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A Survey on Median Filters for Removal of High Density Salt & Pepper Noise in Noisy Image

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Abstract: *Impulse noise in image is present due to bit errors in transmission or induced during the signal acquisition stage. There are two types of impulse noise, like salt and pepper noise and random valued noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Several non-linear filters have been established as reliable method to remove the salt pepper noise without damaging the edge details. Survey of non-linear Median Filters for the removal of high density salt pepper noise is presented in this paper. The basic non linear filter i.e. standard median filter (MF) and different variants such as adaptive median filters (AMF), and decision based median filters (DBMF) are described in this paper.*

Key Words- *Adaptive Median Filter (AMF), Decision Based Algorithm (DBA), Salt and pepper noise, Standard Median Filter (SMF), Unsymmetric trimmed median filter.*

1. Introduction

Generally spatial filter consist of a neighborhood and predefined operation that is performed on the image pixels encompassed by the neighborhood. Filtering creates a new pixel with coordinates equal to coordinates of center of the neighborhood and whose value is result of filtering operation. A filtered image is generated as the center of the filter visits each pixel in input image. If the operation performed on the image is linear then it is called linear filtering otherwise known as non-linear filtering. [1].

Images are often corrupted by various types of noise such as Gaussian noise, random noise and impulse noise. There are two models of impulse noise, namely, random valued impulse noise and salt and pepper noise. Random valued impulse noise produces impulse (noisy or corrupted pixel) whose gray level lies within a predetermined range. Noise removal can be achieved by using a number of existing linear filtering techniques which are mathematically simple. A major class of linear filters minimizes the mean square error (MSE) criterion. These linear filtering techniques work well when noise is additive. These techniques fail when noise is non additive and are not effective in removing impulse noise. This has leaded the researchers to use nonlinear signal processing techniques. Some of these are as shown in figure 1.

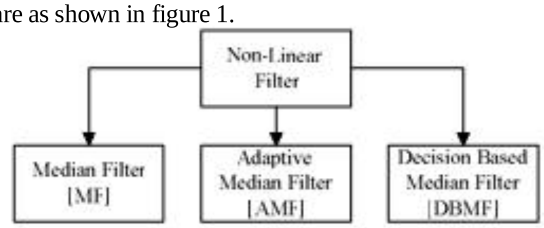


Figure 1. Types of non-Linear Filters.

2. Theory on Non Linear Filter types

2.1 *Standard Median Filtering*

Non-linear filters response is generally based on the ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result. The best-known filter in this category is median filter which, as its name implies, replaces the value of pixel by the median of intensity values in the neighborhood of that pixel. [1] Median filter are quite popular because, for certain types of random noise, they provide excellent noise-reduction capability with considerably less blurring than linear smoothing filters of similar size. However, the major drawback of standard median filter (MF) is that the filter is effective only at low densities [1].When the noise level is over 50% the edge details of the original image will not be preserved by standard median filter. At high noise densities SMFs often exhibits blurring for large window sizes and insufficient noise suppression for small window size. [4].

2.2 Adaptive Median Filtering

Adaptive median filter (AMF) also works in rectangular window area. Based on two types of image models corrupted by impulse noise, H. Hwang et al. [2] proposed two new algorithms for adaptive median filters. These have variable window size for removal of impulses while preserving sharpness. The first one, called the ranked-order based adaptive median filter (RAMF), is based on a test for the presence of impulses in the center pixel itself followed by the test for the presence of residual impulses in the median filter output. The second one, called the impulse size based *adaptive* median filter (SAMF), is based on the detection of the size of the impulse noise. In RAMF, corrupted pixel is detected using minimum, maximum and median of the intensity values from the window under consideration. Then corrupted pixel is replaced by median of the window which is not an impulse value and which is obtained by increasing size of the window until it reaches maximum window size. SAMF detects and replaces impulse noise of size 1 or 2 or 3 pixels by median filtering while noise free pixels are replaced by mean of the window. It has been found that, the performance of AMF is better than that of median filters at lower noise density levels. However, at higher noise densities, the edges are smeared significantly because large numbers of pixels are replaced by median values which are less correlated with actual pixel value [4].

2.3 Decision based median filters

In decision based filters, the pixel is said to be corrupted if its value is either ‘0’ or ‘255’ otherwise the pixel is deemed as uncorrupted. To filter only the corrupted pixels different techniques are developed. Such three techniques namely decision based algorithm, decision based unsymmetric trimmed median filter and modified decision based unsymmetric trimmed median are discussed further.

2.3.1 *Decision Based Algorithm*

Srinivasan K.S. and Ebenezer D. presented fast and efficient decision-based algorithm (DBA) for removal of high density impulse noises [5]. Impulse noise pixels can take the maximum and minimum values in the dynamic range (0,255). The DBA processes the corrupted image by first detecting the impulse noise. The detection of noisy and noise-free pixels is decided by checking whether the value of a processed pixel element lies between the maximum and minimum values that occur inside the selected window. If the value of the pixel processed is 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 and is replaced by the median value of the window or by its neighborhood values. At higher noise densities, the median value may also be a noisy pixel in which case neighborhood pixels are used for replacement; this provides higher correlation between the corrupted pixel and neighborhood pixel [8].Higher correlation gives rise to better edge preservation. Performance comparison shows that peak signal to noise ratio (PSNR) and image enhancement factor (IEF) of proposed filter is greater than that for the other methods such as standard median filter, adaptive median filter In addition, the DBA uses simple fixed length window of size 3x3, and hence, it requires significantly lower processing time compared with AMF and other algorithms. However replacement of noisy pixel value with neighborhood pixel value leads to streaking occurs at high noise densities.

2.3.2 *Decision based unsymmetric trimmed median filter (DBUTMF)*

To overcome this drawback of DBA, decision based unsymmetric trimmed median filter (DBUTM) is presented by K. Aiswarya, V. Jayaraj, and D. Ebenezer in [**6**]. In DBUTM, the central corrupted pixel is replaced by a median value of the pixels in 3 x 3 window. This median value is obtained by trimming impulse values from current window if they are present. It is unsymmetric filter because only impulse values i.e. corrupted pixels are trimmed to obtain median of the window. The performance comparison done by author shows that PSNR and IEF of DBUTM are greater than that for SMF, AMF and DBA up to 90% noise density.

However, at very high noise density of the order of 80% to 90%, the number of corrupted pixels increases. So it happens that, all neighboring pixels of central pixel are 0's or 255's or both of them, and then trimmed median cannot be obtained. So this algorithm does not give better result at very high noise density.

2.3.3 *Modified decision based unsymmetric trimmed median filter (MDBUTMF)*

As stated at high noise density DBUTMF fail to give suitable performance for removal of salt pepper noise present in image and hence to overcome this drawback, Esakkirajan, T. Veerakumar, Adabala N. Subramanyam, and C. H. PremChand presented a modified decision based Unsymmetric trimmed median filter algorithm for the restoration of gray scale, and color images that are highly corrupted by salt and pepper noise [2]. In this algorithm each and every pixel of the image is checked for the presence of salt and pepper noise. The three different cases are illustrated for the processing pixel,

Case 1. If the selected window contains salt/pepper noise as processing pixel (i.e., 255/0 pixel value) and neighboring pixel values contains all pixels that add salt and pepper noise to the image, then the median value will be again noisy. To solve this problem, the mean of the selected window is found and the processing pixel is replaced by the mean value.

Case 2. If the selected window contains salt or pepper noise as processing pixel (i.e., 255/0 pixel value) and neighboring pixel values contains some pixels that adds salt (i.e., 255 pixel value) and pepper noise to the image. To remove the salt pepper noise from image first the 1-D array of the selected image region is obtained and the 0 and 255 values will be eliminated and median of remaining array values is calculated. This median value is then replaces the processing pixel.

Case 3. If the selected window contains a noise free pixel as a processing pixel, it does not require further processing.

Authors have shown that the performance of MDBUTM in terms of PSNR and IEF is better than other filters like SMF, AMF, DBA and DBUTM up to 90% noise density.

3. Results

It has been found from the survey that the performance of MDBUTM filter is better than that of MF, AMF, DBA and DBUTM.The qualitative analysis of different algorithms at 80% noise density for Baboon image is shown in Figure 2. Figure 3 shows quantitative analysis of MF, MDBUTM algorithms at 80% noise density for captured image 3. It could be observed from the image that quality of restored image using MDBUTM filter is better than that of other algorithms. The filter performance is quantitatively measured by the peak signal to noise ratio (PSNR) and image enhancement factor (IEF) as defined in (1) and (3) respectively.

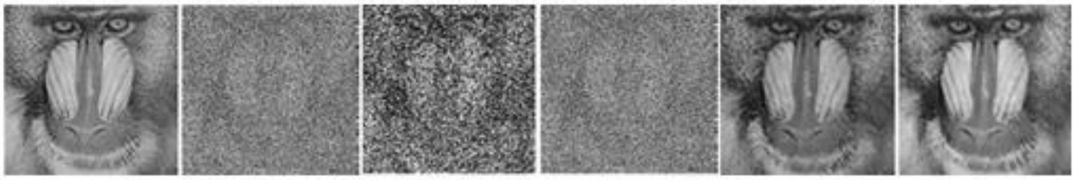
$$\text{PSNR in dB} = 10\log_{10} [255^2 / \text{MSE}] \quad (1)$$

$$\text{MSE} = [\Sigma_i\Sigma_j (Y(i,j) - \hat{Y}(i,j))^2] / [M*N] \quad (2)$$

$$\text{IEF} = [(\Sigma_i\Sigma_j \eta(i,j) - Y(i,j))^2] / [\Sigma_i\Sigma_j (\hat{Y}(i,j) - Y(i,j))^2] \quad (3)$$

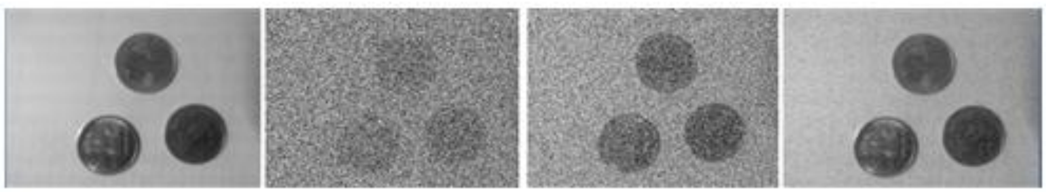
Where,

MSE: Mean Square Error.
M*N: Size of the image.
Y : Original image.
$\hat{Y}$: Denoised image
η : Noisy image.



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

Figure 2.Results of different algorithm for Baboon image
(a) Original image, (b) image corrupted by 80% noise,
(c)Output of MF, (d) Output of AMF,
(d)Output of DBA, (f) Output of MDBUTM,



(a) (b) (c) (d)

Figure 3.Results of different algorithm for captured image
(a) Original image, (b) image corrupted by 80% noise,
(c)Output of MF, (d) Output of MDBUTM,

TABLE-I

Noise %	MF	AMF	DBA	MDBUTM
10	26.34	28.43	36.4	37.91
20	25.66	27.40	32.9	34.78
30	21.86	26.11	30.15	32.29
40	18.21	24.40	28.49	30.32
50	15.04	23.36	26.41	28.18
60	11.08	20.60	24.83	26.43
70	9.93	15.25	22.64	24.30
80	8.68	10.31	20.32	21.70
90	6.65	7.93	17.14	18.40

Comparison of PSNR values (in dB) for different algorithms for "Lena" image at different noise intensities

TABLE-II

Noise %	MF	AMF	DBA	MDBUTM
10	10.36	23.20	390.67	648.98
20	28.17	37.76	358.91	568.43
30	30.02	42.57	322.89	590.83
40	23.12	40.98	268.49	424.18
50	11.72	36.11	208.77	345.13
60	6.73	25.21	190.70	261.66
70	3.31	7.89	128.58	171.69
80	2.00	2.91	67.42	101.72
90	1.37	1.31	33.85	34.23

Comparison of PSNR values (in dB) for different algorithms for "Lena" image at different noise intensities

The quantitative performance comparison of different algorithms in terms of PSNR and IEF at various noise levels for Lena image is given in table I and II respectively. It shows that PSNR and IEF values of MDBUTM filter are greater than those of other filters. It means that performance of MDBUTM filter is better than that of other filters.

4. **Conclusive Discussion**

In this paper author have reviewed different types of non linear median filters used to remove high density salt and pepper noise from the noisy image. Result shows that qualitative performance of MDBUTM filter is better than that of MF, AMF and DBA. The performance of MDBUTM filter in terms of PSNR and IEF is higher than that of MF, AMF and DBA even at high noise density levels. As a conclusion of survey, it is observed that the performance of modified decision based unsymmetric trimmed median filer is superior to other filters even at high noise densities.

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