High Density Impulse Noise Removal using Advanced Median Filter for Preserving Image Quality Metrics

Maheswaran U Vengadapathiraj M Manimaran B Arunajayashree R

***Abstract:** In this work, a procedure to remove the high density salt and pepper noise from a corrupted image is developed and to compare the output image with the original image through the image quality metrics. As a common practice the corrupted pixels are replaced by the median of neighboring pixel values by considering a constant number of neighboring pixels. But in this proposed method the corrupted pixels are identified and are replaced by the median of the neighboring pixel values which are adjustable, to preserve and improve the image quality metrics. This method makes a comparison between the corrupted and uncorrupted pixels and performs the median filtering process only on the corrupted ones. In this work a 3x3, 5x5 and 7x7 square neighborhood are used. The output images are observed with low neighborhood as well as high neighborhood pixel values. The calculation of PSNR (Peak Signal to Noise Ratio) and MSE (Mean square error) value for each dimension with different percentages are considered for the comparative analysis.*

***Keywords:** Advanced Median filter, Image Quality Metrics, MSE, PSNR*

I. INTRODUCTION

An image is a two dimensional signal defined by the mathematical function f (x, y) where x and y are the horizontal coordinate and vertical coordinates respectively. The value of f (x, y) at any point represents the pixel intensity at the particular point specified by x and y values in the image coordinates. [1] Noise is an undesired signal component present along with the desired components that interferes with the original message signal and corrupts the parameters of the message signal. [2] This change in the image pixel value during the communication process, leads to the message becoming erroneous. Predominantly the noise addition happens at the channel or at the receiver. In general, the Image noise is a random (not present in the object imaged) variation of brightness or color information in images, and is usually a feature of electronic noise. It can be caused by the sensors and circuitry of a scanner or digital camera [2]. Digital images are disposed to various forms of noises [3].

Noise is the outcome of errors in the image acquisition method that result in pixel values that do not reflect the true intensities of the real picture [2]. If the image is scanned from a photograph made on film, the film grain is a cause of noise. Noise can also be the effect of damage to the film, or the error present in the scanner itself. If the image is acquired directly in a digital format, the mechanism for acquiring the data can host the noise. Electronic transmission of image data can introduce some types of transmission noises. The Salt and Pepper noise is generally caused by flopping of the pixel elements in the camera sensors or faulty memory locations or timing errors that occurs during the digitization. In the images that are corrupted by Salt and Pepper noise, the noisy pixels can take only the maximum and the minimum values within the dynamic range. The term impulse noise is also used for this type of noise [4] . Other noises such as spike noise, random noise are all independent noises. Dust particles in the image acquisition source or over heated faulty components can cause this type of noise. Image is corrupted to a small extent due to noise. With the developments of the advanced complex medical imaging equipment, the medical image quality has been improved significantly, and the noise in the majority of images cannot be identified artificially, the projection data in the actual scanning process can still be interfered certainly by various denoising methods using noise removal filters. But in such cases the filtered image suffers a blurring effect that in turns affect the quality of the image. For the median filtering techniques each pixel is considered for calculating the median and also every pixel is replaced by the determined median. Hence the affected pixels are considered to calculate the median and unaffected pixels are also replaced by this determined median. Researchers have been premeditated a lot to remove this high density salt and pepper noise from images. In this work, an advanced median filter is proposed for denoising an image corrupted by Impulse noise with different percentage of noise density and the output images are compared with the original one to check the preservation of the image quality metrics.

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II. TECHNOLOGY

A. Median Filter

The median filter considers each pixel in the image in turn and looks at its nearby neighbors [1]. The median is calculated by the following steps. At first all the pixel values from the surrounding neighborhood are sorted in their ascending order. From the sorted list of pixel values the median value is determined. The determined median value is considered to replace the initial pixel value. If the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values can be used. The Figure below illustrates an example calculation

Fig. 1.Calculating the median value of a pixel neighborhood.

121	125	126	130	140
122	**121**	**126**	**127**	135
118	**120**	**160**	**125**	134
119	**116**	**119**	**123**	133
111	116	110	120	130

In the above example the pixel having value 160 is considered for median calculation. Its eight neighboring pixels are considered for determining the median value. On sorting, the Sorted values of pixels are 116, 119, 120, 121, 123, 125, 126, 127 and 160. So, 160 will be replaced by 123. As can be seen, the central pixel value of 160 is rather unrepresentative of the surrounding pixels and is replaced by the median value: 123. In this example a 3×3 square neighborhood is used here.

B. Image Quality Metrics

The Quality of the image can be tainted due to the parodies that occur during image acquisition and preprocessing [14]. Noise addition, blurring, ringing and compression artifacts are few examples of the distortion parodies.

Image quality metrics are very important parameters that correlate well with the subjective perception of quality by the human observer. Quality metrics are also capable of tracking unperceived errors as the processing of image is growing. If an image is available with good quality and without distortions, that image can be used as a reference image for estimating the quality of other test images.

For Instance, on evaluating the quality of a compressed image, an uncompressed version of the same image can provide some useful reference. In such cases, one can use full-reference quality metrics readily to compare the target image with the reference image to arrive at a conclusion about the quality of the image.

Full-Reference Quality Metrics: Full-reference algorithms compare the input image against a pristine reference image without distortion. These algorithms include, MSE—Median-squared error (MSE). MSE measures the average squared difference between actual and ideal pixel values. This metric is the modest to calculate but it is less correlated with the quality of human perception.

The Mean Square Error can be mathematically determined as

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\| f(i,j) - g(i,j)\|^2$$

PSNR: Peak signal-to-noise ratio (PSNR) is another quality metric of an image which speaks about the maximum extent of noise addition that happened within in the image during any stage of an image processing function. PSNR is derived from the median square error, and it represents the ratio of the maximum pixel intensity to the power of the distortion. PSNR estimation is as simple as MSE estimation, but this metric is also having less correlation with human visual perception.

$$PSNR = 10\log_{10}(255 * {}^{255}/_{MSE})$$

C. Advanced Median Filter

In this paper an advanced median filter is used to classify the pixel as a noisy pixel or as an uncorrupted pixel by making comparisons with the pixel under test and its surrounding neighbor pixels. The size of the neighborhood and the threshold for the comparison are made variable in this technique.

A pixel is labeled as impulse noise, if it is heavily uncorrelated from majority of its neighbors or if it is not structurally aligned with the neighboring pixels. After labeling the impulse noise pixels, the noisy pixels are then substituted by the median pixel value of the pixels in the neighborhood which are passed in the noise labeling test. The advanced median filter changes size of Sxy (the size of the neighborhood) during operation.

III. PROPOSED WORK

A. Algorithm

To implement the advanced median filter with variable neighborhood size, the following algorithm is deliberated. The Image under test is assumed to be affected by high density impulse noise. The gray scale version of the image is retrieved for the process.

The dimension of the noisy image considered for test is estimated and a two dimensional nxn filter window is taken. Initially the window size n, can be taken from3 and in further steps it can be increased as 5, 7 etc. The Window is fixed over every pixel of the image and its pixel intensity p (i, j) is tested for each pixel.

If the value of p (i, j) is in the range (0,255), then the median value of the surrounding neighboring pixels are calculated and substituted for the pixel, where the window is placed. If the pixel intensity is not contained in the range (0,255) the algorithm is preceded by increasing the window size to 5 and then to 7.

The Algorithm is repeated for each and every pixel of the image matrix and the median for each pixel value is found using the advanced median filter. The new median value is substituted for the pixel, where the filter window is placed.

It is represented as a pseudo code as follows.

Level A:
A1 = Zmed - Zmin
A2 = Zmed – Zmax
IF A1 > 0 AND A2 < 0,
GOTO level B;
ELSE Increase the window size;
IF window size < Smax
REPEAT level A;
ELSE
OUTPUT Zxy;
Level B: B1 = Zxy – Zmin;
B2 = Zxy – Zmax;
IF B1 > 0 AND B2 < 0
OUTPUT Zxy;
ELSE
OUTPUT Zmed;
Where
Zmin → minimum gray level value in Sxy
Zmax → maximum gray level value in Sxy
Zmed → median of gray levels in Sxy
Zxy → gray level at coordinates (x, y)
Smax → maximum allowed size of Sxy

B. Process Flow

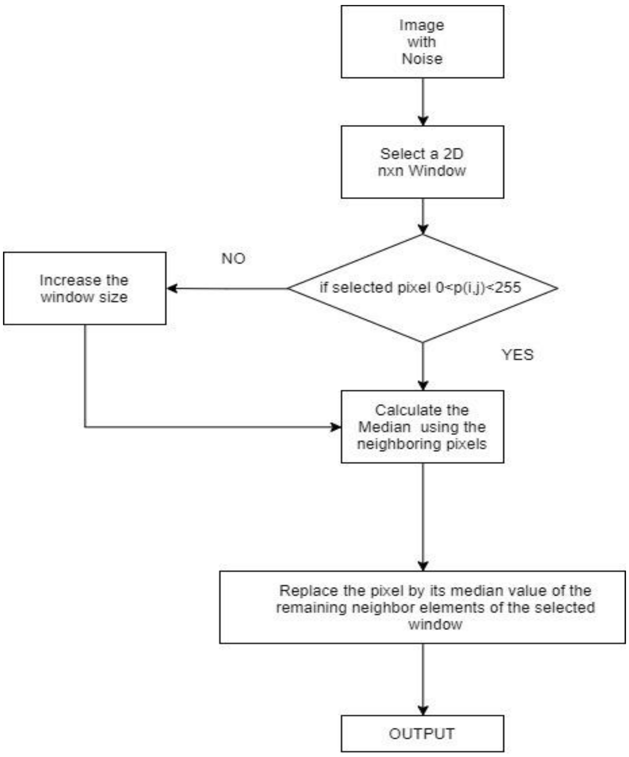

Fig. 2. Process flow For the Advanced Median Filter Algorithm

IV. EXPERIMENTAL RESULTS

The experiment is carried out using a lenna.jpg test image. The Advanced median filter is applied over this test image and the experimental results are tabulated for 3x3, 5x5 and 7x7 windows. After applying the advanced median filter to this test images, the image quality metrics such as MSE and PSNR are estimated in each case and are tabulated as follows.

Fig. 3. Test Image for the experimental analysis

The output image for a 3x3 window for different noise density values such as 10%, 20%, 30%40%, 50%, 60%, 70% and 80% images are shown below and the image metrics are tabulated.

Fig. 4.Results for a 3x3 filter for various noise density values

Figure 4(a),4(b),4(c),4(d),4(e),4(f),4(g) and 4(h) show the results of a 3x3 advanced median filter application over the test images for noise densities 10%,20%,30%40%,50%,60%,70% and 80% respectively. The Image metrics are calculated after the 3x3 filter application is tabulated below.

Table I: Image Quality metrics of 3x3 window for various noise density values

Noise Density%	MSE	PSNR
10	80.16	29.09
20	102.06	28.04
30	129.61	27.004

40	161.95	26.03
50	216.00	24.78
60	302.87	23.03
70	426.80	21.82
80	771.94	19.52

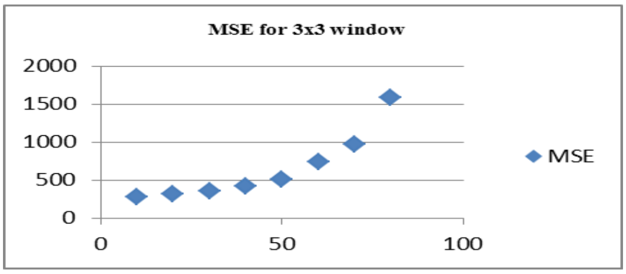

Fig. 5.MSE of a 3x3 filter for various noise density values

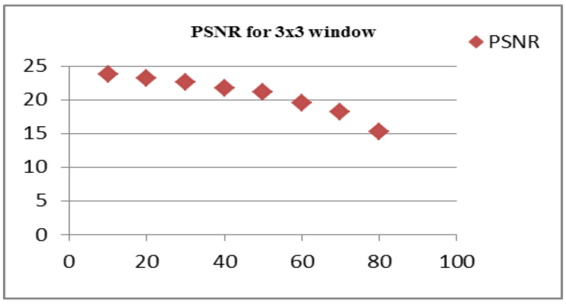

Fig. 6.PSNR of a 3x3 filter for various noise density values

For a 3x3 window, the MSE and PSNR values are abstemiously good but the image contains some considerable noise also. When the noise density is 10%, the MSE value is 80.16 and PSNR value is 29.09. At 20% of noise density, the MSE value is getting high and PSNR value is getting low. Because the more the noise density, the worse the performance. When noise density is 30%, the MSE value is 129.61 and PSNR value is 27.004. At 40% of noise density, the MSE value is 161.95 and PSNR value is 26.03. For higher noise density values the performance of the 3x3 filter is not appreciably good. Next to 3x3 window size, the same image is tested with a 5x5 sized window and the increase in the number of neighborhood pixels is tested for various noise densities. The output image for a 5x5 window for different noise density values such as 10%, 20%, 30%40%, 50%, 60%, 70% and 80% images are shown below and the image metrics are tabulated.

Fig. 7.Results for a 5x5 filter for various noise density values

Figure 7(a),7(b),7(c),7(d),7(e),7(f),7(g) and 7(h) show the results of a 3x3 advanced median filter application over the test images for noise densities 10%,20%,30%40%,50%,60%,70% and 80% respectively. The Image metrics are calculated after the 5x5 filter application is tabulated below.

Table II: Image Quality metrics of 5x5 window for various noise density values

Noise Density%	MSE	PSNR
10	174.33	25.71
20	207.96	24.68
30	247.08	24.2
40	292.09	23.47
50	368.4	22.35
60	512.06	21.03
70	794.16	19.01
80	1261.02	16.17

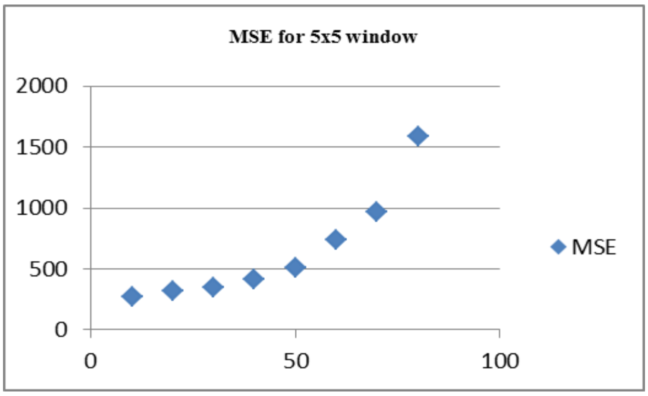

Fig. 8.MSE of a 5x5 filter for various noise density values

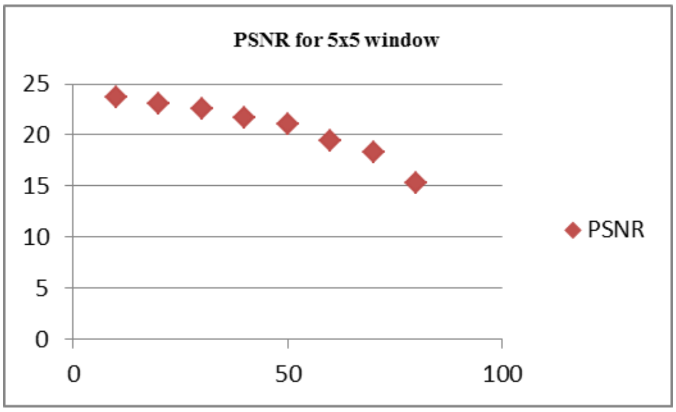

Fig. 9.PSNR of a 5x5 filter for various noise density values

In case of applying a 5x5 window, when the noise density is 10%, then the output image is clearer than the output image for the case of noise density equaling 20%. Comparing the output figures for various noise densities from figure 7, it is obvious that the output image is getting blurred more as the noise density increases.

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But when comparing the output figures from figure 4 and figure 7, the image quality is perceived to be improved in case of 5x5 window application. The MSE and PSNR are calculated by comparing the output images with input image. The calculation of MSE and PSNR values for a 5x5 window are provided in table 2.

Fig. 10. Results for a 7x7 filter for various noise density values

Figure 10 (a), 10 (b), 10 (c), 10 (d), 10 (e), 10 (f), 10 (g) and 10 (h) show the results of a 7x7 advanced median filter application over the test images for noise densities 10%,20%,30%40%,50%,60%,70% and 80% respectively. The MSE and PSNR values are calculated after the 7x7 filter application is tabulated below.

Table III: Image Quality metrics of 7x7 window for various noise density values

Noise Density%	MSE	PSNR
10	272.42	23.74
20	317.64	23.11
30	350.94	22.52
40	414.79	21.64
50	508.16	21.07
60	740.25	19.44
70	971.01	18.25
80	1584.06	15.28

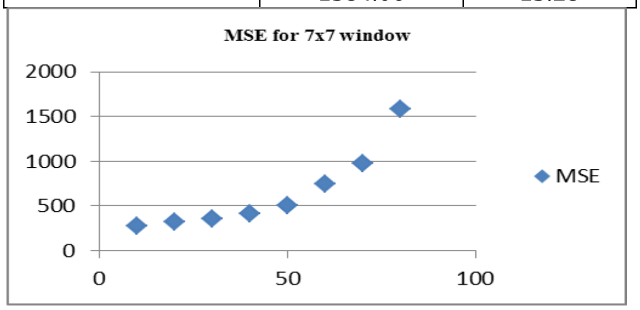

Fig. 11. MSE of a 7x7 filter for various noise density values

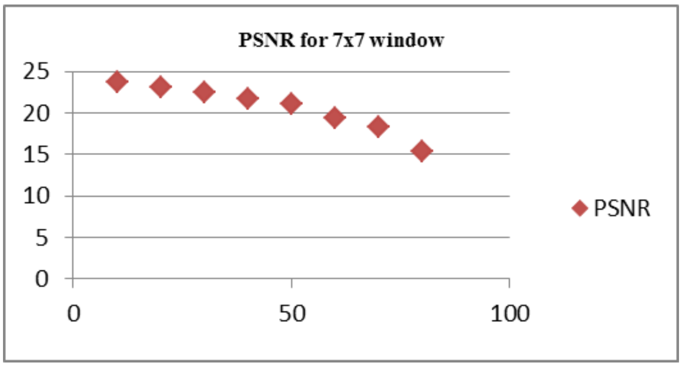

Fig. 12. PSNR of a 7x7 filter for various noise density values

From the results it is obvious that, for a 7x7 window, the MSE and PSNR value is quite low but the image contains less noise than a 3x3 and a 5x5 window using images.

V. CONCLUSION

In this work, a noise removal technique using advanced median filter with neighborhood adjustment has been developed, which shows larger neighborhoods producing more severe smoothing than lower neighborhoods. On using a 3x3 window in this technique, even though the MSE and PSNR values are found to be less, the amount of noise removal is more when compared to a larger window, which shows a poor performance. Windows with larger neighborhood, though possessing less image quality metrics, has very low noise performance. The main disadvantage of this technique is that it produces a blurred image if it is a high density noisy image The performance of this technique is better than mean filtering techniques. So, larger neighborhoods will produce more severe smoothing than lower neighborhoods. Hence it is suggested to use with small sized windows for a high density noises and large sized windows for images affected by moderate noise density. A modification is required to reduce the blurring that occurs due to the severe smoothing due to the median filtering can be carried out as future works.

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