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An Enhanced Decision Based Adaptive Median Filtering Technique to Remove Salt and Pepper Noise in Digital Images

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Abstract

In this paper, we present an algorithm to remove Salt and Pepper noise from grayscale images. It is an enhanced adaptive median filtering algorithm which initially calculates median without considering noisy pixels in the processing window. If the noise-free median value is not available in the maximum processing window, the last processed pixel value is used as the replacement. Moreover, in extreme situations such as noise corrupted pure black and white images, a threshold value is used to determine the pixel value. Experimental results show that our algorithm can perform better than the other non-linear filters, suppressing noise level more than 90% while preserving visual quality and necessary details of the image.

Keywords: Adaptive Median Filter (AMF), Noise, Salt and Pepper.

I. Introduction

Noise is an undesirable product of image. The digital image acquisition process converts an optical image taken with an optical device into a continuous stream of electrical signals that is later sampled in the primary process by which noise appears in digital images [1].

Salt and Pepper noise is a special case of Impulse noise where a percentage of pixels in an image is transformed either in to the lowest or highest intensity (0 or 255). It is generally caused by malfunctioning of camera sensors, faulty memory locations in hardware or transmission in a noisy channel. Salt and Pepper is a type of noise that is commonly present in images during image acquisition. It has undesirable impact on digital images; therefore it is necessary to remove them before the noise corrupted image is used in various image processing applications. Accordingly, many filtering techniques were proposed for the restoration purpose to remove Salt and Pepper type noise. The Standard Median Filter (SMF) was once one of the most widely used non-linear noise filtering techniques to remove this noise, largely due to its de-noising capability and computational efficiency. However, when the noise level is as high as 50%, it fails to preserve details and edges of the image.

Fig. 1 shows the functionality of median filter, where at each processing window of fixed size, the middle pixel is replaced by the median of its neighbouring pixels [1].

A number of improved methods such as Adaptive Median Filter (AMF) [1] and Weighted Median Filter (WMF) [2] have been proposed to overcome this problem. These filters windows containing a set of number pixels (such as a 3x3 window containing 9 pixels) and identify possible noisy pixels and then replace them by using the median filter or its variants, while leaving all the other pixels unchanged. The common drawback among all of these filtering techniques is that the noisy pixels are replaced without taking into account local features such as the presence of edges. Hence details of the images and edges are not recovered satisfactorily, especially when the noise level is high.

123	125	126	130	140
122	143	126	127	135
118	120	150	125	134
119	115	119	123	135
111	116	110	120	130

Neighbourhood values:
115, 119, 120, 123, 125, 126,127,143, 150
Median value: 125

Fig. 1: The functionality of the median filter.

Noise adaptive fuzzy switching median (NAFSM) filter was an improved filtering technique comparing to traditional non linear filters. Initially, the detection stage utilizes the histogram of the corrupted image to identify noise pixels. These detected "noise pixels" become the subject to the second stage for the filtering action, while "noise-free pixels" are retained and left unprocessed. Then, the NAFSM filtering mechanism employs fuzzy reasoning to handle the uncertainty that may be present in the extracted local information as introduced by noise. It's the Hybrid of Simple adaptive median filter (AMF) and fuzzy switching median filter where –Adaptive median filter (AMF) expands the size of its filtering window according to the local noise density and meanwhile, the inherited switching median selects only "noise-free pixels" for processing and the resorted fuzzy reasoning deals with producing an accurate correction term when restoring detected "noisy pixels" [3]. These papers exhibit good performance but performance degrades when image

is affected with high density noise (80% or above) and the restored image shows blurring effect due to the failure to estimate the local information and at the same time undesired information exists in the recovered image.
A decision based algorithm (DBA) was proposed, which first detects the Salt and Pepper noise in the image. The noisy and noise-free pixels in the image are detected by checking the pixel values against the maximum and minimum values in the window selected. The maximum and minimum values that the impulse noise exists will be in the dynamic range (0, 255) .If the pixel being currently processed has a value within the minimum and maximum values in the currently processed window, then it is a noise-free pixel and no modification is made to that pixel and if the value doesn't lie within the range, then it is a noisy pixel and will be replaced by either the median pixel value or by the mean of the neighbouring processed pixels , if the median itself is noisy [4]. However, it shows good performance at low noise rates, but still fails to suppress impulse noise effectively and preserve image details when noise rate is 70%. The performance degrades hugely with the noise density of 90% or more.

II. An Enhanced Decision Based Adaptive Median Filtering Technique to Remove Salt and Pepper Noise in Digital Images

A. Adaptive Median Filtering

The Adaptive Median Filter performs spatial processing to determine which pixels in an image have been affected by noise. It classifies pixels as noise by comparing each pixel in the image to its surrounding neighbour pixels. The size of the neighbourhood is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbours, as well as being not structurally aligned with those pixels to which it is similar, is designated as impulse noise. These noisy pixels are then replaced by the median value of the pixels in the neighbourhood that have passed the noise detection test.

Notations:

S_{xy} = Processing Window (Size)
Z_{min} = Minimum Grey Level Value in S_{xy}
Z_{max} = Maximum Grey Level Value in S_{xy}
Z_{med} = Median of Grey Levels in S_{xy}
Z_{xy} = Grey Level at Coordinates (x, y)
S_{max} = Maximum Allowed Size of S_{xy}

Algorithm:

Level A: $A1 = Z_{med} - Z_{min}$
$A2 = Z_{med} - Z_{max}$
if A1 > 0 AND A2 < 0, go to level B
else increase the window size
if window size < S_{max}, repeat level A
else output Z_{xy}

Level B: $B1 = Z_{xy} - Z_{min}$
$B2 = Z_{xy} - Z_{max}$
if B1 > 0 AND B2 < 0, output Z_{xy}
else output Z_{med}

B. Proposed Work

The key concept of the proposed algorithm is to consider only the noise-free pixels during calculating the median from the window. The pixel values of 0 or 255 will be omitted and median is calculated from the rest of the pixel values. Thereby, the adaptive windowing approach is used which enables our algorithm to expand the size of its filtering window based on the local noise density and thus facilitates to filter high density of salt-and-pepper noise.

Step 1: Starting from the middle pixel of an image with a 3x3 initial window size. The scanning process will be done through the whole image from middle to the upper left, upper right, lower left and lower right corners of the image. The idea is shown in fig. 2.

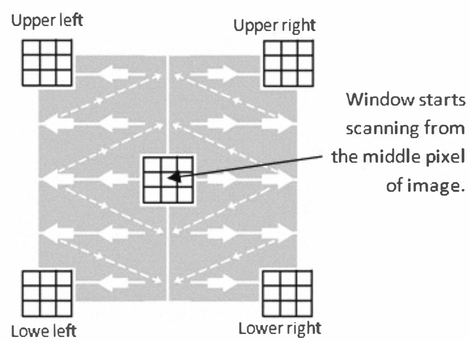


Fig. 2: Scanning process of the window of the proposed algorithm.

Step 2: Calculate median from the pixel values of the current window except values of 0 and 255.

Step 3: This step checks the following conditions:-
(a) If the median is noise-free (i.e. at least one noise-free pixel remains in window) then replace the centre pixel with the median and go to Step 5.
(b) If the median is noisy (that means no noise-free pixel is found in window) then increase the window size by one pixel at each of its four sides and perform the Step 2 up to maximum window size.
(c) If the maximum window size (7x7) is reached and still no median is found, then go to next step (Step 4).

Step 4: This step considers the last processed pixel (which was processed just before the current centre pixel). As the scanning starts from the middle pixel, it is more likely of getting last processed pixel within the image boundary.
(a) If the last proceed pixel is not 0 or 255 then replace the current centre pixel with that processed pixel.
(b) If the last processed pixel is 0 or 255 then consider the current maximum window size (7x7) and calculate the number of 0's and 255's in this window. If the number of 0's is greater than threshold value, then it is considered that the region is originally made up of 0 values (pure black region) and the centre pixel will be replaced by 0. Likewise, if the number of 255's is greater than threshold value, then it is assumed that the region is originally made up of 255 values (pure white region) and the centre pixel will be replaced with 255. (Here, threshold value is considered as 50% pixels in the current window. This value is determined from the experiment which is shown in the simulation part).

Step 5: Slide the window to the next pixel.

C. Flowchart

The flowchart for the proposed algorithm is presented below-

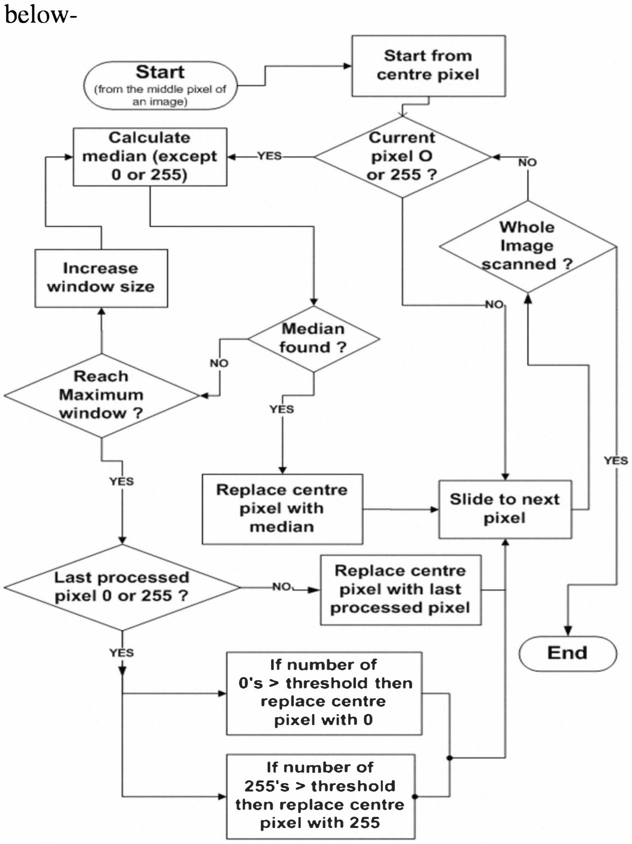


Fig. 3: Flow chart of the proposed algorithm.

III. SIMULATION AND PERFORMANCE ANALYSIS

We have used Matlab as the simulation tool. The proposed filter is tested with Image 'Lena.jpg' of size 512 x 512. The image is corrupted by Salt and Pepper noise at various noise densities and performance is measured using the parameters such as Signal-to-Noise Ratio (SNR), Peak-Signal-to-Noise Ratio (PSNR), Mean Absolute Error (MAE), Mean Square Error (MSE), and Universal Quality Index (UQI). Equations are shown below, where X is original image, Y is restored image, MAX is the maximum intensity, M is the maximum row size and N is the maximum column size, σ^2 is the variance.

$$\text{SNR} = \frac{\sum(|x_{ij} - y_{ij}|)^2}{\sum x_{ij}}$$

$$\text{PSNR} = 10 \log_{10} \frac{(MAX)^2}{MSE}$$

$$\text{MSE} = \frac{1}{MN} \sum (y_{ij} - x_{ij})^2$$

$$\text{MAE} = \frac{1}{MN} \sum |y_{ij} - x_{ij}|$$

$$\text{UQI} = \frac{4\sigma_{xy}\bar{x}\bar{y}}{(\sigma_x^2 + \sigma_y^2)[(\bar{x})^2 + (\bar{y})^2]}$$

Threshold value is taken as 50% of the total pixels in the window. Fig. 4 shows the curve which indicates that the performance is higher for using this threshold value for a gray image of pure black and pure white region.

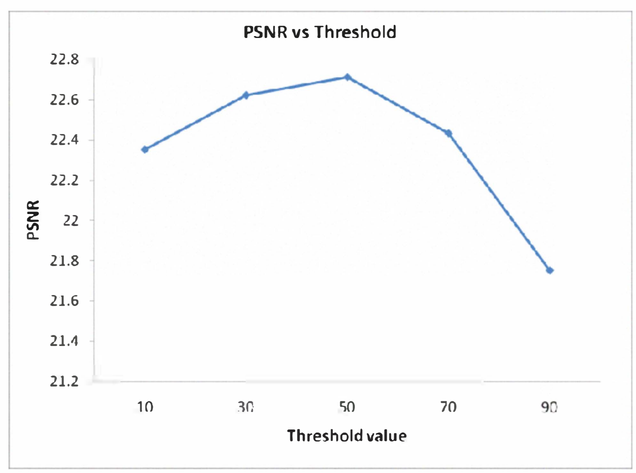
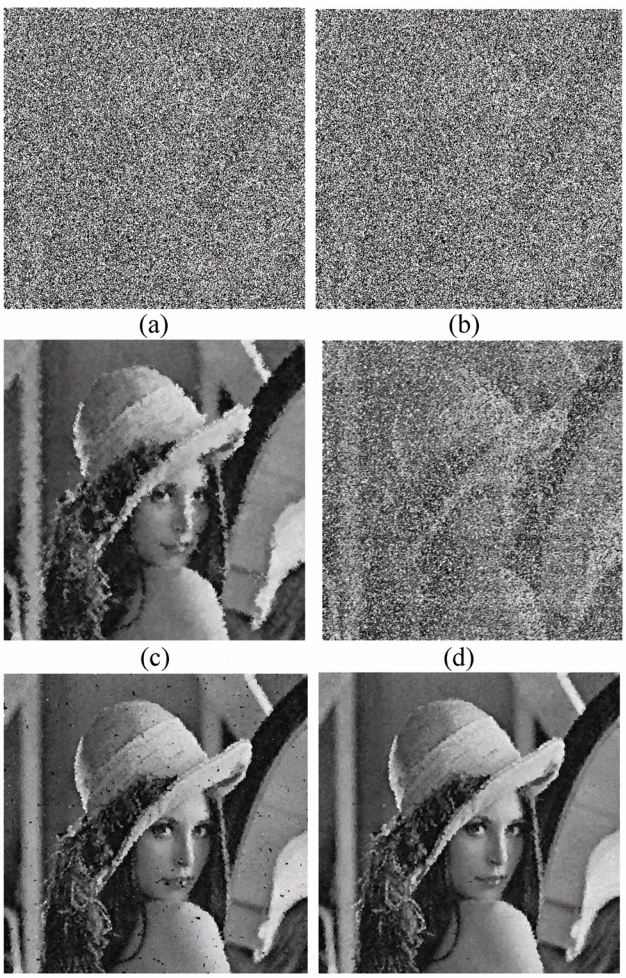


Fig. 4: Higher PSNR for taking 50% pixels in the current window.

(a) (b)

Fig. 5: (a) Lena.jpg Image corrupted with 40% of Salt and Pepper noise and (b) same image restored with the proposed algorithm.



(a) (b) (c) (d) (e) (f)

Fig. 6 (from upper left): (a) Lena Image corrupted with 90% noise and same image restored with (b) SMF, (c) AMF, (d) DBA, (e) NAFSM Filter and (f) Proposed Algorithm.

In the implementation we have considered the worst case scenario. However, it is very tough to detect Salt and Pepper noise in an image that only contains pixel values 0 and 255. In figure (Fig. 7) a gray image that contains pure black and white regions is shown.

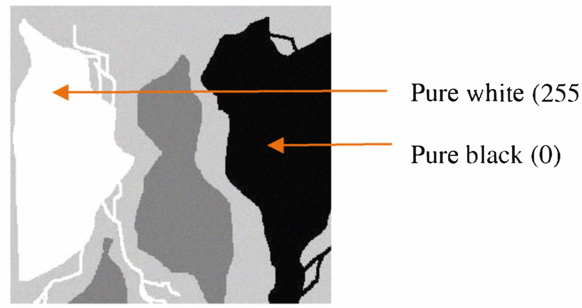
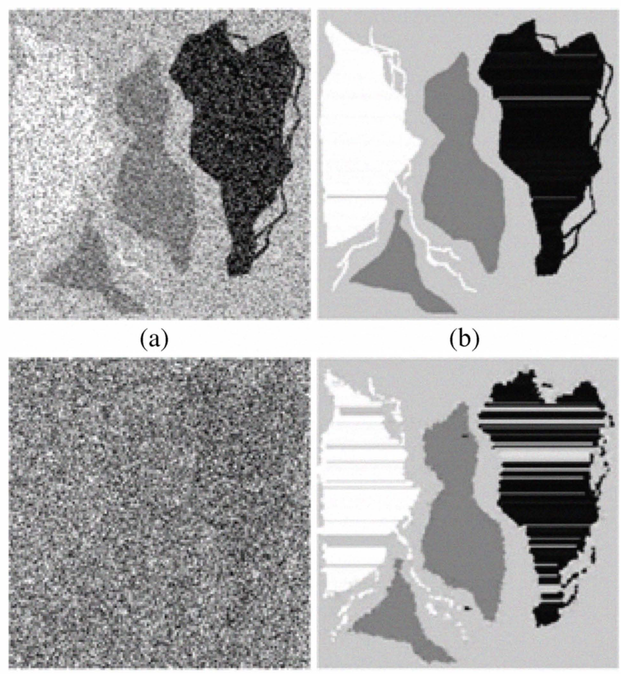


Fig. 7: A gray image of pure black and white regions.



(a) (b) (C) (d)

Fig.8: (a) The image of Fig. 7 is corrupted with 30% Salt and Pepper noise (b) restored using proposed algorithm, (c) corrupted with 60% noise and (d) restored using proposed algorithm.

The information is presented through Table I~III, which demonstrate the comparing results among Standard Median Filter (SMF), Adaptive Median Filter (AMF), Decision Based Algorithm (DBA), Noise Adaptive Fuzzy Switching Median filter (NAFSM) and proposed algorithm in terms of PSNR, MAE and UQI.

Table I: Comparative results of various filters in terms of PSNR for Lena.jpg image.

Noise Level (%)	SMF	AMF	DBA	NAFSM	Proposed
10	15.1	38.95	32.32	39.37	40.17
20	12.18	34.92	28.31	35.9	36.5
30	10.36	32.31	24.43	33.59	34.28
40	9.13	30.29	21.46	31.79	32.57
50	8.12	28.58	18.96	30.24	31.03
60	7.35	26.93	16.63	28.72	29.6
70	6.68	25.27	14.6	27.33	28.28
80	6.09	23.33	12.65	25.7	26.67
90	5.58	20.81	10.82	22.36	24.35
95	5.35	18.76	10.01	16.74	21.67

Table II: Comparative results of various filters in terms of MAE for Lena.jpg image.

Noise Level (%)	SMF	AMF	DBA	NAFSM	Proposed
10	12.83	0.6	1.7	0.58	0.54
20	25.23	1.29	2.65	1.19	1.12
30	38.29	2.12	4.59	1.89	1.77
40	50.75	3.02	7.44	2.62	2.45
50	63.9	4.1	11.54	3.49	3.24
60	76.43	5.32	17.6	4.45	4.09
70	89.24	6.85	25.79	5.58	5.12
80	102.01	8.91	37.21	7.03	6.45
90	114.87	12.51	52.58	9.92	8.67
95	121.16	16.22	61.27	18.08	11.45

Table III: Comparative results of various filters in terms of UQI for Lena.jpg image.

Noise Level (%)	SMF	AMF	DBA	NAFSM	Proposed
10	0.72	1	0.99	1	1
20	0.54	1	0.98	1	1
30	0.4	0.99	0.96	0.99	1
40	0.3	0.99	0.92	0.99	0.99
50	0.22	0.98	0.85	0.99	0.99
60	0.16	0.98	0.76	0.98	0.99
70	0.11	0.97	0.63	0.98	0.98
80	0.07	0.95	0.46	0.97	0.97
90	0.03	0.9	0.24	0.93	0.96
95	0.01	0.85	0.12	0.79	0.92

The proposed algorithm uses a maximum window size of 7X7 which makes it possible to preserve edges and details with the presence of very high density noise such as 95%. As our proposed approach does not take noisy pixels into account while calculating the median, which enables the algorithm to perform faster compared to other Median Filters. Graph comparisons are shown in Fig. 9(a) to Fig. 9(e).

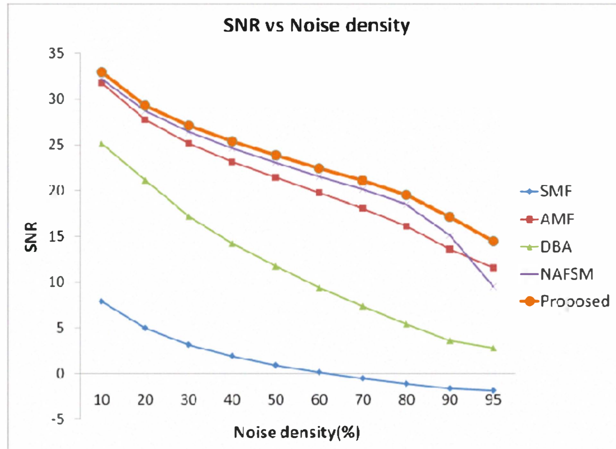


Fig. 9 (a): Graph comparison in terms of SNR.

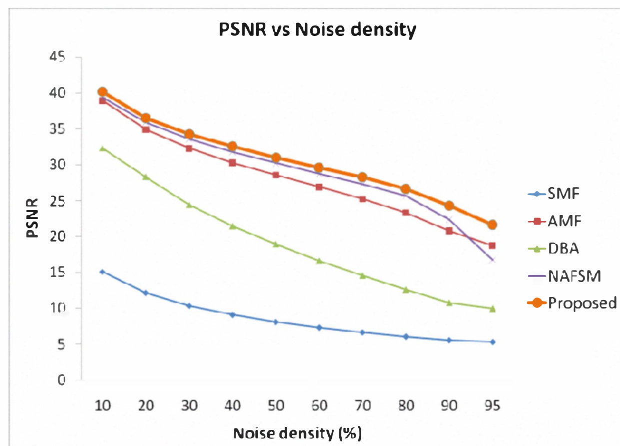


Fig. 9 (b): Graph comparison in terms of PSNR.

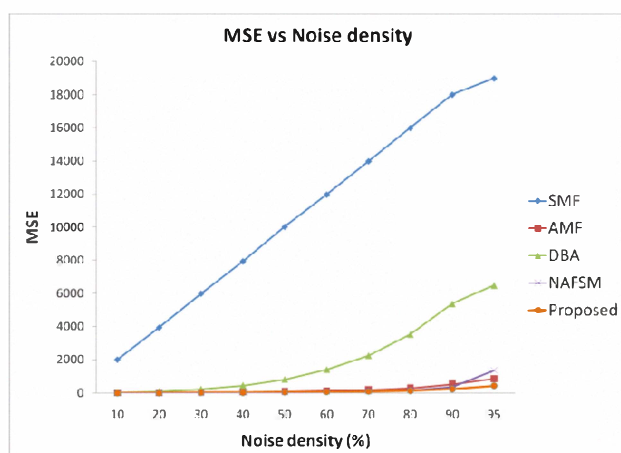


Fig. 9 (c): Graph comparison in terms of MSE.

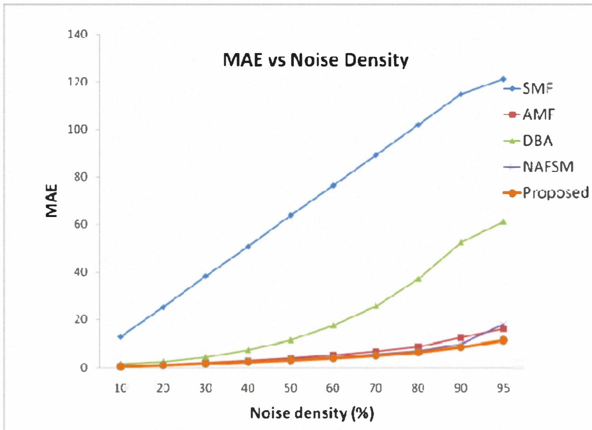


Fig. 9 (d): Graph comparison in terms of MAE.

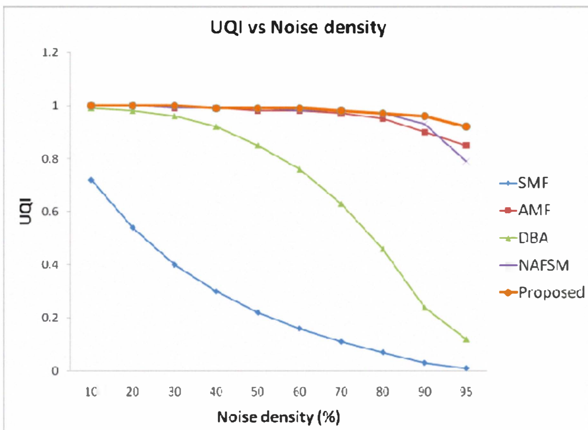


Fig. 9 (e): Graph comparison in terms of UQI.

IV CONCLUSION

An enhanced decision based adaptive median filtering is proposed in this paper to remove Salt and Pepper noise in digital images. The algorithm shows optimum noise suppression capabilities for low density noise as well as that of high density noise. Although for lower densities all the discussed algorithms in this paper performs reasonably well, for noise level up to 50% Standard Median Filter and Adaptive Median Filter fail to preserve necessary details. Recently proposed Noise Adaptive Fuzzy Switching Median Filtering and Decision Based Algorithm show good de-noising capability at higher density but they produce streaking effect when the noise density is above 80%. On the other side, our proposed algorithm shows satisfactory results at high noise density and it is designed to preserve necessary details implementing the concept of starting image scanning from the middle position of the image. The proposed algorithm also has the mechanism to detect and restore pure black and pure white regions of an image quite well while corrupted with salt and pepper noise. An improved method of calculation of median as well as further adaption and consideration of threshold value help to preserve details and visual quality of the image. Due to limited window size it also requires less computation time.

V. REFERENCES

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