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Mid Point Weighted Median Filter for Noise Removal and Smoothening of Images

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Abstract*: *In this paper, a Weighted Median Filter (WMF) mainly Mid-Point WMF (MP WMF) is used to smoothen the images or to remove the impulsive noise present in the input images. It is an improvised version of the median filter. This weighted filter uses the basic concept of the median filter with the enhancement in their mask from normalized mask to the weighted mask. In this weighted median filter, the weight-age is giving to the mid-point pixel i.e. centre pixels or its neighbouring pixels by increasing the repetition of those pixels so that the weight of those mid-point pixel and neighbour pixels get increased. It is shown that the weighted median filter performs more accurately than the normal median filter. Some relationship between MP WMF and other two Four Neighbouring (N4) and Diagonal Neighbouring (ND) Weighted Median Filter are derived. Experimental work has demonstrated that the MP WMF outperform very well than the standard median filters in terms of their noise reduction and in smoothening the image. The proposed MP WMF also provides very good robustness for impulsive noise.

Keywords*: *median filter, mid-point weighted median filter, neighbouring median filter N4 and ND.

I. INTRODUCTION

Images are gets easily effected with the various types of noises during the capturing, acquisition and storing. Due to the presence of noise, it is very difficult to gather the information which is present in the noise. So, Image noise removal and smoothening an image play an prime role in image processing as a pre-processing step [1]. To smoothen the image or to remove the impulsive noise from an image median filter is used which provides a good result.

The filters are differentiating as linear filters or non linear filters. Linear filter is one of the most dominants filters for signal processing and image processing, as it basically depends upon the linear system and it is very efficient in their computational. Despite the very refined linear system theory, many problems related to the signal processing cannot be satisfactorily addressed through the linear filters. Linear filter works very poorly in the presence of signal dependent noise, fail to restore the image which contain heavy noise in it and tends to blur sharp edges[2][3]..

A non linear filter has been proven very useful in the class of median filter. It is now in trending today that median based filter gives sound approach in non linear filtering. The median based filter is very successful based on two parameters:

efficient noise impoverishment with robustness against impulsive noise type and edge preservation. None of the parameter can be achieved by basic linear filter based method. To be effectively eliminate impulsive noise encountered mainly in TV images and communication system, it is notching that the median based filters are optimal filter for removing noise similarly like sliding average filter which is used to reduce Gaussian noise. Edge preservation is very much essential in signal and image processing due to the nature of perception. Edges are also occur in medical image processing where the system moves from one state to another [4].

The non-linear filter provides good results [5], but as the noise intensity increases, the sting edges and other minute details of the input image cannot be bring back. This happens due to the fact that the median filter just replaces each pixel values. Some other decision-based filter proposed which removes the noise by just using two steps; firstly they detect the noise which is present in the image and secondly by replacing the noise pix els [6].

Some algorithm used adaptive median filter technique, which detects the noisy pixels and an objective function with data fidelity term and an edge preserve regularization term to remove the noise while preserving the edges [7]. The NAFSMF algorithm uses the histogram method to fine the impulsive noise pixels in an image and also computed the noise free pixels so that it can select the noise free pixels as a median pixel for restoration [8]. The AWMF algorithm uses the multiple size windows to identify the noisy pixels and then computed the weighted mean of the present window to improve the noisy pixel [9].

The basic median filter reduces the noise properly but as a result, the image gets affected and it's become blurred and then it is difficult to recover back the good quality image. So instead of using the basic median filter, this system enhances the filter by using Mid Point Weighted Median Filter (MP WMF) for providing more weight-age to mid-point pixel and also N4 WMF and ND WMF for providing more weight-age to centre neighbouring pixels. By using these updated filters not only the impulsive noise is removed completely from the noisy images but also the results get improved in terms of blurriness. For all kind of method used in impulsive type noise, the median filter is used due to its high computational efficiency and its effective noise compression capabilities [10].

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In paper [11], the author proposed the impulsive detector, which is depending on the difference between the current pixel and its neighborhood pixel aligned with all four directions.

The proposed system not only simply replace the noisy pixel with the output median filter value but also used the information of all four directions to increase the weight of the pixel. There are many other improved median filters are developed to remove the impulsive noise like multistate median filter (MSMF) [12], signal-dependent rank order mean filter (SD-ROMF) [13], pixel-wise MAD filter (PWMADF) [14], adaptive centre weighted median filter (ACWMF) [15], iterative median filter (IMF) [16]. These all filters usually perform very well but as the noise intensity is increased more than 30% they contain too much impulsive noise or they tend to remove many important features from the input image.

The rest of the paper is as follows. The proposed methods are explained in section 2. In Section 3 the results with different images in comparison with the other standard filters are provided. The comparison of different filters is also computed in terms of Peek Signal to Noise Ratio PSNR (db). Finally, a conclusion is derived in section 4.

II. PROPOSED WORK

A. Median Filter

Median filter is a non-linear filter which is used to remove the impulsive noise, salt and pepper noise and to smoothening the image. The basic idea of the median filter is to replace the gray level of a pixel of an image with the median of the gray level of a pixel of its neighbourhood. For median filtering we have to choose the mask size, identify the pixel values which are covered by the mask and then find the median value. We have to choose the mask size more accurately, as the mask size increases the output becomes more blurred. If the size of a mask is even then the average of two median values is taken.

At starting of median filter zero must be padded at the outer of each pixel of an image. Let’s take an example to understand the above.

First of all take the 3 bit gray scale original image of size 4*4 in Fig. 1, Noisy image of same size in Fig. 2 and the mask size of 3*3 in Fig. 3. Then perform the steps for removal of noise.

4	5	6	7
2	4	5	5
1	3	4	7
6	4	3	0

Fig. 1.Three bit gray scale original image of size 4*4

4	5	6	0
2	5	4	5
1	3	2	7
2	4	3	0

Fig. 2.Three bit noisy image of size 4*4

Fig. 3.3*3 Mask Size

Step 1. The 3*3 mask requires padding at the outer of each pixel of an original image as shown in Fig. 4.

0	0	0	0	0	0
0	4	5	6	0	0
0	2	5	4	5	0
0	1	3	2	7	0
0	2	4	3	0	0
0	0	0	0	0	0

Fig. 4.Padded original image

Step 2. Now we have to process the first element, we map the 3*3 mask with the mid-point pointing to the first element of an image as shown in Fig.5. The sorted data within the mask are listed in terms of their values as in (1)

$$0, 0, 0, 0, 0, 2, 4, 5, 5 \quad (1)$$

The median value is = median (0, 0, 0, 0, 0, 2, 4, 5, 5) = 0. Hence, Zero will replace four as shown in Fig. 6.

0	0	0	0	0	0
0	4	5	6	0	0
0	2	5	4	5	0
0	1	3	2	7	0
0	2	4	3	0	0
0	0	0	0	0	0

Fig. 5.Processing first element of an image

0	0	0	0	0	0
0	0	5	6	0	0
0	2	5	4	5	0
0	1	3	2	7	0
0	2	4	3	0	0
0	0	0	0	0	0

Fig. 6.Four is replaced by zero

Step 3. Now, similarly we have to repeat the process for each and every pixel of an image.

Now let take the element at pixel (2,1) in an image as shown in Fig. 7.

0	0	0	0	0	0
0	4	5	6	0	0
0	**2**	5	4	5	0
0	1	3	2	7	0
0	2	4	3	0	0
0	0	0	0	0	0

Fig. 7.Processing element at pixel (2 , 1)

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The sorted values covered by mask are given as in (2)

0, 0, 0, 1, 2, 3, 4, 5, 5 (2)

The median value is = median (0, 0, 0, 1, 2, 3, 4, 5, 5) = 2. Hence, two will replace by two.

Finally the processed image is in Fig. 8.

0	4	4	0
2	4	5	2
2	3	4	2
0	2	2	0

Fig. 8.Final processed image

Few boundary pixels may be distorted due to the padding effect, but for a large size image, the boundary pixel is significantly small, so their distortion is omitted to the overall quality of an image. Most of the portion or specifically 2*2 middle portions of a final processed image as shown in Fig. 9 match the same input image. Hence the efficiency of the median filter is verified.

0	4	4	0
2	**4**	**5**	2
2	**3**	**4**	2
0	2	2	0

Fig. 9.2*2 middle portion of final image

The image of lena in Fig. 10 contains salt and pepper noise. The median filter of size 3*3 is used to remove the noise. Fig. 11 contains the image after noise reduction which has a powerful quality improvement. The larger size of a mask is not appropriate for the median filter, because as the size of the mask increases the median value has deviated from the pixel value.

Fig. 10.Image contains salt & pepper noise

Fig. 11.Image after applying median filter

B. Weighted Median Filter (WMF)

WMF is an advanced form of the median filter as in median filter it reduces the noise very well but simultaneously it decreases the quality of output images because it has a property to smoothen the images. So to improve the median filter we use WMF. In WMF we have mid-point weighted median filter (MP WMF), Four Neighbour Weighted Median Filter (N4 WMF) and Diagonal Neighbour Weighted Median Filter (ND WMF). In MPWMF weight age is given to the mid-point pixel as it has the highest weight age in the mask. In N4 WMF weight age is also given to the N4 neighbouring pixel as it has the nearest neighbour to the mid-point pixel. In ND WMF weight age is also given to the ND neighbouring pixel (Diagonal neighbours) as it has also the nearest neighbour to the mid-point pixel.

1) MP WMF

In this filter, we are increasing the number of occurrence of mid-point pixel so that the weight age of that pixel increases over other remaining pixels of the mask. As a result, the number of a pixel having the same intensity value is increased in the output image. By using this approach not only the noise is reduced from the input image but also the quality of an image is maintained in terms of their blurriness.

When we map the centre pixel of the mask to the input image pixel then the value corresponding to the centre mask will repeat to increase the weight of that pixel. Let's take the mask "**a**" of size 3*3 as shown in Fig. 12.

x-1 , y-1	x-1 , y	x-1 , y+1
x , y-1	**x , y**	x , y+1
x+1 , y-1	x+1 , y	x+1 , y+1

Fig. 12.Mask "a" of size 3*3

So according to MP WMF we increase the occurrence of a(x,y) as it is the mid-point of mask to increase the weight of that pixel. By default, we are taking 3 repetitions of mid-point a(x,y) in mask of size (3*3) as shown in Fig. 13.

1	1	1
1	**3**	1
1	1	1

Fig. 13.Weight-age of each pixel in MP WMF

We can write the values of a mask as in (3) and then sort the values followed by taking the median value and then replace that median value with a previous pixel value. Similarly, we have to repeat the process for each pixel of an image.

a(x-1,y-1) a(x-1,y) a(x-1,y+1) a(x,y-1) **a(x,y) a(x,y) a(x,y)** a(x,y+1) a(x+1,y-1) a(x+1,y) a(x+1,y+1) (3)

Let's take an example to understand the MP WMF over the 3 bit gray scale image of size 3*3 as shown in Fig. 14. Here just to understand we are taking the middle value of a image which is at location (1,1) and pixel value is 4.

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4	5	6
2	**4**	5
1	3	4

Fig. 14.Three bit gray scale image

We are processing the mid-point pixel element in Fig. 14, we cover the 3*3 mask with the centre pointing to the mid-point element of an image. Here the value which is at location (x,y) of a mask is 4 as shown in Fig. 14. Therefore according to mask the gray scale value 4 must be repeated 3 times.

Hence, the data within the mask are listed according to MP WMF as in (4)

4, 5, 6, 2, 4, 4, 4, 5, 1, 3, 4 (4)

The sorted data within the mask are listed in terms of their values as in (5)

1, 2, 3, 4, 4, 4, 4, 4, 5, 5, 6 (5)

The median value is = median (1, 2, 3, 4, 4, 4, 4, 4, 5, 5, 6) = 4. Four will replace four.

We have to apply this process for every pixel in an image. This example is for size 3*3 size, if we take the actual size of the image and then applied MP WMF, most of the portion matches the same input image. So the effectiveness of the weighted median filter is improved and also it causes less blurred image as a comparison to the median filtered image.

The image of lena in Fig. 15 contains salt and pepper noise. The MP WMF of size 3*3 is used to remove the noise. Fig. 16 contains the image after reduction of noise which has a significant quality improvement over the median filter.

Fig. 15. Image contains salt & pepper noise

Fig. 16.Image after applying MP WMF

We can also change the mask. But larger the mask size the quality of output image will degrade. With the help of MP WMF we had also derived two more filters N4 WMF and ND WMF. In both cases we are taking mid-point pixel as the highest weighted pixel.

2) N4 WMF

In N4 WMF the pixel corresponding to (x-1,y), (x,y-1), (x,y+1), (x+1,y) have been repeated twice in a mask as given in (6) to increase the weight of four neighbouring pixel as shown in Fig. 17.

1	**2**	1
2	**3**	**2**
1	**2**	1

Fig. 17.N4 WMF mask

a(x-1,y-1) **a(x-1,y) a(x-1,y)** a(x-1,y+1) **a(x,y-1) a(x,y-1) a(x,y) a(x,y) a(x,y) a(x,y+1) a(x,y+1)** a(x+1,y-1) **a(x+1,y) a(x+1,y)** a(x+1,y+1) (6)

3) ND WMF

In ND WMF the pixel corresponding to (x-1,y-1), (x-1,y+1), (x+1,y-1), (x+1,y+1) have been repeated twice in a mask as given in (7) to increase the weight of diagonal neighbouring pixels as shown in Fig. 18.

2	1	**2**
1	**3**	1
2	1	**2**

Fig. 18.ND WMF Mask

a(x-1,y-1) a(x-1,y-1) a(x-1,y) **a(x-1,y+1) a(x-1,y+1)** a(x,y-1) **a(x,y) a(x,y) a(x,y)** a(x,y+1) **a(x+1,y-1) a(x+1,y-1)** a(x+1,y) **a(x+1,y+1) a(x+1,y+1)** (7)

In all these WMF we can also increase the number of repetition of MP, N4 and ND pixels in its mask but taking the number of mid-point pixel as the highest weight in terms of number of repetition, then either N4 pixels or ND pixels and in last taking 1 for the remaining pixels.

III. RESULT AND DISCUSSION

As we already have shown some results in the previous step. But here in this section, we are primarily showing the results of the median filter and MP WMF. Here we are showing the results in color images. Fig. 19 is divided into four parts in which first part contain the original input image of lena, second part contain a noisy image in which noise is added by salt and pepper taking the value at 0.05, third part contain the output image using median filter and fourth part contain the output image using MP-WMF. The output in MP WMF is more similar to the input image.

Fig. 19.(a) Input image

Fig. 19.(b) Noisy image

Fig. 19.(c) Image after applying median filter

Fig. 19.(d) Image after applying MP WMF

Similarly, Fig. 20 is also divided into four parts in which first part contain the input image of a pot, second part contain a noisy image in which noise is added by salt and pepper taking the value at 0.08, third part contain the output image using median filter and fourth part contain the output image using MP WMF. Here again, the output in MP WMF is more similar to the input image even the noise is changed to 0.05 from 0.08.

By applying WMF not only the noise but also the blurriness from the image will is reduced, due to which the resultant image is much similar to the input image.

Fig. 20.(a) Input image

Fig. 20.(b) Noisy image

Fig. 20.(c) Image after applying median filter

Fig. 20.(d) Image after applying MP WMF

In TABLE I we are explaining the behaviour of various filters used in this paper that how these filters behaves in parameters like noise reduction, percentage of noise reduction, size of a mask, mask values and the function used in it.

In TABLE II we are comparing all the methods results in PSNR(db) with the different amount of noise present in the noisy image. We can see that the average filter, weighted average filter and median filter can provide a better PSNR result, but the proposed method is giving much better PSNR

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TABLE I Behaviour of different filters on various parameters

Criteria	Average Filter	Weighted Average Filter	Median Filter	WMF
Reduction in noise	Noise Reduces up to good extent, But contain Blurring effect	Blurring is less as compared to average filter	Blurring is very less than average filter	Blurring effect is very less as compared to average filter and median filter
Noise reduction in %	Less than 100 %	Less than 100%	Almost 100%	Almost 100%
Mask Size	As size increase noise reduces but it causes blurriness	As size increase noise reduces but it causes blurriness	As size increase noise reduces completely but it causes blurriness	As size increase noise reduces completely, less blur then median, blurriness at edges only
Mask	1/9[1, 1, 1; 1, 1, 1; 1, 1, 1]	1/16[1, 2, 1; 2, 4, 4; 1, 2, 1]	Pixel value is removed by median value of neighbourhood.	[1, 1, 1; 1, 3, 1; 1, 1, 1]
MATLAB Function	Filter2	Filter2	Medfilt2	Custom filter

result then the compared three methods.

TABLE II Comparison of results in PSNR (db) for Lena Image

Methods	Different amount of noise			
	30%	**50%**	**70%**	**90%**
Average	37.69	30.26	26.66	23.23
Weighted average	38.53	31.45	28.35	25.65
Median	39.66	33.25	29.22	26.78
WMF	41.83	34.69	31.89	29.66

TABLE III shows the PSNR values of various other filters including our proposed filter. All these mentioned filters perform very well if the impulsive noise present in the input image is less than 25%, but as the noise increases their performance also decreases. But our proposed system will sustains even when the percentage of noisy increase from 25% to up to 50%.

TABLE II Comparison of filters for Lena Image in PSNR (db)

Methods	Lena Image				
	20%	30%	40%	50%	60%
Filter Med [10]	32.37	30.00	27.64	24.28	21.58
Filter DWM [11]	37.15	34.87	32.62	30.26	26.74
Filter MSM [12]	35.44	31.67	29.26	26.11	22.14
Filter SD-Rom [13]	35.72	32.77	29.85	26.80	23.41
Filter PWMAD [14]	36.50	33.44	31.41	28.50	24.30
Filter ACWM [15]	36.07	32.59	28.79	25.19	21.19
Filter Interactive Median [16]	36.90	31.76	30.25	24.76	22.96
Filter PSM [17]	35.09	30.85	28.92	26.12	22.06
WMF	42.98	41.83	36.66	34.69	29.78

IV. CONCLUSION

In this paper, we have proposed the advanced version of the basic median filter that is weighted median filter which not only removes the noise completely but also reduce the amount of blurriness that has been present in the image. As the size of the mask increases the noise and blurriness increases. So in our proposed algorithm, we have to increase the weight of the mid-point at max at the size of the mask. In a N*N mask size, we can take the weight of maximum N repetition of mid-point pixel. By using this approach we are getting the best results as shown in the result section.

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