Novel Random Valued Impulse Denoising Technique

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Abstract

The pictures in the advanced arrangement are generally corrupted by drive commotion which is because of the unexpected blunders in correspondence channels or electronic sensors. Most existing strategies fall flat at high clamor thickness. Here another versatile insertion procedure is foreseen for reclamation of exceptionally corrupted pictures by arbitrary esteemed drive clamor. This new method gives a more corrected preferred picture quality over the standard Versatile Middle Channel, Standard Middle Channel, Choice Based Calculation, Dynamic Exchanged middle Channel, Choice Based Un-symmetric Trimmed Middle Channel and altered Choice Based Un-symmetric Trimmed Middle Channel. The strategy anticipated is confirmed for its proficiency against various pictures and is found to give enhanced Pinnacle Motion to-Commotion Proportion.

Keywords: Denoising, interpolation, random valued impulse noise.

1. Introduction

The idea of Computerized Picture Preparing assumes an imperative job in numerous territories, for example, therapeutic imaging, remote detecting, printing, media transmission, security and resistance applications [9,15]. The advanced pictures acquired through imaging gadgets are frequently undermined by drive clamor which is because of the startling blunders in correspondence channels or electronic sensors. Motivation clamor can be gathered into two kinds: settled esteemed drive commotion (FVIN) and arbitrary esteemed drive commotion (RVIN). In FVIN, the tainted pixel goes up against an esteem which is equivalent to either 0 or 255. Be that as it may, in RVIN, the defiled pixel goes up against any incentive between the base 0 and greatest 255. So evacuating RVIN is a confounded procedure in contrast with expulsion of FVIN.

In the strategy where Best in class Exchanging Middle Channel (PSMF) [5,12] is utilized, the change between the present pixel esteem and the middle an incentive in the sifting outline is coordinated with a limit esteem which has been pre-characterized, picks whether a motivation is accessible. The key hindrance of this technique is in touching base at a strong choice. This burden is overwhelmed by the Versatile Rank-requested Exchanging Middle Channel (ARSMF) [17]. This strategy painstakingly channels those pixels which are corrupted by motivation commotion and leaves the remaining estimations of the simple pixels whole. Additionally Choice Based Unsymmetrical Trimmed Middle Channel is anticipated in [1,18] where if the dealt with pixel in the casing has an estimation of either 0 or 255, at that point that esteem is changed by the middle of the lingering esteems in the edge. In the event that the picture has high commotion densities, at that point the sheared middle esteem [7] additionally will be like handled pixel. Therefore this strategy creates in able for pictures with high commotion densities. Roy et al. in [22] anticipated a versatile channel for the end of high

commotion thickness in shading pictures yet at the same time not futile against irregular esteem drive clamor.

In the numerical based middle channel [8], the estimations of pixels inside the chose edge are composed in the emerging request. On the off chance that the pixel of enthusiasm for the area of intrigue lies between the most extreme and the base, at that point the pixel is thought to be uncontaminated pixel. In the event that this condition isn't fulfilled, at that point the Middle pixel is viewed as debased by commotion and the difference in the middle and every pixel in the window is thought and this is useful to the corrupted pixel. The anticipated versatile interjection procedure recognizes the edges plainly, gives great bring about distinguishing and sifting of exceedingly pillaged pictures by irregular esteemed motivation clamor. The outcomes demonstrate enhanced Pinnacle Motion to-Commotion Proportion (PSNR) and Basic closeness list measurements.

The lingering research article is organized in the given request. Area 2 offers a short clarification about the frameworks in presence. Segment 3 gives a knowledge perspective of the anticipated calculation. Segment 4 expounds on the outcomes with a short note on assessment measurements pursued by end in area 5.

2. Contribution in this paper

- This paper introduces interpolation based detection and Filtering for Random valued Impulse noise.
- Both the detection and Filtering is done in a single process, which reduces the time complexity.
- Adaptive interpolation algorithm makes it to achieve high accuracy during filtering.

3. Prevailing detection methods

3.1. Four Phase Detector (FPD)

This method [6] of removal of RVIN operates in maximum four detection phases with some advancement in two phase detector [11,19]. The detection process in this method operates using similar valued neighbour criterion. After each of the detection phase, the median of the luminance values of the non-corrupted pixel is computed and the corrupted pixel is replaced with this value.

Considering a pixel $x = x_{i,j}$, with x_x representing the pixels in a 3x3 window centered at x. The most similar pixels to the tested pixel in the window are determined. The mean of the absolute difference of the three pixels and the tested pixel is computed by the equation

$$STAT_1 = \frac{1}{3} \sum_{r=1}^{3} S_{x,y}^r$$

The value of $STAT_1$ is compared with the threshold values which have been predetermined based on earlier experiments. The best suitable threshold values for this phase is $T_1 = [8,15,45]$. If the $STAT_1$ is greater than the threshold value selected, then the pixel of interest is considered to be a noisy pixel. The filtering step is used to suppress the noisy pixel. The median of luminance value of the uncorrupted pixels within the window is computed and the corrupted pixel is replaced with the computed value. If it is found that all the pixels within the selected window are corrupted by Impulse Noise, then the window sixe is increased till we obtain a window where at-least one pixel remained uncorrupted.

The above procedure is repeated for all the three threshold values. The PSNR value of the filtered images is obtained and the image with the best PSNR is selected as the noise image for the second phase.

In the second phase the image with best PSNR value at the end of first phase is selected as IN corrupted image. Similar to first phase three threshold values are selected as $T_2 = [8,11,15]$. Here let $y_x$be the pixels in a 5x5 window centred at x. The most similar three pixels with respect to the tested pixel in the neighbourhood with e chessboard distance 1 and the most similar three pixels with respect to the tested pixel in the neighbourhood with chessboard distance 2 are selected.

The mean of the absolute difference of the three similar pixels at chessboard distance 1 and the tested pixel and the mean of the absolute difference of the three similar pixels at chessboard distance 2 and the tested pixel are computed by the equation

$$STAT_2 = \frac{1}{6} \left(\sum_{r=1}^{3} S_{1x,y}^r + \sum_{r=1}^{3} S_{2x,y}^r \right)$$

where $S_{1x,y}^r = |I_x - I_y|$ and $S_{2x,y}^r = |I_x - I_y|$.

As the case with phase 1, the mean is compared with the threshold value of T_2. If $STAT_2$ is greater than the threshold value selected the pixel of interest is said to be a noisy pixel and this pixel is suppressed through filtering.

Similar to phase 1, the above procedure is repeated for all three threshold values and three images are obtained. The PSNR value of the three images is computed.

The best PSNR value from phase 2 is selected and this is compared with the best PSNR obtained in phase 1. The best PSNR selected from phase 2 if is found smaller than the best PSNR selected from phase 1, the detection process is terminated and the resultant image obtained of the best PSNR in phase 1 is accepted as the best result. Else the third phase is proceeded with the best image of phase 2.

In the third phase the best restored image of phase 2 is taken as the corrupted image. As the usual procedure of previous phase the threshold values is selected as $T_3 = [3,6,9]$. The steps followed in phase 1 are repeated.

The best PSNR selected from phase 3 if is found smaller than the best PSNR selected from phase 2, the detection process is terminated and the resultant image obtained of the best PSNR in phase 2 is accepted as the best result. Else the fourth phase is proceeded with the best image of phase 3.

In the fourth phase the image with best PSNR obtained from phase 3 is taken as the corrupted image. As the usual procedure of previous phase the threshold values is selected as $T_4 = [3,6,9]$. The steps followed in phase 2 are repeated.

The best PSNR selected from phase 4, if is found smaller than the best PSNR selected from phase 3, the detection process is terminated and the resultant image obtained of the best PSNR in phase 3 is accepted as the best result. Else the image with best PSNR obtained from fourth phase is accepted as the best restored image3.

3.2. Rank Order Absolute Difference (ROAD)

In ROAD [4,14] generally the neighbourhood size is selected as odd number, this is so because it gives a definite centre pixel value. If the size of neighbourhood is selected to be even, then a median is obtained which is nothing but the arithmetic mean of the two center pixels in the window.

Having a corrupted image B, with the window size to be (2N+1)X(2N+1) the absolute difference is obtained by the relation
$d_k = |B(i,j) - B(i+s, j+t)|$, where $-N \le s,t \le N$
(s,t) $\ne$ (0,0) and k varies from 1 to (n-1), where n represents number of pixels in the sliding window.

Here we consider s=4 where s represents the minimum number of absolute differences m_1, m_2, m_3,m_4.....m_s in the selected frame which are to be used for obtaining the ROAD value.

The selected minimum absolute difference values are added as shown by the formula to obtain the ROAD value.
$$ROAD = \sum_{l=1}^{s} m_l, 2 \le s \le 7 \text{ for } N = 1$$

This ROAD is then compared with a threshold value denoted by T which is a predefined value based on earlier experiments. The value of ROAD if is found to exceed the threshold T, then the pixel is classified as corrupted else uncorrupted.

The drawback of the method[20] is that it would provide poor results if half the number of pixels in the region of interest are corrupted.

3.3. Rank Order Logarithmic Difference (ROLD)

In case of RVIN, some noise pixels at the center of window may at times be close in value to their uncorrupted neighbours. In such a situation, the ROAD value may not take a large value, there by not able to distinguish the pixel of interest as noise. So one way to deal with such an image, is to find a means to increase these ROAD values, at the same time maintaining small the ROAD values of uncorrupted pixels. Hence we use the logarithmic function of ROAD to obtain ROLD value [20].

Having a corrupted image B, with window size (2N+1)x(2N+1) the absolute difference is obtained by the formula
$ad_n = |B(i,j) - B(i+s, j+t)|$, where $-N \le (s,t) \le N$.
(s,t)$\ne$(0,0) and k the number of pixels in window.

The logarithmic function of the obtained absolute difference is given by the equation $d_x = \log_a ad$ where $1 \le x \le n-1$.

To maintain the absolute difference in the range [0,1], we use the transformation denoted by $s_x = 1 + max\{d_x, -b\}/b$ where x is in the range of $[0,1/a^b]$ with a and b to be positive integers.

In the case of an 8-bit gray level image, the x is [0,(8/255)] where $8/256 = (1/2)^5$ with a= 2 and b=5.In similarity with ROAD, the s minimum values $s_i = \{s_1, s_2, s_3, s_4..... s_s\}$ in the frame are chosen and these values are added to obtain the ROLD value as given by
$$ROLD = S_i \text{ where } i=1,2,3,....s.$$

The obtained ROLD is then equated with the verge T, which is a predefined value based on earlier experiments. The value of

ROLD if is found to exceed the threshold T, then the pixel is classified as corrupted else uncorrupted.

The value of S for a 5x5 window and for a 3x3 window is selected as 12 and 4 respectively.

The major disadvantage of this detector is in the method adopted for selection of positive numbers where a & b plays a major role in the accuracy of detection. Also deciding on the value of T is also a difficult process.

3.4. Impulse Detector (ID)

This method [16] operates with main focus on the edges in the four main directions in the window selected. Having an image B with impulse noise, the pixel of interest named as B(i,j) and the window size as (2N+1)x(2N+1). The four direction indices namely d_1, d_2, d_3 & d_4 in the major four directions are determined, where

$$d_n = \sum_{k=1}^{(2N+1)-1} w_{s,t} |B(i,j) - B(i+l,j+k)|$$

where $l \leq n \leq 4$, $-2 \leq (l,k) \leq 2$, $(s,t)=(I,j)$ and the weight $w_{s,t} = \begin{cases} 2; & -1 \leq (s,t) \leq 1 \\ 1; & otherwise \end{cases}$

Then the directional indices are compared to obtain the minimum value among them denoted by $P=min\{d_n\}$

This P value is then matched with the margin selected value T. Similar to ROAD & ROLD, if the P value is found greater than T, then pixel of interest is said to be corrupted else uncorrupted. The main disadvantage of this method is the selection of T.

3.5. Standard Deviation (SD)

This method [2] operates on determining the accurate or optimal direction which is used to detect whether the pixel of interest is noisy or not.

Here the four direction indices denoted by d_1, d_2, d_3 & d_4 are determined with equal number of pixels in each direction. The pixels available in every direction d_1, d_2, d_3 & d_4 are arranged in the ascending order.

The rearranged vectors are represented by I_1, I_2, I_3 & I_4. In this rearranged vectors, the smallest and the largest values are neglected thus obtaining new vectors r_1, r_2, r_3 & r_4.

The Standard Deviation of these vectors is obtained which is denoted by σ_1, σ_2, σ_3 & σ_4.

The vector with minimum SD is chosen as the optimal direction and the vector is denoted by r_P, with the elements of r_P given by

$$r_P(k)=[r_P(1), r_P(2), r_P(3), \ldots\ldots r_P(n)].$$

Then the similarity parameter s of the optimal direction vector with the pixel of interest is determined by measuring the normalized distance between pixels in optimal direction and the pixel of interest Bi,j. Given by

$$s_k = \sum_{k=1}^{n} |[r_{p(k)} - Bi,j]/255|$$

n – total number of pixels in r_P

The s_k is obtained by adding the value of s_1, s_2, s_3,….s_n. This s_k is compared to the threshold value T. If similarity value s exceeds the T then the pixel of interest is said to be corrupted else uncorrupted.

3.6. Robust Outlyingness Ratio (ROR)

This method [3,17] helps to determine how a pixel looks similar to an impulse noise. Using this method, the pixels are classified into four clusters. Considering an image B corrupted by noise, with a window size (2N+1)x(2N+1) centered at B(i,j).

Taking a 5x5 window size, the set of pixels in the selected window of size 5x5 is given by

$$\Omega(N) = \{B(i+k, j+l)\} ; -N \leq l, k \leq N.$$

The median of the pixels in the selected window is determined by

$$Med(\Omega(N)) = Median (\Omega(N))$$

Now we determine the absolute difference between every pixel in the window and median as given by

$$AD(\Omega(N)) = |\Omega(N) - Med(\Omega(N))|$$

The median absolute difference is obtained by taking the median of the absolute differences. $MAD(\Omega(N))=Med(AD(\Omega(N)))$

Then determine the normalized median absolute deviation as given by

$$MADN(\Omega(N))= MAD(\Omega(N))/0.6457$$

The robust outlyingness ratio (ROR) is determined by $ROR(B(i,j)) = |(B(i,j)-Med(\Omega(N))/MADN(\Omega(N))|$

This ROR of every pixel is then compared with T and the pixels are grouped into four clusters as given below

If ROR > 3, the pixel fits to most like cluster
If 2< ROR ≤ 3, the pixel fits to second like cluster
If 1< ROR ≤ 2, the pixel fits to third like cluster
If 0< ROR ≤ 1, the pixel fits to fourth like cluster

3.7. Adaptive Fuzzy Switching Median Filter

This method [21] consists of two phase. In first phase, the processing windows are divided into two equal size clusters based on gradient values (vertical, horizontal and two diagonal directions). Cluster which has minimum sum of gradients and the one with relatively greater gradient values are given to fuzzy inference system to check whether the current pixel is noise-free, edge or a noisy. Depending upon fuzzy membership value and local information, the corrupted pixels are restored in the second phase.

4. Proposed method

The overall architecture for the removal of Random-valued impulse noise is shown in Figure 1. Here, the noisy image is read as input and Interpolation [10] is used to detect the noisy pixel present in an input image and in the filtering stage Interpolation technique is used to substitute the detected noisy pixel. Therefore, it produces a noise-free image as an output image.

The working Principle of proposed architecture is:

1. Read the corrupted image and choose the pixel value of either 3×3 or 5×5 window and it is represented as O_r.
2. Calculate the interpolation value of the pixels and it is represented as I_r.
3. Find the absolute difference, $D = I_r - O_r$.
4. If the absolute difference is greater than the threshold value then replace the current pixel value with the interpolated value. Denoised image will be obtained.
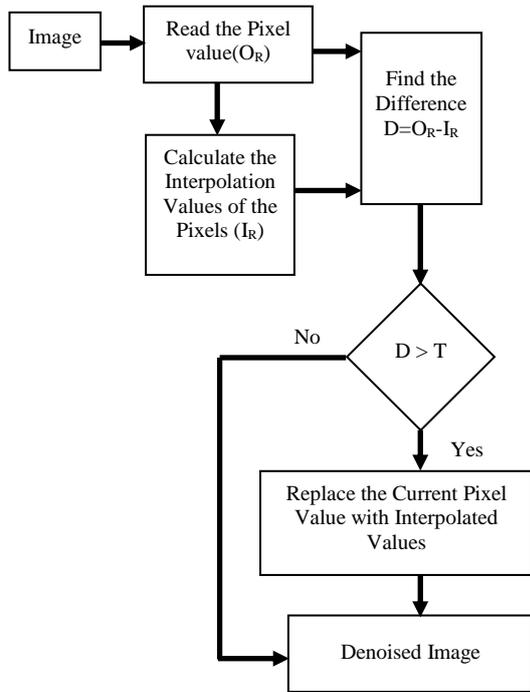
Fig. 1: Block diagram of the proposed system

This Interpolation is defined as "filling in the pixels in between". Interpolation is to create acceptable images at altered resolutions from a single low-resolution image. Interpolation is the calculation of the value of a function between the values already known or filling in the pixels in between. The proposed interpolation technique processes the corrupted images by first detecting the RVIN. The architecture for proposed interpolation system is shown in the Figure 2.

To classify the smooth and sharp sections on the image with noise [13] and to intercalate the obtained noise component, the difference costs of $H_{i,j}$(horizontal) and $V_{i,j}$(vertical) are calculated first as given by the subsequent equations for every pixel location present in the 5 X 5 window size.

$$H_{i,j} = \sum_{l=-2}^{2} \sum_{m=-2}^{1} (N_{i+l,j+m} - N_{i+l,j+m+1})$$

		P_{U2}		
		P_{U1}		
P_{L2}	P_{L1}	$P_{i,j}$	P_{R1}	P_{R2}
		P_{D1}		
		P_{D2}		
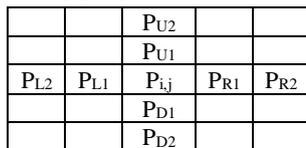
$$V_{i,j} = \sum_{l=-2}^{1} \sum_{m=-2}^{2} (N_{i+l,j+m} - N_{i+l+1,j+m})$$

where$N_{i,j}$is the noise-free pixel at pixel location(i,j), and $H_{i,j}$ and $V_{i,j}$ denote the horizontal and vertical costs, respectively.

The replacing interpolated value is calculated horizontally if the horizontal cost value is less than vertical cost value and vice-versa. The Interpolated values to replace the noisy pixels are calculated using the following equations respectively.
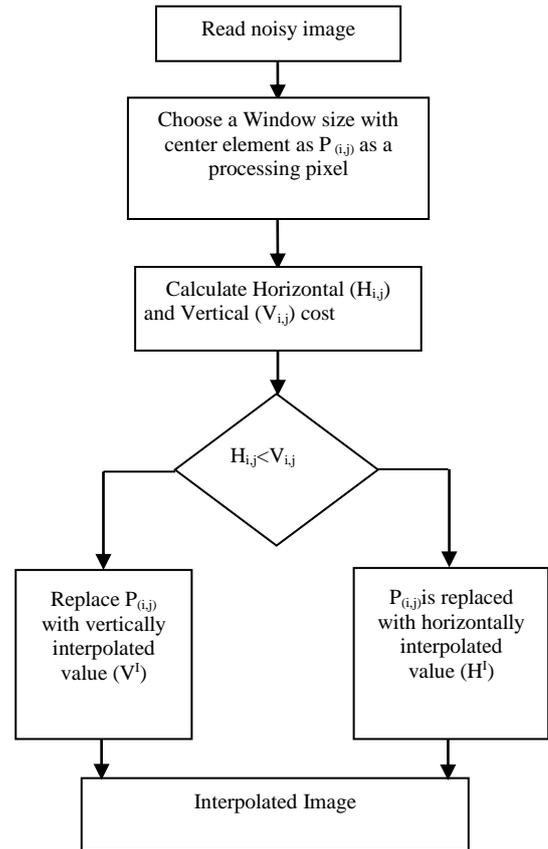

Fig. 2: Block diagram of the Adaptive Interpolation Algorithm

if T1<T2, then use median filter to replace the noisy pixel.
where, T1=min (Hi,j, $V_{i,j}$) andT2 ((Hi,j+ $V_{i,j}$)/2)
elseifHi,j<$V_{i,j}$

$$H^I = \left[H^G_{i,j-1} + H^G_{i,j+1} \right] \Big/ 2$$

else

$$V^I = \left[V^G_{i-1,j} + V^G_{i+1,j} \right] \Big/ 2$$

Where $H^G_{i,j}$ and $V^G_{i,j}$ denote the horizontal and vertical gradient is calculated as shown below
From this
Horizontal gradient,

$$H^G_{i,j} = \left[P_{L1} + P_{L2} + P_{R1} + P_{R2} \right] \Big/ 4$$

Vertical gradient,

$$V^G_{i,j} = \left[P_{U1} + P_{U2} + P_{D1} + P_{D2} \right] \Big/ 4$$

where P_{L1}, P_{L2}, P_{R1}, P_{R2}, P_{U1}, P_{U2}, P_{D1}, P_{D2} are the surrounding pixels.

5. Results and discussion

To prove that the method proposed outperforms the other existing methods in terms of edge region a cropped image of the girl image is taken which is then contaminated by 30% random valued impulse noise. The corrupted image is then restored by the different methods and the proposed method. The visual comparison of the results shows that the proposed method outperforms the other existing methods as shown in Figure 3& Figure 4 below.
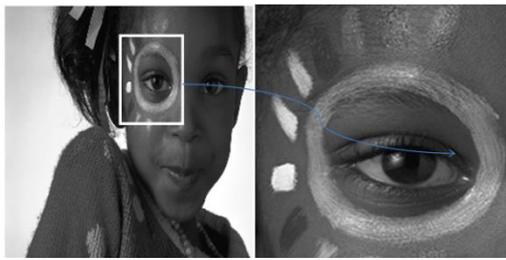
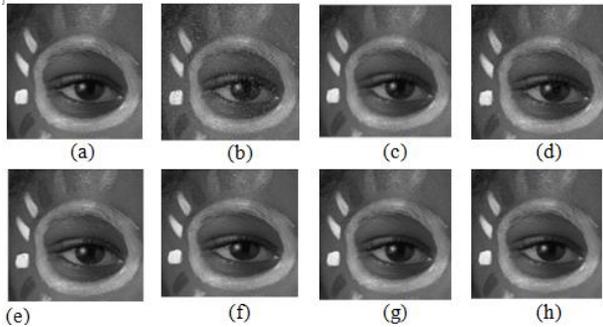**Fig. 3:** Input girl image and cropped region of girl image

Fig 4: Results of altered filters in restoring 30% corrupted Cropped Girl image (a) Original (b) ROLD (c) ID (d) SD (e) ROR (f) FPD (g) AFSM (h) Proposed

To further confirm that the proposed method out performs the other existing methods again the standard Lena test image is used. In the process of detection of the corrupted pixels, the number of corrupted pixels which were not detected as noise are represented by the Miss and the number of pixels that were wrongly identified as corrupted are represented as False.

The Table 1 below represents the above fact for the different methods of detection and compares it with the proposed method at different percentage of corruption as represented by the first row.

The 50% corrupted Lena image is then detected for random valued impulse noise and the detected pixel are restored by using the proposed method. Figure 5 represents the Lena image and the outcome of the image degraded by 50% impulse noise.

TABLE 1 Assessment of noise detection for Random Valued Impulse Noise added Lena mage

| Methods	20% Miss	20% False	40% Miss	40% False	60% Miss	60% False	80% Miss	80% False
ROAD	12,86	541	30,881	796	1569	78,625	657	98,612
ROLD	11,17	1580	30,371	4322	49,504	12,406	60,950	14,879
ID	15,49	1518	31,596	3135	58,192	10,107	68,173	13,124
SD	3868	11,598	13,286	14,768	55,725	12,778	60,435	22,311
ROR	4210	9820	8969	10,099	15,589	12,524	17,522	18,470
FPD	4104	11,774	7341	30,779	16,790	24,982	19,560	28,592
AFSM	5510	9220	8112	10,887	15,899	11,523	17,734	15,466
Propose	6186	6407	8104	9619	15,511	10,226	17,691	13,316
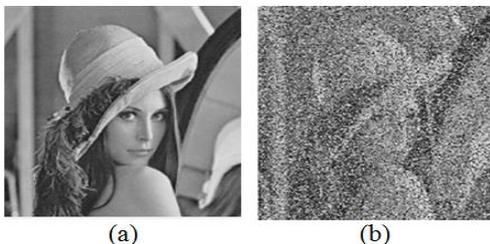
Fig. 5: (a) Input image (b) 50% random valued impulse noise added image

Fig. 6: Results of different filters in restoring 50% corrupted Lena image (a) Original (b) ROLD (c) ID (d) SD (e) ROR (f) FPD (g) AFSM (h) Proposed

Figure 6 represents the results of the different restoration schemes and the proposed scheme.

The output of the various restoration schemes and the proposed scheme for differing percentage of impulse noise is compared in terms of PSNR for the same test image through Table 2. Also Figure 7 gives the comparison of MSE of the restored images from existing methods with the proposed method.

Table 2. Assessment of the Peak Signal to Noise Ratio values for restored image pretentious by the impulse noise with various noise contaminated ratios by various denoising methods.

| Method	Lena 20%	Lena 40%	Lena 60%	Lena 80%	Pepper 20%	Pepper 40%	Pepper 60%	Pepper 80%
Road	27.09	19.35	15.21	12.43	26.34	19.34	15.09	12.33
Rold	26.41	19.61	14.94	12.07	26.45	19.45	14.89	12.17
Id	25.89	19.09	14.90	12.34	25.34	19.00	14.70	12.12
Sd	27.20	19.98	15.35	12.88	27.17	19.78	15.56	12.78
Ror	27.09	20.86	16.07	13.04	26.89	20.70	16.01	13.14
Fpd	28.09	21.07	17.12	13.78	27.56	20.68	17.03	13.68
Afsm	28.10	21.56	17.87	14.04	27.60	20.95	17.82	14.01
Proposed	28.15	22.71	19.22	16.8	27.75	22.53	19.07	16.56
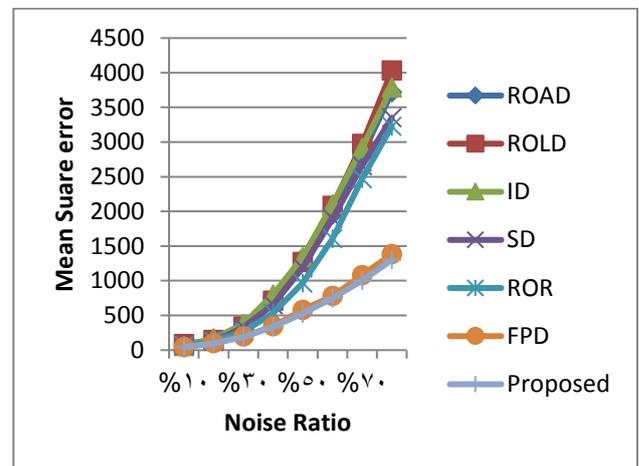
Fig. 7: Comparison of the Mean Square Error values of the Lena image degraded by impulse noise with diverse noise ratios for different denoising methods

6. Conclusion

A few commotion recognition and nonlinear channel have been proposed. At high clamor thickness the current discovery systems wrongly distinguishes the uncorrupted pixel as a ruined one and Pinnacle Flag to Commotion Proportion is diminished and the Mean Square Blunder is expanded for high thickness Arbitrary Esteemed Motivation Commotion influenced pictures. So to defeat this downside the calculation called Arbitrary Esteemed Drive Denoising utilizing Insertion is proposed. This technique

will recognize the boisterous pixels precisely. For separating stage, Interjection procedure is a proficient one on the grounds that the recognized uproarious pixels are supplanted by the introduced esteem. Hence, it will protect the fine points of interest of a unique picture.

The proposed methodology can be adjusted to different commotion models, for example, salt-and-pepper motivation clamor, irregular esteemed drive commotion, and blended clamor by altering the parameters in the calculation. The calculation for both recognition and separating stage performed well under the picture that has been defiled with over 60% commotion densities.

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