Fuzzy Decision Based Median Filter for Removal of Impulse Noise

Kanika Gupta, Nandita Goyal

Abstract*: *This paper presents the advanced fuzzy decision based median filter for removal of impulse noise present in digital images. The digital images are easily gets disturbed by different types of noises and traditional filters are not able to handle all types of noises present in the digital images. The fuzzy approach is adopted to improve the all other traditional median filters to achieve the optimum performance. This can be seen by adjusting the parameters of fuzzy image filter. The two blocks i.e. of original image and noisy image are taken and the third block can be obtained through the product of these two blocks. The final output image which can be seen as a result of taking mean and median of third block. From the point of view of execution time and PSNR ratios, the image filtering results demonstrates the feasibility and effectiveness of the proposed filter.

Keywords: Median Filter, Fuzzy Image Filter , Salt and pepper Noise.

I. INTRODUCTION

Digital images plays very important role in our daily life applications. A large portion of image processing is devoted to Image restoration. Image Restoration is the process where we remove the degradations or disturbances that are generated while obtaining the digital images [1]. Degradation or disturbances comes from noise as well as blurring due to photometric and electronic sources. The Digital Image acquisition process converts the image taken from an optical device into electrical signals which are continuos in nature and later they are sampled by some primary processes which introduce the noise in the image [2].

In the image denoising process, the knowledge and source of noise about the type of noise plays a very significant role. Generally, the digital images are corrupted with different types of noises modelled with Salt and Pepper distributions, Erlang, Gaussian and Rayleigh. There are various filters and methods available to restore the original image from noisy image. Selecting the right method for Image restoration plays an important role in getting the original image which is free from all types of noises present in the digital image. The denoising methods converge towards some specific problem area. The denoising method which is used for the satellite images may not be suitable for the medical images. Salt and Pepper noise is a special type of Impulse noise in digital image processing where lower intensity takes the value of 0 while higher intensity takes the value of 255 in an digital image This type of noise is introduced into the digital images during the image acquisition process. Several traditional filters have been proposed in the past for digital images which are contaminated with the different types of Impulse Noise.

A number of filters like Weighted Median Filter [4] and Adaptive Median Filter [3] have been introduced to deal with this problem but these filters works well for very low density. The common drawback of these filters is that the noisy pixels are replaced without taking into the account of local features of an image when the noise level is high. In decision based filter [5], the decisions are taken on predefined value which is very difficult to define. This is the major drawback of this method. At high density, the median value will be taken as 0 or 255.In such cases previously processed pixels are used for the replacement. The repeated replacement of these neighbouring pixels will produce the jagging effect.

Noise Adaptive fuzzy switching median filter (NAFSM) [2] is a hybrid nonlinear filtering technique for adaptive median filter [3] and Fuzzy switching median filter. It finds the “noisy pixel” by making the use of histogram of an image during “noisy pixel” detection stage. The information of all the “noisy pixels” is stored in a mask and then it performs the desired filtering actions. After that, the fuzzy reasoning is applied to extract the local features of an image. The main drawback is the blurring effect.

This paper presents a new fuzzy decision based median filter for minimising the impulse noise and preserving the actual image details with much precision and accuracy.

II. THE STRUCTURE OF PROPOSED DECISION BASED FILTER

In the structure of proposed filter, firstly the input image i.e. original image is given. Then the noise is introduced into it and resultant is noisy image. After this the noise is detected, traditional filter is applied and the output is filtered image which has not sharp edges or local features. Then, again this filtered image is passed through proposed decision based filter to get the improved filtered image which has preserved sharp edges and details.

The following will be the proposed block diagram in which the fresh input image is given and some noise is also introduced in this and the resultant is noisy image and then the application of filter is applied on that image.

The resultant output of this filter is to get the filtered image which is free of noise.

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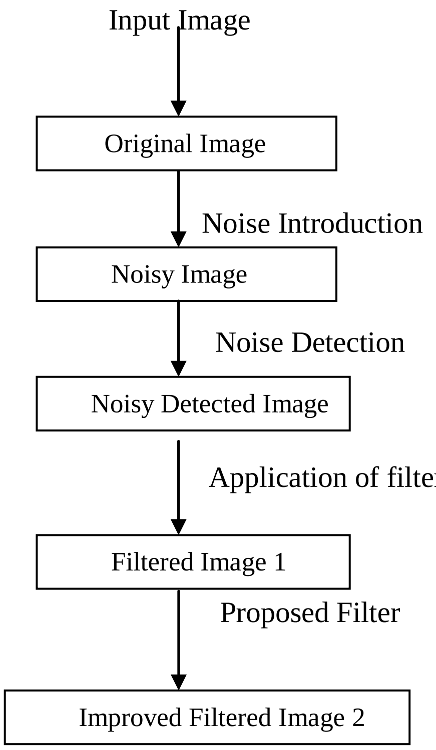

Figure 1: Block Diagram of proposed filter

III. FUZZY DECISION BASED MEDIAN FILTER

The proposed decision based median filter consists of two stages: i) Detection stage ii) Filtering stage. The filter firstly detects the actual salt and pepper noise intensities before knowing the location of corrupted "noisy" pixel. After taking the location of corrupted or "noisy" pixel, it is subjected to next stage i.e. filtering stage; otherwise it is considered to be "noise-free" pixel. The "noise-free" pixels are retained and are skipped by filtering stage in order to preserve fine image details.

A. Detection Stage

To gain knowledge of the salt and pepper noise intensities in an image, the proposed method will utilize the noisy image histogram. Based on the fact that if an image is corrupted by salt and pepper noise, then it will produce two peaks i.e. at the minimum and maximum will be shown in the noisy image histogram. The detection stage actually starts with the search of these two intensities in the histogram. But this is always not the case when image contains fewer amounts of salt and pepper noise intensities. It will produce the peak at "noise-free "intensities rather than at salt and pepper noise intensities. As when detected wrongly, the salt and pepper noise intensities will be left unfiltered.

As the proposed method will search for two local maximums representing the two salt and pepper noise intensities respectively in the histogram. When these two intensities are found i.e salt and pepper noise intensities, the search will be halted. Generally, when an image is stored as an 8-bit integer, Salt noise=255 and Pepper noise=0

These two intensities will be used to identify the possible "noisy pixels" in an image. A binary mask Ndetect (i, j) will be created to mark the location of "noisy pixels" in an image i.e

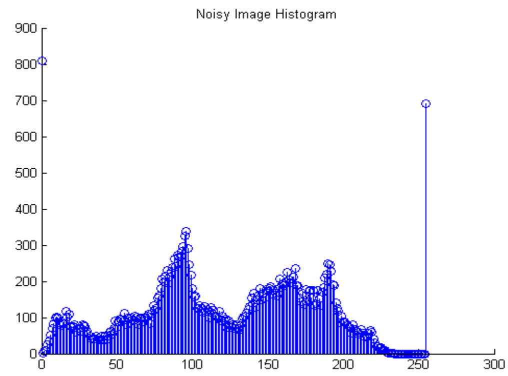

Figure 2: Histogram of "Peppers" image corrupted with 5% of salt-and-pepper noise

$$N_{detect}\ (i,j) = \begin{cases} False\,, & Salt\ or\ pepper\ noise\ detected \\ True, & No\ Noise \end{cases}$$

where i,j ε (-1,…,0,…,+1)

N_{detect} =True represents the "noise free" pixels in an image and N_{detect}=False represents the "noisy pixels" in an image which is subjected to next stage i.e. filtering stage for these two intensities.

B. Filtering Stage

After the binary mask N_{detect} (i,j) is created, the "noise pixels" marked with N_{detect} (i,j) =False will be replaced by an estimated correction term. The proposed filter uses a square filtering window with odd dimensions. Then the "noise free" pixels will all be used as candidates for the selection of median pixel. This criterion for selecting only "noise free" pixels is applied to avoid selecting a "noise pixel" as the median pixel. However, the quantity of "noise free" pixels will not be large in number because more "noise free" pixels will yield the high computing time and yield an inaccurate correction term. The results can be seen from the several standard test images which produces the optimum peak signal-to-noise ratio (PSNR) and fastest processing time.

Since the detection of "noisy pixels" is based on the detected salt and pepper noise intensities,"noise free" pixels might be wrongly identified as "noise pixels" at uniform regions of image having same intensities as of salt and pepper noise intensities. As a result, filtering window will expand continuously and the selected median pixel will not be the appropriate correction term. So, the search for "noise free" pixels will be stopped immediately when the filtering window has reached its maximum size. In this case, the first four pixels in the filtering window defined by:-

$$w(i,j) = \{\, I(i+k, j+l)\,\}$$

where k, l ε $(-1,0,1)$

will be used to calculate the median pixel i.e. Med (i,j).

$$Med\ (i,j) = Median\,\{\ I\ (\,w * N_{detect}\ )\,\}$$

Figure 3: Local Information extracted from noisy "Peppers" image using maximum operator

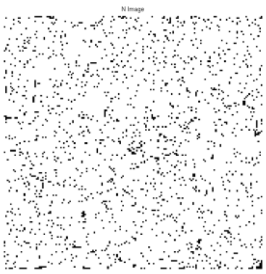

Figure 4: Local Information extracted from noisy "Peppers" image using minimum operator

After the median pixel Med (i, j) is computed, the local information in a window is extracted by calculating the absolute luminance difference i.e. M_D (i, j).

$$M_D(i+k, j+l) = Maximum\{|I(i+k, j+l) - I(i,j)|\}$$

with $(i+k, j+l) \neq (i,j)$

Then, the local information is defined as the maximum absolute luminance difference in the filtering window.

$$D(i,j) = max(M_D(i+k, j+l))$$

The selection of maximum operator rather than minimum operator can be clearly shown where the "noisy pixels" will be set to the maximum intensity 255 while "noise free" pixels can take various values in dynamic range. This conveys the local information about the image such as image edges, image details and "noise free" pixels for further computation. Conversely, the minimum operator is not able to distinguish between the "noisy pixels" and "noise free pixels" when the minimum absolute luminance difference is applied to the equation.

As part of filtering mechanism in the proposed filter, the method of fuzzy reasoning is applied to extracted local data D (i, j).The fuzzy set defined by the fuzzy membership function F (i, j).

$$\mu(i,j) = \begin{cases} 0 & M_D(i,j) < TH_1 \\ SM_D(i,j) + c & TH_1 \leq M_D(i,j) \leq TH_2 \\ 1 & M_D(i,j) \geq TH_2 \end{cases}$$

where the local information M_D(i,j) is used as the fuzzy input variable and two predefined thresholds TH_1 and TH_2 are set to optimal values for better performance and S is defined as slope and c is the intercept which are :-

$$S = \frac{1}{TH_2 - TH_1} \qquad c = -TH_1/TH_2 - TH_1$$

Finally, the correction term to retain the detected "noise pixel" is a linear combination between the processing pixel I(i,j) and median pixel M_D (i,j).The restoration term U (i,j) is given here as:-

$$U(i,j) = [1 - \mu(i,j)]I(i,j) + \mu(i,j).M_D(i,j)$$

where a fuzzy membership function μ (i,j) lends a weight on whether more of pixel I(i,j) or MD (i,j) is to be used.
The proposed filter has some improvement over the existing filters that here two blocks of image are taken and multiplied together. It is finally replaced by mean and median of those blocks of images.

$$U_{improved} = [1 - \mu(i,j)\, U(i,j)] + \frac{Mean(i,j) + Median(i,j)}{2}$$

where

$$Mean(i,j) = Mean\{ I(w * N_{detect})\}$$
$$Median(i,j) = Median\{ I(w * N_{detect})\}$$

IV. SIMULATION RESULTS AND DISCUSSION

In this section, the comparison of the proposed filter will be seen with other salt and pepper noise based on their results of simulation. The parameters taken for comparison are peak signal-to-noise ratio PSNR (dB) and processing time. Visual inspection is also to be carried out on the final output image for its accuracy and precision.
Several standard test images (Pepper, Lena, Barbara, Gold hill, Living room, mandrill etc.) are frequently used in Digital Image Processing literature which are embedded with salt and pepper noise ranging from 5% to 95% with an increment of 5% which are to be used for results

Figure5:a) Original "Peppers"

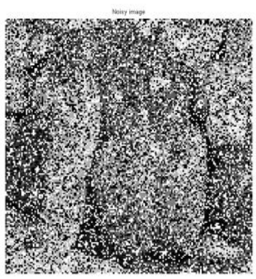

Figure 5: b) "Peppers" Image introduced with 50% of salt and pepper noise.

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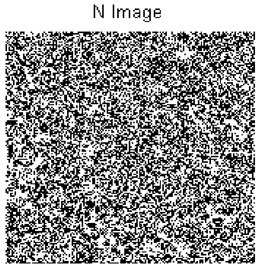

Figure 5: c) Extracted black and white pixels from "Peppers" Image.

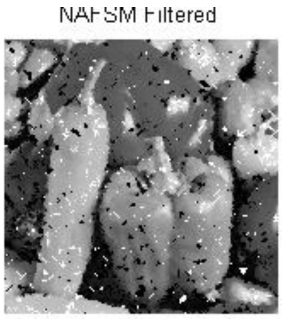

Figure 5: d) "NAFSM Filtered Image" for "peppers" Image

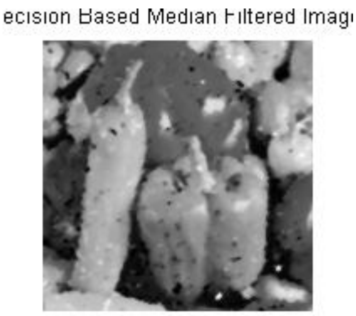

Figure 5: e) "Decision based median Filtered Image" for "peppers" Image

Figure 6: a) Original "Barbara" Image

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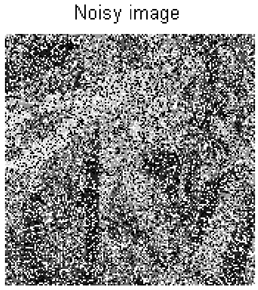

Figure 6: b) "Barbara" Image introduced with 50% of salt and pepper noise

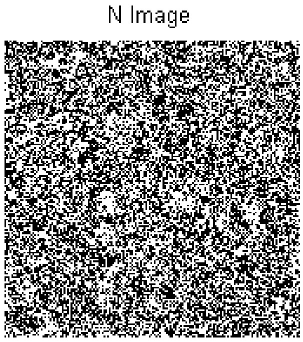

Figure 6: c) Extracted black and white pixels from "Barbara" Image.

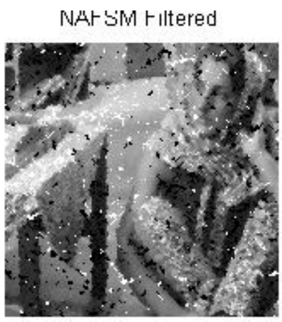

Figure 6: d) "NAFSM Filtered Image" for "Barbara" Image

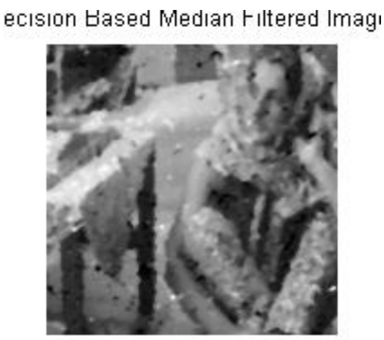

Figure 6: e) "Decision based median Filtered Image" for "Barbara" Image

Table-I: Comparison of PSNR results for the "Peppers" image with different filters containing various % of salt-and-pepper noise

Filters	PSNR(in dB)		
	5%	20%	30%
Original	19.7	13.7	11.9
CWM(3*×3)	33.0	27.3	23.5
CWM(7∗7)	29.4	26.7	26.1
TSM(3∗3)	34.7	27.7	23.8
TSM(7∗7)	32.7	26.6	23.9
MED(3∗3)	29.7	26.9	23.8
NAFSM	25.8	25.3	25.2
DBMF	33.50	32.00	30.21

Table-II: Comparison of Execution time results for the "Peppers" image with different filters containing various % of salt-and-pepper noise

Filters	Execution time(in seconds)		
	5%	20%	30%
Original	76.5	88.6	72.8
CWM(3*×3)	44.0	43.7	44.1
CWM(7*×7)	50.3	50.4	50.5
TSM(3∗3)	86.9	88.9	93.8
TSM(7∗7)	104.0	104.3	105.7
MED(3∗3)	8.8	8.8	8.8
NAFSM	11.7	11.6	11.5
DBMF	2.05	2.38	2.45

V. CONCLUSION

A new efficient decision based median filter (DBMF) has been presented. The proposed filter is set by modified fuzzy median filter. Fuzzy rules are applied to adjust all the parameters by considering every direction around the processed pixel. The main idea of the proposed decision based median filter is to find out the local variations in the image due to image. The parameters like PSNR and Execution time obtained in the experimental results have provided much better performance than all the traditional filters, especially in high noise ratio images. The proposed filter shows the satisfactory performance at high noise density and it is designed to preserve necessary image details

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