

Weighted Square Masking Filter for Efficient Removal of Impulse Noise

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Abstract – Generally the removal process of impulse noise from digital images tends to be difficult due to the uncertain nature of impulse noise. Understanding the uncertainty of impulse noise is also difficult. Recently, Cloud model (CM Filter) filtering has been used to remove the impulse noise in order to get the better output image in denoising process. But CM filtering and other older methods which are used for the impulse noise removal are not upto the requirements due to time elapsing and moderate improvement in PSNR values. In order to get the better PSNR of output image within a short duration, an algorithm namely Weighted Square Masking (WSM) has been proposed in this paper. This WSM filtering method uses the fuzzy mean filter as a part of it. An image which is affected more than 90% of impulse noise can also be recovered effectively by using this WSM filtering.

Keywords – CM Filter, Fuzzy Means Filter, Impulse Noise, Random Circle Masking, Cloud Model Filtering.

I. INTRODUCTION

The basic model which can give the fact of impulse noise in digital transmission, is given in the equation (1),

$$I = (1 - \varepsilon) O + \varepsilon N \quad (1)$$

In equation (1), the original image pixel is represented by O and N denotes the noisy pixel. Similarly, ε gives erroneous value and finally I provides the impulse noise affected image [9].

Impulse noise replaces the original pixel value into either fixed value or random value. If the replaced value fixed like 0 or 255, then it can be termed as fixed value impulse noise. For example, salt and pepper noise is a fixed value impulse noise.

The uncertain nature of the random value impulse noise is higher when compared to the fixed value impulse noise. Since 1990, several methods have been proposed to improve the denoising level of the filtering but they have not reached the satisfactory mark [12].

Initially, a simple median filtering was designed to remove the impulse noise. This filter is a technique which operates nonlinearly in order to remove the noise. It was used as pre processing technique which improves the results in post processing techniques such as edge detection [5]. At that point of time period, this simple median filter was used in various image processing applications.

A progressive switching median filtering technique had been developed later to retrieve the digital images which were affected by fixed impulse noise such as salt and pepper noise. This method has a preprocessing step namely switching scheme which is used to filter a part of image pixels [8]. After that progressive method was developed for processing the noisy pixels through several

iterations. It suits only for the low density noisy images which are affected by fixed value impulse noises.

The adaptive median filtering is an advancement of standard median filtering. This algorithm uses spatial filtering and smoothing process for denoising [11]. The only benefit of this methodology is the partial preservation of the edges which provides little improvement in PSNR value of output images.

The CWM filter which can be expanded as center weighted median filter which gives more importance i.e. weight to the center pixel of every window [2]. This filter can be used not only for impulse noise affected images but also to remove the white Gaussian noise. Due to the allotment of highest value to center pixel, this process is easy to implement and also for processing but PSNR values are not upto requirement.

The multi-state median (MSM) filter is the improvement of CWM filter which has difference in its center weights. In this, the varying center weights are depending on the local signal statistics [4]. The evaluation of the efficiency of this filter can be calculated by simulation process.

A method called pixel wise MAD was developed later for impulse noise removal. Here a parameter called median of the absolute deviations from the median – MAD is calculated [15]. This MAD parameter is used for the separation of image pixels from noisy pixels. This filter does not require any stored parameters or optimization technique. It can be used to remove both types of impulse noise. This method is easy to implement and better in process compared to previous methods.

After pixel wise MAD, a two-stage iterative method to remove random-valued impulse noise was developed. This method has two stages. In first stage, adaptive center weighted median filter is used to find out the noisy pixels. In the second stage, the noise candidates which are found out in the first stage are restored by the use of a detail-preserving regularization method and it also preserves the edges and uncorrupted pixels [14]. Alternatively, the above two stages were processed.

The logistic method [10] of impulse noise removal initially identifies the corrupted pixels from the image which is affected by random valued impulse noise. The pixels are compared with its neighbor pixels with respect to intensity. The different pixels were identified from the similar neighbors [7]. It was mainly used to remove the Gaussian noise and partly removes impulse noise.

II. CLOUD MODEL FILTER

Recently, a filter named cloud model filter has been proposed and is used to detect and remove the impulse noise from digital images. It is a cognitive method which

is based on natural language cognitive model. This process is working with the combination of the fuzziness and randomness [16]. It creates an intermapping between the qualitative and quantitative information. The cloud model process is based on the three parameters for qualitative concept. They can be given as the expected value Ex , the entropy En and hyper entropy He .

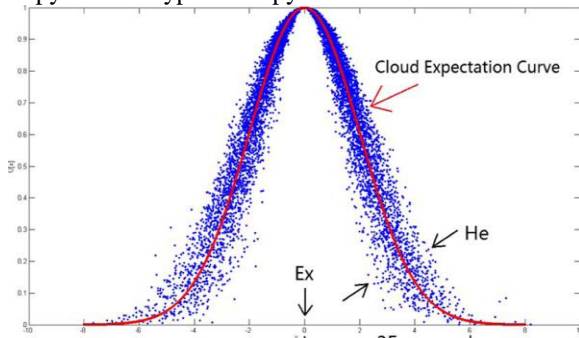


Fig.1. Cloud C (0, 2, 0.3).

The expectation of cloud drop distribution in the domain is termed as the expected value Ex . This parameter Ex finds out the drops which provide better details. The uncertainty measurement of the qualitative concept is denoted as En [6]. It gives the fuzziness and randomness of the model. The value region can be given by the use of En of the drops which are acceptable by the concept. This parameter also reflects the correlation of the fuzziness and randomness of the cloud model.

The third parameter He is the uncertainty measurement based on entropy value En . For example, a cloud can be denoted as $C(Ex=0, En=2, He=0.3)$. This cloud can be given by the above Fig. 1.

The cloud has been developed by combination of the drops. The probability of certainty increases when the drops are approaching Ex . 99.99% of the whole quantity has been taken by the drops which are occurring within the region $[Ex-3En, Ex+3En]$. This region is contributing 99.74% of the cloud model.

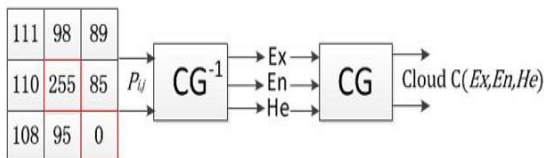


Fig.2. Calculated cloud that represents the observed neighborhood.

The contribution of the drops which are presented outside the region $[Ex-3En, Ex+3En]$ can be neglected. This is known as "The 3En rule" [1].

A curve will be produced due to all the drops and the expectations of certainty degrees due to that drops [1]. This curve is termed as CEC (cloud expectation curve). The Fig.1. is an example for CEC with cloud $C(Ex=0, En=2, He=0.3)$.

Let us consider an example pixel window which is in Fig.2. to know the details about certainty degrees. In Fig.2, CG represents the cloud model generator [3] and Fig.3. gives the produced cloud curve. Table 1 provides the certainty degrees for the uncertainty detection.

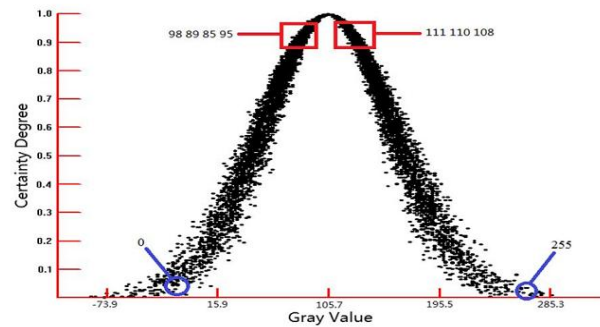


Fig.3. Cloud C (105.7, 44.9, 47.8) represents the neighborhood in Fig 2.

The Table shows that the certainty degrees for 0 and 255 are less compared to the certainty degrees of the other values. The overall cloud model process can be represented by the block diagram in Fig. 4.

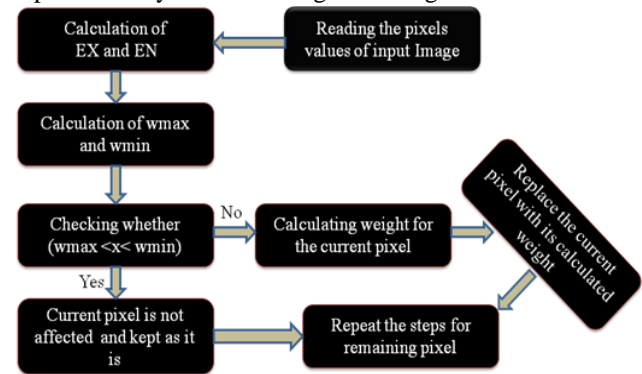


Fig.4. Impulse noise removal process based on cloud model

The block diagram shows that the first step is to take a pixel to check whether it is affected by impulse noise. Then Ex and En values are calculated. With the use of these Ex and En , the calculation of $wmax$ and $wmin$ are carried out [13].

Table 1: Representation of certainty degree of each pixel

Gray value	Certainty degree
111	0.99298
98	0.99298
89	0.93352
110	0.99536
255	0.00400
85	0.89963
108	0.99865
95	0.97222
0	0.06297

And then the condition $wmax < x < wmin$ is checked out. If the taken pixels satisfy this condition then the pixel will be remain unchanged. If the taken pixel value does not satisfy the condition, then the WFM filtering process will be carried out. From this process, mean weight will be calculated for the current pixel and that mean weight will replace that current noisy pixel.

III. WEIGHTED SQUARE MASKING FILTER

In this paper, Weighted Square Masking filter (WSM) has been proposed. The WSM filter can be carried out with the use of square vectors. The Weighted Square Masking filter has two main steps i.e. square vector calculation and weighted fuzzy mean filtering.

In Weighted Square Masking filter, the detection process is carried out with the use of square vector calculation and similarity parameter analysis. After that, the weighted fuzzy analysis will be used for filtering if necessary. The Weighted Square Masking filtering process is carried out as in the Fig. 5.

A. Square Vector Calculation

At first, a pixel is taken for the process of denoising. After that, $n \times n$ window will be taken in order to keep the current pixel as center pixel.

As shown in Fig. 6. Four vectors will be taken which are through the center pixel and the four square vectors which are the outline pixels of the $n \times n$ window. Each and every red line will produce a vector which can be denoted from D1 to D8. These eight vectors can be given as follows,

- D1 = [102 209 102 118 105 6 108 108 109]
- D2 = [131 100 89 106 105 102 180 98 34]
- D3 = [232 37 228 102 105 103 138 74 197]
- D4 = [100 100 102 103 105 107 22 95 108]
- D5 = [102 149 103 106 232 106 109 115]
- D6 = [131 115 112 110 108 108 109 110]
- D7 = [109 68 107 34 197 99 101 128]
- D8 = [34 98 100 39 100 58 29 5]

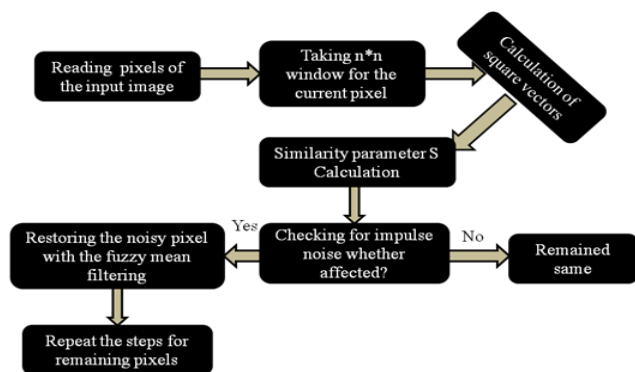
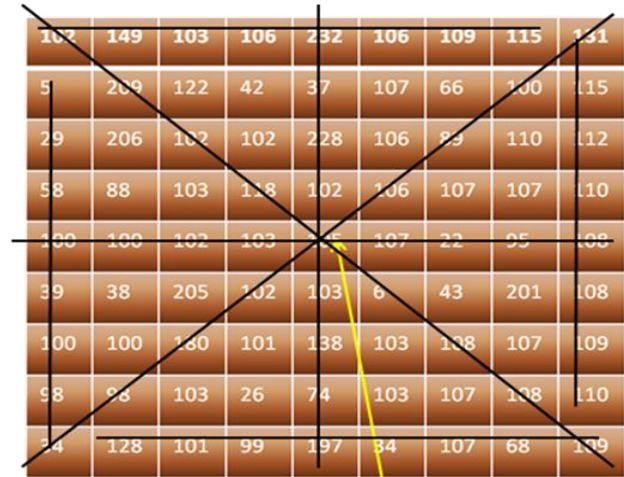


Fig.5. Pseudo random noise masking based impulse noise removal

In the next step, the center pixel in the first four vectors will be neglected. Hence we will have eight pixels in each vector set as follows,

- D1 = [102 209 102 118 6 108 108 109]
- D2 = [131 100 89 106 102 180 98 34]
- D3 = [232 37 228 102 103 138 74 197]
- D4 = [100 100 102 103 107 22 95 108]
- D5 = [102 149 103 106 232 106 109 115]
- D6 = [131 115 112 110 108 108 109 110]
- D7 = [109 68 107 34 197 99 101 128]
- D8 = [34 98 100 39 100 58 29 5]



Centre Pixel = 105

Fig.6. Identification of directional vectors

In the third step, the pixels in each vector set are aligned in ascending order i.e. from smallest to largest values. After neglecting the largest and smallest pixels, the vectors are,

- R1 = [102 102 108 108 109 118]
- R2 = [89 98 100 102 106 131]
- R3 = [74 102 103 138 197 228]
- R4 = [95 100 100 102 103 107]
- R5 = [103 106 106 109 115 149]
- R6 = [108 109 110 110 112 115]
- R7 = [68 99 101 107 109 128]
- R8 = [29 34 39 58 98 100]

B. Weighted Fuzzy Analysis

In the second stage, the similarity parameter calculation is carried out. To calculate the Similarity parameter S, we need the direction to process which should be optimum.

It is necessary to calculate the standard deviations of all vector sets. So the calculated standard deviation functions can be given as,

- STD1= $std([102 102 108 108 109 118])$
- STD2= $std([89 98 100 102 106 131])$
- STD3= $std([74 102 103 138 197 228])$
- STD4= $std([95 100 100 102 103 107])$
- STD5= $std([103 106 106 109 115 149])$
- STD6= $std([108 109 110 110 112 115])$
- STD7= $std([68 99 101 107 109 128])$
- STD8= $std([29 34 39 58 98 100])$

From all calculated standard deviation values, the smallest value set direction will be the required direction to find out the similarity Index.

Similarity index parameter S is calculated using the equation which is given below.

$$S = \sum abs \left(\frac{(Pop - Kcp)}{255} \right) \quad (2)$$

Where, Kcp-current pixel under process
Pop-Pixels in the optimum direction

The identification of noisy pixel is important step and this can be carried with the help of threshold value T. The threshold value should be in a particular limit which depends on the size of the taken window. It also depends on the similarity parameter S. The threshold value T is used to find the noisy pixels.

$$P_{out} = \begin{cases} P_o, & \text{if } S \in T, (0 \leq T \leq x - 3) \\ P_n & \text{else} \end{cases} \quad (3)$$

Where, P_o - original pixel; P_n - noisy pixel

The equation 3 is used to find out the noisy pixel. If the current pixel is found to be noisy, then the weighted fuzzy mean filter process will replace the noisy pixel with its weight. This process is continued for all the pixels in the taken input digital image.

IV. SIMULATION RESULTS

The PSNR value comparison is carried out to evaluate the performance efficiency of the Weighted Square Masking filter. The WSM filtering algorithm has been applied on the Lena digital images color and gray. The images are shown in the following Fig 7 and 8.



Fig.7. Execution of WSM filter - Removal of impulse noise from Lena gray 7(a) Original image 7(b) noisy image 7(c) Denoised image



Fig.8. Execution of WSM filter - Removal of impulse noise from Lena colour 8(a) Original image 8(b) noisy image 8(c) Denoised image

The Table II represents the various values of mean square errors (MSEs) for cloud model and also for Weighted Square Masking filter. Table. III shows the comparison of cloud model filtering with the proposed WSM filtering based on the PSNR values for basic Lena gray and Lena colour images.

Table II: Performance comparison - MSE

Noise density (%)	Lena gray		Lena colour	
	CM	WSM	CM	WSM
10	767.913	7.6407	619.507	7.5930
20	1.4726 e+003	9.5695	1.2068 e+003	9.4801
30	2.1333 e+003	12.9226	1.7393 e+003	12.5509
40	2.7902 e+003	17.3906	2.2324 e+003	17.4790

Table III: Performance comparison - PSNR

Noise density (%)	Lena gray		Lena colour	
	CM	WSM	CM	WSM
10	44.34	78.59	46.45	78.65
20	37.69	76.64	40.11	76.72
30	33.94	74.03	36.24	74.28
40	31.36	71.45	33.66	71.41

The above Table III shows the application of cloud model and WSM filtering with various noise levels. This clearly shows the great improvement in PSNR values when compared to cloud model.

IV. CONCLUSION

The removal of impulse noise that too particularly random valued impulse noise from digital images in digital transmission can be improved with the use of WSM filtering. Since last two decades lot of methods to remove the impulse noise from digital images have been proposed. But the level of performance was not up to the requirement.

The Weighted Square Masking filter can produce much better results when compared to other methods. From the use of this method the originality level up to 98% can be retrieved.

In future, the proposed WSM filter can be improved to recover the various types of noises from digital images.

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