Direction based Fuzzy filtering for Color Image Denoising

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Abstract - *Image filtering is a key technology for de-noising corrupted images in image processing applications. During capturing, digital images are polluted by noise and hence they may not show the features or colors clearly. Image filtering is used to remove the noise in an image and improves the contrast to provide better input for various image processing applications. In order to tackle conflicting issues of noise smoothing and edge preservation, this paper presents a novel approach, that is, direction based fuzzy filtering for noise detection and removal.The proposed method uses fuzzy membership functions in order to replace the noisy pixels based on the degree of membership of the neighboring pixels within a sliding window and also preserve the edges by using direction concept. Experimental results shows that our method is very effective and fast for removing impulsive noise while preserving the edges and small or sharp details in the image.*

Key Words: DE noising, fuzzy, Impulsive Noise, PSNR.

1. INTRODUCTION

Digital images plays an important role in daily life applications such as satellite television, computer tomography as well as in areas of research and technology such as geographical information systems and astronomy. Many scientific data sets picked by the sensors are normally contaminated by noise. Image noise is an unwanted noise that adds extraneous information. Thus, a prime task in image processing is to extract the original information from the corrupted image.

Before the image data is analyzed, denoising is a necessary and the first step to be taken. It is necessity to apply an efficient denoising technique to recompense for such data corruption.

Image denoising is one of the important and essential components of image processing. The goal of denoising algorithm is to remove the unwanted noise while preserving the important signal features of the image or characteristics related to that image. Noise elimination introduce artifacts and blur in the images. By image filtering some sort of improvement or enhancement in images can be achieved. Usually, Impulse noise can be classified into two types: fixed value and random value impulse noise. In fixed value impulse noise, a noisy pixel takes either 0 (minimum value) or 255 (maximum value). In case of random-valued impulse noise (RVIN), there is not any pre-assumption about the value of the impulsive Noises. Therefore the image Denoising task is to detect the noisy pixel and then to correct them with the original pixel of the image.

The fuzzy filtering is able to reduce noise in a comprehensible way with expert knowledge. This paper shows a robust and efficient technique for de-noising high density impulse noise using a direction based fuzzy technique. Direction based fuzzy technique is used for preserving the edges and remove the impulse noise. Our proposed method provides superior performance compared to other similar filters in terms of both de-noising and details preservation.

2. LITERATURE REVIEW

An JingYu et al, 2016 [1] This paper shows a new method for image denoise for furnace flame images. He concluded that the proposed method can effectively remove the impulse noise and Gaussian noise and it improves the quality of the flame images and also it is better than the traditional denoising method.
M. Mozammel Hoque Chowdhury et al, (2014) [2] focused on a robust De-Noising Model for image enhancement with Adaptive Median Filtering. The effectiveness of the proposed method has been justified using different types of noisy images.
A.K.M. Zaidi Satter et al, (2013) [3] used a new approach for image de-noising with a fuzzy rule-based filtering. The effectiveness of the Fuzzy rule-based de-noising has been tested with different types of gray scale images with simple and complex background.
B. Singh et al, (2013) [4] focused on removal of high density salt & pepper noise in noisy color images using proposed median filter. A comparison has been arranged among the proposed method, the standard median (SM) filter and the center weighted median (CWM) filter, which proves the superiority of the proposed filtering method.
Debajyoti Misra et al, 2013 [5] He used the Genetic Algorithm for removal of Rician Noise. He concluded that GA based filter has provided high level of noise reduction which is useful both from the visual inspection as well as quantitative analysis of the performance matrix consider in the research.
Wen-jing Shao et al, 2012 [6] used a hybrid method for image denoise. He concluded that the algorithm combining with Lucy-Richardson algorithm and non-local means filter algorithm achieves the better performance in de-noising and raising image resolution.

3. REVIEW OF BACKEND

3.1 Proposed System Model

Proposed System Model work as, a high quality image is taken and some known noise is added to it. This would be given as the input to the denoising algorithm, which produces or give an image close to the original high quality image. The performance of this method is evaluated on the basis of PSNR and MSE calculated in each type of image.

Methodologies:

3.1.1 Input Image: Firstly, we take a original coloured image .

3.1.2 Noise Addition: After taking an original image, the noise is added to it. The noise model is use for adding noise in the coloured input image.

Let *a* be the probability of the impulse noise corruption of the color image. Since a color image has three vector components, each component is being corrupted with a respective corruption probability. Let ar , ag and ab be the probabilities of impulse noise corruption of the three components respectively.

$$Y=\left\{\begin{array}{l} x \text{ with probability } 1-a \\ \{nr, xg, xb\} \text{ with probability } a.ar \\ \{xr, ng, xb\} \text{ with probability } a.ag \\ \{xr, xg, nb\} \text{ with probability } a.ab \\ \{nr, ng, nb\} \text{ with probability } [1-(ar, ag, ab)].a \end{array}\right\}$$

X={xr, xg, xb} and Y= {yr, yg, yb} represents the original and the corrupted vector pixels respectively. And the impulsive noise is represented by the random vector n={nr,ng,nb} which can be a vector of 0 or 255 or both.

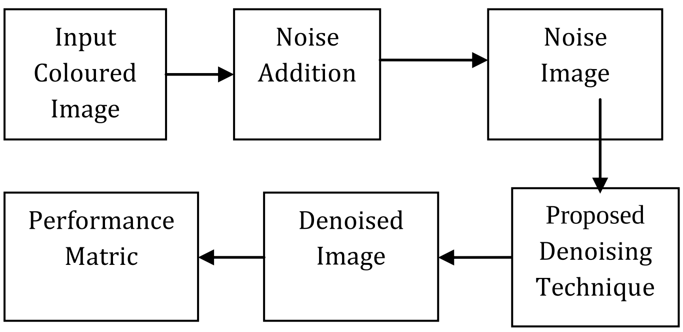


Fig- 1: Proposed System Model

3.1.3 Noise Image: After adding a noise we will get the noised image.

3.1.4 Proposed Denoising Technique: After getting a noised image, we use proposed denoising technique i.e. direction based fuzzy filtering technique is used.

3.1.5 Denoised Image: After applying this proposed technique we will get the denoised image.

3.1.6 Performance Matric: After getting denoised image, performance matric i.e. PSNR, MSE is calculated.

3.2 Proposed System Algorithm:

3.2.1 Direction:

Proposed technique considers the directional statistics. In proposed detector, assume that X represents two dimensional image contaminated with impulse noise. A sub-image of size (2M + 1) × (2M + 1) is considered around a central pixel X(i,j) and directional indices are computed in the first step. Directional indices of the considered sub-image are computed using the difference between the central pixel and its neighbors aligned in four main directions using the convolution masks d_1 ,d_2 , d_3 , d_4 as shown in fig.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -4 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & -4 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

(d_1) (d_2)

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & -4 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -4 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

(d_3) (d_4)

Fig- 2: Directional Kernels

$$d_l = 1/4 \sum_{s<-N_l} \left| s - X_{i,j} \right| , \; l=1,2,3,4 \qquad (1)$$

Where N_l , l = 1,2,3,4, denote 16 neighboring pixels aligned in horizontal, vertical and two diagonal directions without including the pixel $X_{i,j}$ at central location.

3.2.2 Calculate mean deviation:

Mean deviation of the neighboring pixels from the middle pixel is computed in a predefined neighborhood of size (2M + 1) × (2M + 1), using the following equation:

M_d (i,j) = $\sum_{i=-M}^{M}\sum_{m=-M}^{m}|X(i+l,j+m)-X(i,j)|/2(M+1)^{2}$-1 ,

k $\geq$ 1 (2)

Pixels that are corrupted and edge pixels usually result in large M_d (i,j) values.

3.2.3 Calculate fuzzy membership function larger and smaller:

Two trapezoidal shaped fuzzy membership functions namely LARGER and SMALLER are used in the proposed fuzzy inference system as shown in fig. Parameters [a,b] for the construction of these fuzzy functions are computed using the following equations:

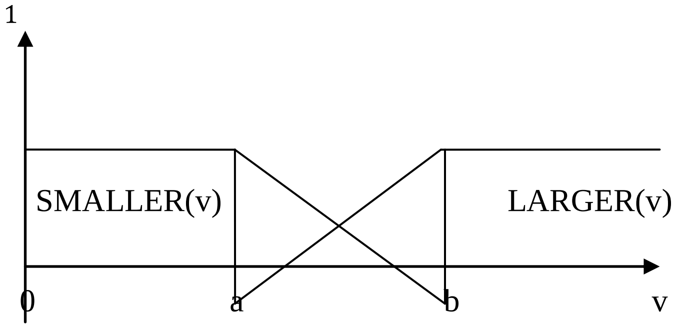


Fig- 3: Fuzzy membership functions Larger(v) and Smaller(v).

a(i,j) = $MIN_{i,m<-\{-k,-----,k\}}[M_d$(i+l)(j+m)] (3)

b(i,j) = a(i ,j) + 0.2*a(i ,j) (4)

where, (i,j) corresponds to minimum of M_d (i,j) in window of size (2K + 1) × (2K + 1), and b(i, j) is dependent on a(i,j).

Using fuzzy membership functions constructed above and directional indices as linguistic variables, the original fuzzy rule based system consists of 16 rules. However, in order to reduce computational overhead, we have reduced the rule set to five. The set of five fuzzy rules is as follows:

Rule-1 : R1 = LARGER(a^1)(a,b) × LARGER(a^2)(a,b) × LARGER(a^3)(a,b)×LARGER(a^4)(a,b) (5)

Rule-2 : R1 = SMALLER(a^1)(a,b) × LARGER(a^2)(a,b) × LARGER(a^3)(a,b)×LARGER(a^4)(a,b) (6)

Rule-3 : R1 = SMALLER(a^1)(a,b) × SMALLER(a^2)(a,b) × LARGER(a^3)(a,b)×LARGER(a^4)(a,b) (7)

Rule-4 : R1 = SMALLER(a^1)(a,b) × SMALLER(a^2)(a,b) × SMALLER(a^3)(a,b)×LARGER(a^4)(a,b) (8)

Rule-5 : R1 = SMALLER(a^1)(a,b) × SMALLER(a^2)(a,b) × SMALLER(a^3)(a,b)×SMALLER(a^4)(a,b) (9)

where membership functions LARGER and SMALLER can be expressed mathematically as given below:

$$\text{LARGER}(v) = \begin{cases} 0 & v < a \\ \frac{v-a}{b-a} & a \le v < b \\ 1 & v \ge b \end{cases} \quad (10)$$

$$\text{SMALLER}(v) = \begin{cases} 1 & v < a \\ \frac{v-b}{a-b} & a \le v < b \\ 0 & v \ge b \end{cases} \quad (11)$$

The whole process of noise detection is carried out for each pixel of the input image and a noise map is estimated.

3.2.4 Calculate Noise Map(N_{map}):

The whole process of noise detection is carried out for each pixel of the input image and a noise map is estimated. For this purpose, noise map (N_{map}) equal to the size of the input image X is created which maintains the class labels of the corresponding pixel in input image as computed by the fuzzy inference system. These classes are represented by the labels 1, 0 and 2 respectively in the noise map. The procedure for the construction of noise map using fuzzy inference system is given below:

If maximum of R1, R2, R3, R4 and R5 is equal to R1 then

N_{map} (i, j) = 1

Else if maximum of R1, R2, R3, R4 and R5 is equal to R2 or R5 then

N_{map}(i, j) = 0

Else

N_{map} (i, j) = 2

3.2.5 Noise Filtering Process:

Construction of noise map leads us to noise filtering process. We use class labels in noise map. The Class label = 1 indicates that the pixel is noisy in smooth region. However, class label = 2 indicates that the pixel lies in image regions having textural and detailed information and they need special treatment while removing the noisy component so that distortion of significant image details can be avoided. For this purpose, the proposed filtering technique is used.

Let $X_{i,j}$ is the pixel under consideration, then the noise map (N_{map}) can be used effectively in thenoise filtering process using the following procedure.

If N_{map} (i, j) = 1 then

$$Y_{i,j} = \underset{x<-\Xi}{MED}\{x\}$$

Else if $N_{map}(i, j)$ = 0 then

$$Y_{i,j} = X_{i,j}$$

Else

$Y_{i,j}$ =

$$\begin{cases} \underset{x<-s\Gamma(D^1)}{MED} (X_{i,j}, x), & if\ |d^1 - d^2| \geq |d^3 - d^4| \\ \underset{x<-s\Gamma(D^4)}{MED} (X_{i,j}, x), & if\ |d^1 - d^2| < |d^3 - d^4| \end{cases}$$

Where, $Y_{i,j}$ is restored pixel, $\Gamma(d^1)$ and $\Gamma(d^4)$ are the directions of an edge.

3.3 System Parameters:

3.3.1 PSNR(Peak Signal to Noise Ratio)

$$PSNR = 10\log\frac{255^2}{MSE} \quad (1)$$

3.3.2 MSE(Mean Square Error)

$$MSE = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(\delta(i, j))^2 \quad (2)$$

Where,

$$\delta(i, j) = [a(i, j) - \hat{a}(i, j)]$$

(i,j) is the current pixel position; $a(i, j)$ and $\hat{a}(i, j)$ are the original image and the distorted image respectively, and M and N are the height and width of the image.

So, there are two system parameters that we are used for image denoise.

4. EXPERIMENTAL RESULT

In this experiment result we discuss about the improvement in image denoising. A direction based Fuzzy filtering method has proposed for removal of impulsive noise from an image. The effectiveness of this approach has been justified with various standard and real images of both gray scale and colour ones. We work on the colour images. The colour image contains more information than the gray scale ones, as it has three colour channels (Red, Green and Blue).The performance of our method is tested with various corrupted images at different noise levels i.e. 10% and 20% noise levels. This filtering gives more better results. The 20% corrupted images gives results as shown in fig.

(4a)

(4b)

Fig-4: Snapshots of existing work 4(a) and proposed work 4(b) of onion image.

This figure describes as, we take test image of onion as an input, 20% noise is added to the image and we get the enhanced image.

Table-1: Comparison between base, noisy and proposed image

	20% noise	
Noisy Image	Base Image	Proposed Image
		
PSNR,MSE	PSNR: 25.4634 MSE: 185.2110	PSNR: 80.2546 MSE: 16.9694

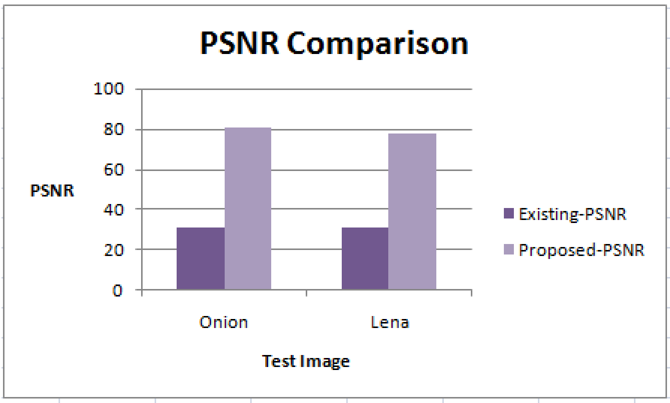
In this table, we show the comparison between noisy image, base image, proposed image. The PSNR,MSE are also given in this table.

Table -2: Representation of mean squared error and peak signal-to-noise ratio values of existing and proposed work.

Test Image	Existing-MSE	Proposed-MSE	Existing-PSNR	Proposed-PSNR
Onion	185.211	6.24E-04	25.4634	80.2546
Lena	148.6771	0.0011	26.4147	77.8386

This table gives a representation of mean squared error and peak signal-to-noise ratio values of existing and proposed work.

Graph -1: Representation of peak signal-to-noise ratio of existing and proposed work of test images of onion and lena.



The graph shows the peak signal-to-noise ratio of existing and proposed work of test images of onion and lena.

5. CONCLUSION

A novel approach called directional based fuzzy filtering is proposed for noise removal that works well for different types of noise levels. It gives result of noise removal and detail preservation especially for images degraded with medium and high noise rates. It gives more better results than simple fuzzy filtering. This method not only gives better speed but Performance metric is also very good i.e. PSNR is more than simple base image and MSE is less than simple base image which is very good for better image quality.

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