented to remove the corrupted pixel by the median or by its neighbouring pixel value according to the proposed decisions by improving the PSNR value but as noise density increases, image gets blurred.

III. NOISE REMOVAL TECHNIQUES

A. DECISION BASED UNSYMMETRIC TRIMMED MEDIAN FILTER (DBUTMF)

Decision Based Unsymmetric Trimmed Median Filter (DBUTMF) algorithm processes the noisy image by using the 3x3 window for each and every pixel of the image as the center of the 3x3 window. If the center pixel value of the 3x3 window is other than 0 or 255, the value is kept unchanged or else if the center pixel value is 0 or 255, it is needed to process that pixel. If all the pixel values of the 3x3 window are 0's or 255's, the median of that 3x3 window replaces the pixel value or else if any of the 3x3 window other than the center pixel contains value between 0 and 255, then the trimmed median value of that 3x3 window replaces the center pixel value. The trimmed median value is the median value of the values in the 3x3 window other than 0 and 255. Thus each and every pixel of the image is taken as center of the 3x3 window and gets processed. After processing all the pixels of the image, the noise free image will be obtained.

ALGORITHM

- Step 1: Select the window of size 3x3. Let the pixel being processed is G_{ij} .
- Step 2: If $0 < G_{ij} < 255$, G_{ij} is an uncorrupted pixel and its value is left unchanged.
- Step 3: If $G_{ij} = 0$ or $G_{ij} = 255$, it is corrupted Pixel and needs to be processed.
- Case (i):** If the selected window contains all 0's and 255's, then replace G_{ij} with the mean of the elements of the window.
- Case (ii):** If any of the elements of the 3x3 window contains value other than 0 or 255, eliminate 0's and 255's and find the median of the remaining elements. Replace G_{ij} with the median value.
- Step 4: Repeat Step 2 and Step 3 until all pixels of the image gets processed.

B. ADVANCED DECISION BASED UNSYMMETRIC TRIMMED MEDIAN FILTER (ADBUTMF)

The idea behind the proposed method is to remove the noisy pixel from the selected 3x3 window and attaining the uniform color. In Decision Based Unsymmetric Trimmed Median Filter (DBUTMF), the trimmed median value of the 3x3 window may not be near to the original pixel value as it considers the processed pixel values along with the uncorrupted pixels in that window. If there are uncorrupted pixels in the 3x3 window, there is nothing to go with the processed pixels. To overcome this drawback, ADBUTMF is proposed. In the proposed method, if the processing pixel value is in between 0 and 255 ($0 < p < 255$), it is noise free pixel. If the pixel value is 0 or 255, and if we have any element of its 3x3 window is other than 0 and 255, the trimmed median copies the pixel value to the new image. If the 3x3 Window containing all the 0's and 255's is processed as follows:

The three pixels of the first row and the first pixel of the second row get processed before the center pixel of the 3x3 window. Therefore in the proposed method, the processed pixel values of those four pixels are considered and the trimmed median of those four values replaces the center pixel of the 3x3 window. Thus the process is repeated until all the pixels of the image get processed.

C. PROPOSED ALGORITHM

The proposed ADBUTMF algorithm processes the corrupted image as follows:

ALGORITHM (Proposed)

- Step 1: Initialize $H=G$ and Select the window of size 3x3. Let the pixel being processed is G_{ij} .
- Step 2: If $0 < G_{ij} < 255$, G_{ij} is an uncorrupted pixel then H_{ij} value is replaced by G_{ij} .
- Step 3: If $G_{ij} = 0$ or $G_{ij} = 255$, it is corrupted Pixel and needs to be processed.
- Case (i):** If the selected window contains all 0's and 255's, then consider the three pixels of the first row and the first pixel of the second row. Find the median of the processed values of those four pixels and replace H_{ij} with that median value.
- Case (ii):** If any of the elements of the 3x3 window contains value other than 0 or 255, eliminate 0's and 255's and find the median of the remaining elements. Replace H_{ij} with the median value.
- Step 4: Repeat Step 2 and Step 3 until all pixels of the image gets processed.

D. ILLUSTRATION OF ADBUTMF ALGORITHM

Each and every pixel is checked for the presence of salt and pepper noise. Different cases of processing will be illustrated in this section. The processing pixel is noisy if its pixel value is 0 or 255. If the processing pixel is noisy and all the other pixel values are either 0's or 255's is illustrated in Case (i) If the processing pixel is noisy and any of the other pixel values is other than 0 and 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 and pepper noise as processing pixel and all the neighboring pixels are also of the noisy pixels:

3x3 window taken from noisy image

0	255	0
0	<255>	255
255	0	255

Where <255> is the processing pixel G_{ij}. Consider the restoring result image “H” of that processing pixel, which will have the four processed pixels as:

32	41	35
39	-	-
-	-	-

The four processed pixel values are [32 41 35 38].

Median of those values is 37. Thus “37” is copied to the pixel

H_{ij} “255”. Therefore the new value of H_{ij} becomes “37”.

Case (ii) If the selected window contains any of the neighboring pixels other than 0 and 255:

74	92	0
0	<0>	255
255	72	255

Where “0” is the processing pixel. Now eliminate the 0’s and 255’s. The elements of the above window are [74 92 0 0 0 255 255 72 255]. Remove 0’s and 255’s from the above elements [74 92 72]. Here the median value is “74”. Hence replace the pixel value H_{ij} by 74.

Case (iii) If the selected window contains the noise free pixel as the processing pixel, the pixel value need not be changed. For example if the processing pixel is 58 then it is noise free pixel.

47	53	51
56	<58>	61
54	57	62

Where “58” is the processing pixel. As “58” is noise free, it need not be processed. Hence “58” is copied to H_{ij}.

IV. EXPERIMENTAL RESULTS

The performance of the proposed algorithm has been tested with different gray scale and color images at different noise intensities varied from 10% to 90%. The performance of denoising the image is measured quantitatively by the IEF, MSE and Peak-Signal-to-Noise Ratio (PSNR) as defined in (1), (2) and (3), respectively:

$$IEF = \frac{\sum_i \sum_j (N(i,j) - O(i,j))^2}{\sum_i \sum_j (R(i,j) - O(i,j))^2} \quad (1)$$

Where N -> Noisy image O-> Original image and R-> Resulting denoised image.

$$MSE = \frac{\sum_i \sum_j (O(i,j) - R(i,j))^2}{M * N} \quad (2)$$

Where M X N is the size of the image.

$$PSNR = 10 \log_{10} \left[\frac{255^2}{MSE} \right] \quad (3)$$

The PSNR and IEF values of the proposed algorithm are compared with the existing algorithms by varying the noise intensity from 10% to 90%. The PSNR comparison of two images are shown in Table 1 and Table 2 respectively. The IEF values of various algorithms on racing car image are shown in Table 3.

TABLE 1: COMPARISON OF PSNR VALUES OF DIFFERENT ALGORITHMS FOR BUTTERFLY IMAGE AT DIFFERENT NOISE DENSITIES (PSNR IN DB)

Noise in %	MF	DBA	MDBA	MDBUTMF	Proposed
10	32.9	39.9	40.6	42.2	41.9
20	30.7	36.7	36.0	38.6	38.6
30	26.8	32.7	32.4	35.3	35.8
40	23.2	31.6	32.0	33.7	34.4
50	20.0	29.6	29.4	31.5	32.5
60	17.2	27.0	27.6	29.7	31
70	15.2	25.5	25.2	27.7	29.9
80	13.5	23.3	23.8	25.5	27.9
90	11.9	20.9	19.5	22.7	24.9

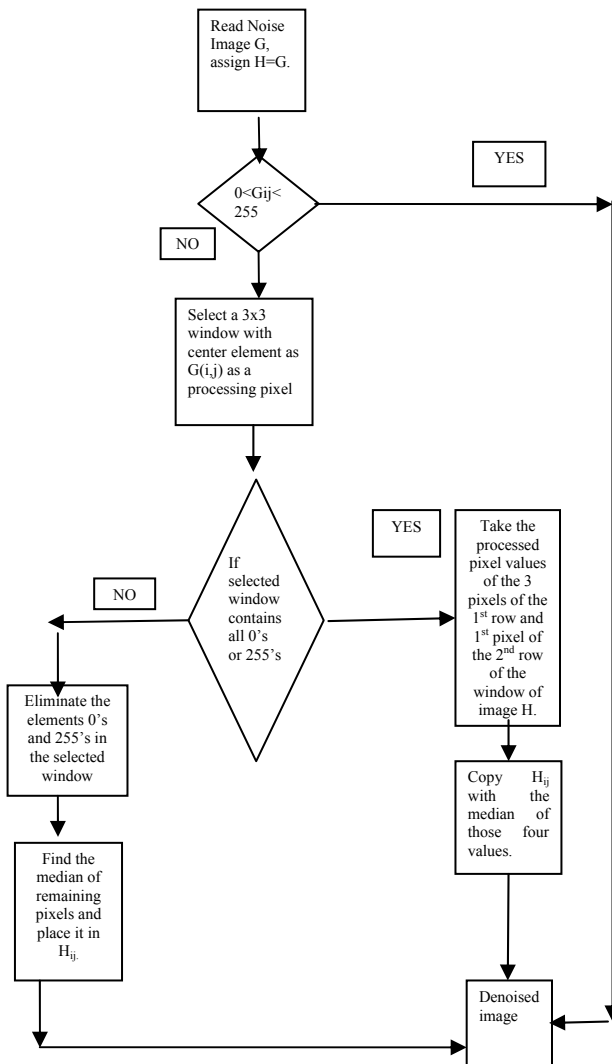


Fig 2.Flow chart of ADBUTMF

TABLE 2: COMPARISON OF PSNR VALUES OF DIFFERENT ALGORITHMS FOR RACING CAR IMAGE AT DIFFERENT NOISE DENSITIES (PSNR IN DB)

Noise In %	MF	DBA	MDBA	MDBUTMF	ADBUTMF
10	27.4	34.0	34.6	34.8	34.9
20	26.0	31.0	31.9	32.4	32.9
30	24.5	29.7	29.8	30.6	31.0
40	22.3	28.2	28.1	28.0	29.1
50	20.0	26.8	25.6	26.8	28.0
60	17.4	24.6	24.6	25.5	27.0
70	15.7	22.5	23.0	23.2	25.7
80	13.8	21.1	21.6	21.6	24.4
90	12.7	18.9	18.1	18.4	21.7

TABLE 3: COMPARISON OF IEF VALUES OF DIFFERENT ALGORITHMS FOR RACING CAR IMAGE AT DIFFERENT NOISE DENSITIES

Noise In %	MF	DBA	MDBA	MDBU TMF	ADBUTMF
10	14.2	55.4	70	70.5	71.2
20	20.8	63.1	70.9	81.7	94.2
30	19.8	65.4	67.4	83.6	89.5
40	14.1	62.9	60.7	62.2	79.7
50	10.1	56.9	42.5	56.8	76.66
60	7.9	39.9	40.3	50.7	72.4
70	6.0	29.1	33.2	35.6	62.4
80	4.6	25.1	27.0	24.8	51.4
90	3.9	17.0	13.3	14.3	32.19

Where MSE stands for Mean Square Error, IEF stands for Image Enhancement Factor.

TABLE 4: COMPARISON OF PSNR VALUES OF DIFFERENT TEST IMAGES AT NOISE DENSITY OF 70% PSNR IN DB

Algorithm	Butterfly	Racing car	Flower
MF	15.2	15.7	14.3
DBA	25.5	22.5	24.4
MDBA	25.2	23.0	25.2
MDBUTMF	27.7	23.2	24.3
ADBUTMF	29.9	25.7	28.3

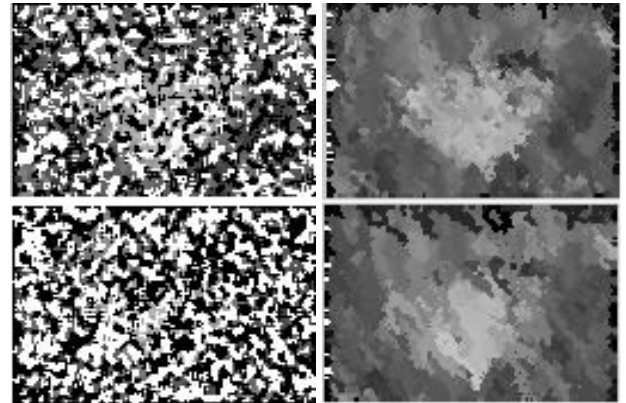
The quantitative analysis of the proposed algorithm against existing algorithms at different noise intensities for Butterfly image is shown in Fig. 3. In this figure the first column represents the processed gray image using Median Filter at 80% and 90% noise densities. A subsequent column represents the results of DBA, MDBA, MDBUTMF and ADBUTMF at 70% and 80% noise densities.

The images are corrupted by 70% Salt & Pepper noise and the PSNR results of the testing images are shown in Table 4. From the table it is clear that the proposed ADBUTMF method gives much better PSNR value irrespective of nature of the input image particularly at high noise intensities.

The proposed ADBUTMF technique can be used for gray scale as well as color images that are corrupted by Salt & Pepper noise. Fig. 4 represents the processed results of color image of butterfly image. The first column represents the processed color image using Median Filter at 80% and 90% noise densities. A subsequent column represents the results of DBA, MDBA, MDBUTMF and ADBUTMF at

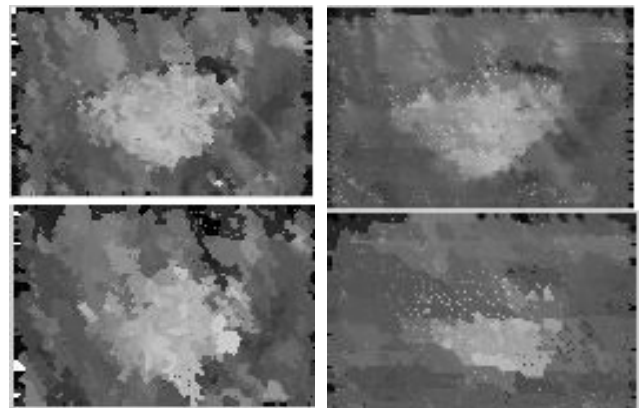
70% and 80% noise densities. From the Fig. 3 and Fig.4, it is clear that the restored image from the proposed algorithm is better than existing algorithms.

Therefore, the proposed ADBUTMF algorithm first checks whether the 3x3 window of the noisy image consists of any uncorrupted pixel. If the window consists of any uncorrupted pixels, the median of the uncorrupted pixels in that window will replace the corresponding pixel in image H, that is $H_{ij} = \text{median of uncorrupted pixels in window of image G}$. If there is no uncorrupted pixel in the window of noisy image, we consider the window of image H. The trimmed median of H replaces H_{ij} .



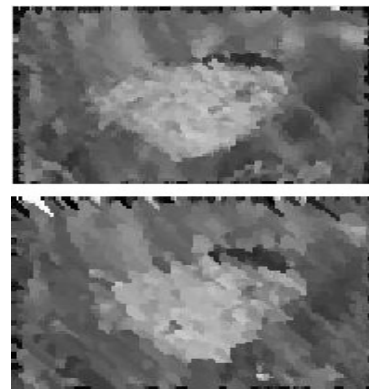
(a) MF

(b) DBA



(c) MDBA

(d) MDBUTMF



(e) ADBUTMF

Fig.3: Gray-scale images restored at 70% and 80%

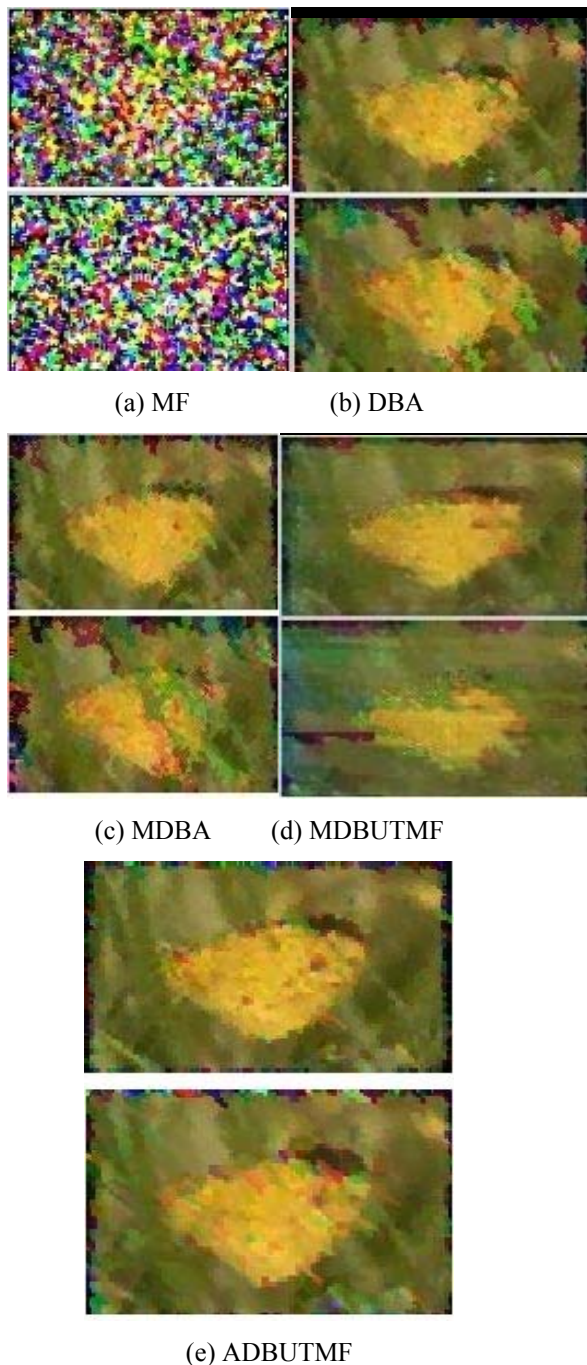


Fig.4 Color images restored at 70% and 80% respectively

V. CONCLUSIONS

In this paper, a novel approach algorithm (ADBUTMF) is proposed which gives better performance in comparison with Median Filter (MF), Decision Based Algorithm (DBA), Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) and other existing noise removal algorithms in terms of PSNR and IEF. The performance of the algorithm is tested against colour and gray-scale images at low, medium and high densities. The proposed ADBUTMF algorithm is effective for salt and pepper noise removal in the images. It shows better results than existing methods even at very high noise densities of 80% and 90%. Both visual and quantitative results are demonstrated.

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