

Removal of low and high density salt and pepper noise using combination of Fuzzy logic and Median Filter



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Abstract: In this paper presents a new algorithm fuzzy based median filter (FBMF) to remove low and high density salt and pepper noise in gray scale Images. Proposed algorithm replaces the noisy pixel by median value when 0's, 255's and other pixel values are present in the selected window and when all pixel values are either 0's or 255's, or combination of these, then the noise pixel is replaced by fuzzy membership value of a selected window. FBMF algorithm is tested on different images and compared with the existing Standard Median Filter (SMF), adaptive median filter (AMF), Decision Based Algorithm (DBA), Modified decision based unsymmetrical trimmed median filter algorithm (MDBUTMF). Results shows that FBMF gives better Peak Signal to Noise Ratio (PSNR) and Image Enhancement Factor (IEF) compared with the existing algorithms in the literature.

Keywords: AMF (Adaptive median filter), DBA (Decision based algorithm), FBMF (Fuzzy based median filter), IEF (Image enhancement factor), MDBUTMF (Modified decision based unsymmetrical trimmed median filter), PSNR (Peak signal to noise ratio), SMF (Standard median filter)

INTRODUCTION

Noise is an undesired signal that corrupts the desired signal. Removing noise from images is an important task. Salt and pepper noise is one type of noise that highly corrupts the signal. Linear and Nonlinear filters are used for removal of salt and pepper noise [1]. The drawback of median filter is efficient only at low noise intensities. At high noise intensities median filter is not efficient. To overcome this problem Adaptive median filter is proposed [2]. But adaptive median filter will perform better performance at low noise intensities, for high noise intensities the size of the processing window has to be increased which leads to low image clarity. To overcome this difficulty DBA is proposed [3]. In this algorithm image is restored by using a 3x3 window. If the processing pixel is 0 or 255 it need to be processed or else it is left unchanged. At high noise intensities the median value will be 0 or 255. In such case, neighboring pixel is used for substitute. This frequent replacement of neighboring pixel produces streaking effect. To overcome the streaking effect modified decision based unsymmetrical trimmed median filter is proposed (MDBUTMF) [6]. In this algorithm the processed pixel is replaced by median value of the window. Median is calculated by removing 0 and 255 pixels in that window and when pixel values are either 0's or 255's, or combination of

these, the noise pixel is replaced by average value of pixels in the selected window. This results in blurring of image. To overcome blurring in image combination of fuzzy logic and median filter is proposed.

EXISTING NONLINEAR FILTERS FOR REMOVING SALT AND PEPPER NOISE

Median Filter

Median filter is a nonlinear filtering technique that is well known for the ability to remove salt and pepper noise, while preserving sharp edges. The median filter is an order statistics filter. Mean filter replaces the average of the pixel values but it does not preserve image fine details. Some fine details are removed with the mean filter. But in the median filter, we do not substitute the pixel value with the average of neighboring pixel values, substitute with the median of those values. The median is calculated by sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value.

Adaptive Median filter

The Adaptive median filter is used for removing salt and pepper noise. AM filter is based on the following steps:

Step1: It checks for pixels that are noisy or noise free in the image, that is pixels with values 0 or 255 are considered.

Step2: For each such pixel, a window of size 3x3 around the pixel is taken.

Step3: If noise is high window size has to be increased that is 5x5.

Step 4: find the median value and replace the processing pixel with median value

Decision Based Algorithm

In DBA the noisy and noise free pixels in the image are detected by checking the pixel value either maximum value or minimum value in the selected window. Minimum value represents pepper noise and maximum value represents salt noise. If the processing pixel has a value is in between 0 and 255 then it is noise free pixel and no need to change anything.

If the value is either 0 or 255, find median value and replace processing pixel with median value. At high noise densities the median value is 0 or 255, again this will cause noise. In this case replace processing pixel with any neighboring pixel value.

Modified decision based unsymmetrical trimmed median filter

Symmetric and asymmetric filters are used for removing noise. Alpha trimmed mean filter is type of symmetric filter, in this noisy pixels are discarded symmetrically. The disadvantage of ATMF is loss of image clarity. To reduce this problem MDBUTMF is proposed. In this algorithm, elements of selected 3×3 window are arranged in either increasing order or decreasing order, by removing the pixel values of 0's and 255's median is calculated. The processing (noisy) pixel values in the image are replaced with median value. This filter is called trimmed median filter because the pixel values of 0's and 255's are removed from the selected window.

PROPOSED ALGORITHM

Fuzzy sets and fuzzy rules:

A fuzzy logic is a generalization of classical logic that allows membership degree between 0 and 1. A fuzzy set S in the universe R is defined by an $R \rightarrow [0, 1]$ mapping membership function μ_s , which assigns every element r in R a degree of membership $\mu_s(R) \in [0, 1]$ in the fuzzy set S . In the proposed algorithm the fuzzy membership function is defined based on number of 0's and 255's in the selected window. For the processing pixel the function is defined as per below equation

$$s(R) = \{s_0, s_{255}\}$$

s_0 = Number of 0's in a processing window

s_{255} = Number of 255s in a processing window

Let $\mu_s(R) \in [0, 1]$ is the membership function of $s(R)$

The fuzzy rule applied for this algorithm is as follows:

Rule1: If s_0 is large negative or s_{255} is small positive then $\mu_s(R)$ is very low.

Rule2: If s_0 is negative then $\mu_s(R)$ is low.

Rule3: If s_{255} is large positive or s_0 is small negative then $\mu_s(R)$ is very high.

Rule4: If s_{255} is positive then $\mu_s(R)$ is high. With these rules fuzzy membership function is defined.

Membership function $\mu_s(R)$:

$$\mu_s(R) = \begin{cases} \text{std}(R) & \text{if } s_0 \geq t_1 \\ \text{std}(R) \times \left(\frac{s_0}{s_{255}} \right) & \text{if } t_2 < s_0 < t_1 \\ \text{mean}(R) & \text{if } s_{255} \geq t_1 \\ \text{mean}(R) \times \left(\frac{s_{255}}{s_0} \right) & \text{if } t_2 < s_{255} < t_1 \end{cases}$$

Where R is the selected neighboring pixel elements, 'std' stands for standard deviation, and mean is average value of the selected window elements. Here t_1 and t_2 are predefined threshold values. Based on threshold values s_0 and s_{255} are defined as follows. If s_0 is greater than t_1 , the pixel belong to low intensity value, if s_0 is in between t_1 and t_2 then pixel belong to medium intensity value, if the s_{255} is greater than t_1 the pixel belong to very high intensity value and if the s_{255} is greater than t_2 and less than t_1 then pixel belong to higher intensity value.

Algorithm for fuzzy based median filter:

Step 1: Select two dimensional window of size 3×3 . Assume the processed pixel is c_{ij} .

Step2: If processed pixel is in between 0 and 255 then c_{ij} is noise free pixel, go to step 3.

Step 3: If $c_{ij} = 0$ or $c_{ij} = 255$ then c_{ij} is a noisy pixel then two cases are given as follows Case i) and ii).

Case i): If the processing window consists of all elements not 0's and 255's, then find the median of the remaining elements. Then replace the processing pixel with median value.

Case ii): If the processing window consists all the elements as 0's and 255's, then four possible statements defined based on salt and pepper noise intensity are as follows: Very High, Very Low, Low and High. Here 'Very High' refers to recurrent occurrence of 255 and 'Very Low' refers to recurrent occurrence of gray level '0'. Then replace the processing pixel by fuzzy membership function.

Step 4: Repeat steps 1 to 3 until all the pixels in the complete image are processed. The threshold values t_1 and t_2 are selected based on the following cases:

Case i: The selected window size is 3×3 in which the number of elements are 9. In the selected window the number of zeros is more than number of 255's. It means that 0's must be

occurred a minimum of 5 times. The same logic will be applicable when number of 255's is greater than number of zeros within the window. This force to select t_2 as 4.

Case ii): In the selected window frequent occurrence of 255's and 0's mean it should have occurred more than 5, this justifying that t_2 as 6.

Case iii): If all the pixels in the selected window are either zero or 255, in which processing pixel is replaced by 128 which is the mean of two extreme gray levels.

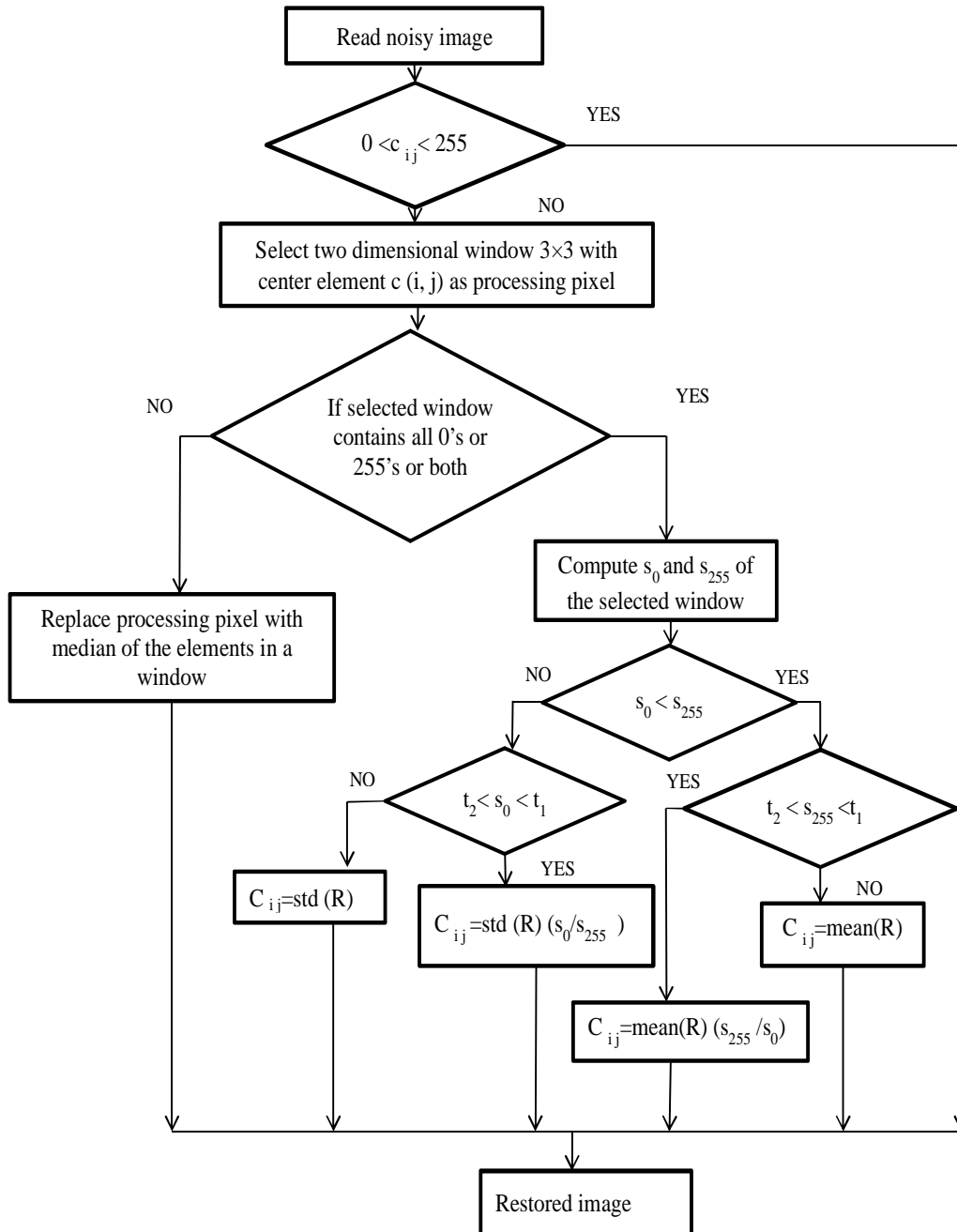


Fig1: Flowchart of proposed algorithm

Illustration of Algorithm

Salt and pepper noise is defined as occurring of zeros and 255's at undesired areas in image. For this algorithm evaluation each and every pixel has to determine whether it is noisy pixel or not. Different cases are illustrated in this section.

Case i): If the central pixel in a selected 3x3 window is noise free pixel, it is left unchanged.

For example,

$$\begin{bmatrix} 35 & 46 & 23 \\ 67 & <65> & 23 \\ 45 & 76 & 45 \end{bmatrix}$$

Here 65 is processing pixel.

Case ii): If the processing pixel is noisy and some pixels are zeros and 255's find median value of that window, replace the noisy pixel with median value. For example,

$$\begin{bmatrix} 65 & 255 & 79 \\ 81 & <0> & 0 \\ 255 & 70 & 90 \end{bmatrix}$$

This window contains central pixel is 0 as noisy pixel, find medial value. Here the median value is 80. Replace the processing pixel with median value.

Case iii): If the processing pixel is noisy pixel and all other pixel values are 0's and 255's then have to replace with fuzzy membership values as explained in algorithm. For example,

$$\begin{bmatrix} 255 & 255 & 255 \\ 0 & <255> & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

The window contains $S_0=5, S_{255}=4$. Define threshold values and find fuzzy membership values for replace noise pixel.

SIMULATION RESULTS

The performance of the proposed algorithm is tested with different gray scale images like lena image size of 255x255. The noise intensity is varied from 10% to 90% .The performance of any image is calculates using PSNR and IEF values. PSNR and IEF equations as follows:

$$PSNR \text{ in dB} = 10 \log_{10} \left(\frac{255^2}{MSE} \right) \tag{1}$$

$$MSE = \frac{\sum_i \sum_j (X(i, j) - Y(i, j))^2}{m \times n} \tag{2}$$

$$IEF = \frac{\sum_i \sum_j (N(i, j) - X(i, j))^2}{\sum_i \sum_j (Y(i, j) - X(i, j))^2} \tag{3}$$

Here MSE stands for mean square error, IEF stands for image enhancement factor, $m \times n$ is size of the image, X represents the original image, Y denotes the restored image, N represents the noisy image. Results of various filters for Lena image and pepper image is shown in fig 2 and fig 3 respectively.

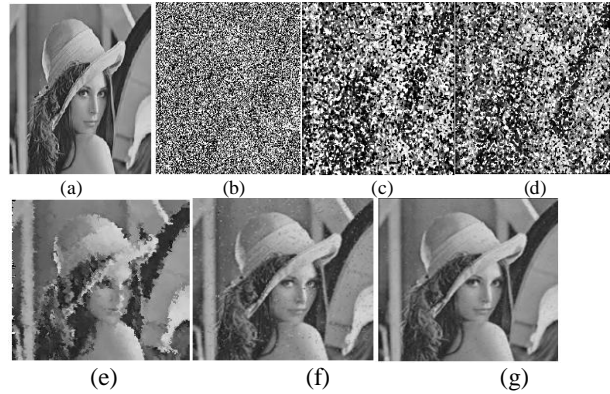


Fig2:Results of different algorithms for lena image at noise density 70%(a)original image (b) noisy image (c) Output of MF.(d)Output of AMF.(e)Output of DBA.(f) output of MDBUTMF(g) output of proposed algorithm.

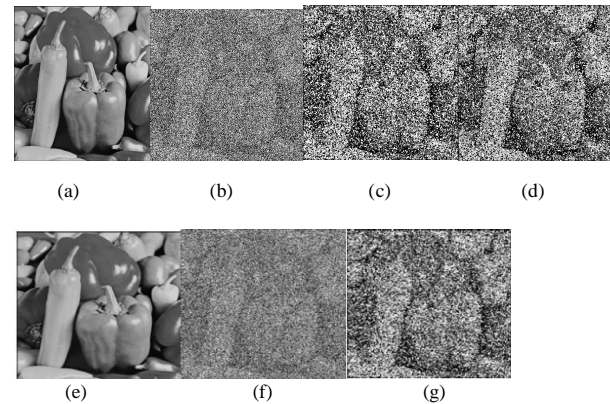


Fig3:Results of different algorithms for pepper image at noise density 80%(a)original image (b) noisy image (c) Output of MF.(d)Output of AMF.(e)Output of DBA.(f) output of MDBUTMF(g) output of proposed algorithm.

The IEF and PSNR values of the proposed algorithm are compared against the existing algorithms by varying the noise density from 10% to 90% for Lena image are shown in Table1 and Table 2 respectively. Table 3 represents comparison of PSNR and IEF for pepper image at noise density is varied from 10% to 90%.From Tables 1, 2 and 3, it is observed that the performance of the combined fuzzy logic and median filter algorithm is better than the existing algorithms. The plots for

analysis of PSNR and IEF values of Lena image is shown in Fig 4 and Fig 5 respectively.

Table 1. Comparison of IEF values of different algorithms at different noise densities of Lena image

ND (%)	MF	AMF	DBA	MDBUTMF	Proposed algorithm
10	21.0	104.7	132.34	652.63	663.8
20	20.3	54.9	104.8	634.4	646.9
30	13.8	25.5	89.2	612.3	623.1
40	7.7	12.3	75.5	593.0	603.3
50	4.3	6.3	54.9	572.1	584.0
60	2.8	3.7	45	555.5	563.6
70	1.9	2.3	32	533.8	544.0
80	1.5	1.7	20.1	516.2	525.9
90	1.17	1.2	12.8	497.9	507.8

Table 2. Comparison of PSNR values of different algorithms at different noise densities of Lena image.

ND (%)	MF	AMF	DBA	MDBUTMF	Proposed algorithm
10	28.5	35.6	36.9	36.4	34.7
20	25.8	29.8	32.7	33.4	33.7
30	22.0	24.7	30.4	31.7	32.0
40	18.2	20.3	28.4	28.3	30.7
50	15.0	16.5	26.1	27.3	29.0
60	12.2	13.2	24.4	26.5	28.9
70	9.8	10.8	22.3	25.8	28.3
80	8.1	8.7	19.7	25.2	27.6
90	6.6	7.0	17.4	24.7	27.2

Table 3. Comparison of PSNR and IEF of different algorithms at different noise densities for Lena image.

	MF	AMF	DBA	MDBUMF	Proposed algorithm
PSNR	8.09	8.66	22.4	27.03	27.7
IEF	1.5	1.7	39.5	520.2	530.0

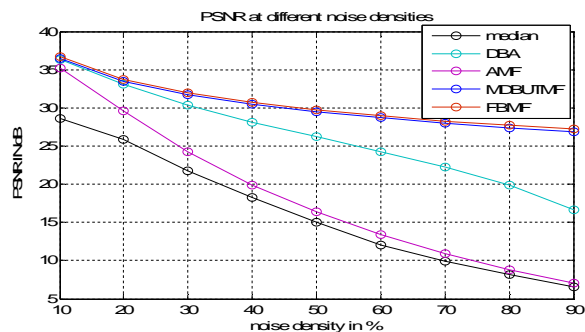


Fig 4: PSNR analysis of different algorithms at different noise densities of Lena image

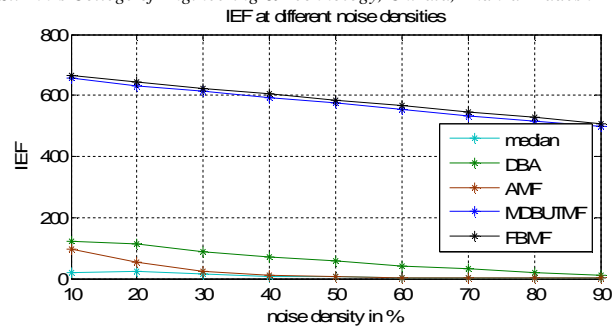


Fig 5: IEF analysis of different algorithms at different noise densities of Lena image

CONCLUSION

Combined fuzzy logic and median filter algorithm is proposed in this paper to remove the salt and pepper noise in images. MF, AMF, DBA, and MDBUTMF are simulated and tested on images with noise levels ranging from 10% to 90% using the factors PSNR and IEF. The results obtained are compared with FBMF algorithm. Simulation results shows that both PSNR and IEF are better than the existing filters even at high levels of noise density. Hence, FBMF is best choice to remove high density salt and pepper noise present in the medical, satellite images.

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