Fuzzy Based Denoising Technique To Remove Random-Valued Impulse Noise For Color Images

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Abstract-*Noise filtering in presence of important image detail information is considered as challenging task in imaging applications. Use of fuzzy logic based techniques is capturing more focus since last decade to deal with these challenges. In order to tackle conflicting issues of noise smoothing and detail preservation, this paper presents a novel approach using fuzzy inference system for random valued impulse noise detection and removal. The method is presented in which the noise detection based upon the entropy of the pixels and then the detected noisy pixel is replaced with the output of the fuzzy weighted filter. Simulation results show that this method outperform many other existing non-linear techniques in terms of noise reduction and fine detail preservation and also performs well in lower and higher noise ratios.*

Keywords-Entropy, Fuzzy, Impulse noise.

I. INTRODUCTION

Image restoration is a science that deals with the images degraded with blur, noise or both. Digital images are often corrupted by impulse noise during the acquisition, storage or trans-mission through communication channels.In this process, some pixel intensities are inevitably distorted while others remain noise-free. The altered pixel intensities do not reveal compatibility with their local neighborhood and if the input image is noisy then sub-sequent image processes such as segmentation and edge detection as well as object tracking in an image/video may perform poorly. Thus noise reduction is an important technology in image analysis. Therefore, image Denoising Techniques are necessary to prevent this type of corruption from digital images.

Noise can also be introduced by transmission errors and compression. Different noise sources like dark current noise usually present due to thermally generated electrons at sensor sites. Shot noise which follows a Poisson distribution, is due to the quantum uncertainty in photoeectron generation. Amplifier noise and quantisation noise arises when number of electrons convert into pixel intensities. Speckle noise is considered as multiplicative noise. It is a granular noise that degrades the quality of images obtained by active image devices such as active radar and synthetic aperture radar(SAR) images. 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 corrupted pixel and then to correct them with the original pixel of the image.The median filter is the most popular choice in removing the impulse Noises from the images because of its effectiveness and high computational complexity. However, when the median filtering is carried out for every pixel across the image, it modifies both noisy and noise-free pixels.

II. RELATED WORK

Kh. M. Singh et al[1] An adaptive switching approach has been presented in which the detection of noise is based on entropy of the pixels. Then the detected noisy pixels are replaced with the output of a fuzzy weighted filter. With a little increase in computational complexity over the basic vector median filter and its varieties, this technique works well both in lower and higher noise ratios. This technique can also be extended for images corrupted with Gaussian noise and mixed Gaussian and Impulse noise.

Simulation results show that this method outperforms many other existing non linear filters in terms of noise reduction and fine details preservation.

T.K et al[2]Proposed a new approach for impulsive noise removal from images. In other words, we can say to suppress noise from the corrupted images. It uses the sparsity of natural images when they are expanded by mean of a good learned dictionary. Before giving a brief introduction about this method, we must know what sparse or sparsity actually means sparsity refers to scattering. The zeroes in the sparse domain give us an idea to reconstruct the pixels that are corrupted by random-valued impulse noise. Actually this idea came from the reality that noisy image in sparse domain of the original image will not have a sparse representation as much as original image sparsity.

Pankaj Kr. Saet al[3]Various efforts has been made for highly corrupted images. A new method is proposed i.e. MWB(Modified Weighted based)filter which is based upon the weighted difference with its current pixel and its neighbors aligned with four main directions. This filter makes full use of the impulse to detect and restore noise.

Simulations showed that this filter provides optimal performances of suppressing impulse with high noise level which may enhance the performance.

A.S.Awad et al[4]A new filtering scheme has been presented based on the contrast enhancement within the filtering window for removal of random-valued impulse noise. The application of the non-linear function for increasing the difference between noisy pixel and a noiseless one results in efficient detection of noisy pixels.As the performance of the filtering system, in general, depends upon the number of iterations used. So, the detection of the noisy pixels depends upon the iterative applications of a non-linear function that progressively increases the gray scale level between noisy and noiseless pixels. The performance of the proposed scheme has been compared with many existing noise detection techniques. The experimental results exhibit significant performance or better efficiency over several other techniques.

M.E.Yuksel et al[5]A two stage image filtering scheme has been proposed using neuro-fuzzy impulse detector. In the first stage, adaptive neuro-fuzzy system(ANFIS) based impulse noise detector is used to locate the noisy pixels while in the second stage, improved vector median filter is used to provide the correct value of the corrupted pixel. The filtering stage changes the pixels in the image when found corrupted by the noise. Simulation results indicate that the proposed scheme performs much better than other variants of vector median filter. For quantitative measurements PSNR peak signal to noise ratio is used for error in luminance values and normalized color difference(NCD)is used to measure the error in chrominance values of the image.

M.Habib et al[6] This method based upon four most similar neighbors(MSN) which considers all the pixels of the sliding window except the central pixel after taking the first order absolute differences from the central pixel. This approach is a two step process-noise detection followed by filtering. Noise detection is relied on fuzzy interference system, fuzzy rules, adaptive threshold while restoration is based on fuzzy based median filter.

Tzu-Chao Lin et al[7] A fuzzy preservation-based total variation filter(FPTV) has been proposed for removal of random-valued impulse noise. In this denoising scheme, adaptive centre weighted median filter(ACWMF)is used to employ the variable window sized technique to improve its detection ability especially in highly corrupted images. The filter(ACWMF) not only checks whether a pixel is noisy or not but it also renders the confidence coefficient(CF)for each pixel to check its potential to be an impulse Then a function is designed with noise level p and CF as its arguments to determine pixel-wise the trade off between smoothness term and the data fidelity term in total variation energy functional. After minimising the energy functional, we obtain the restored image.

Simulation results showed that it outperformed some representative algorithms, both in vision and quantitative measurements like peak signal-to-noise ratio(PSNR) and mean absolute error(MAE).

III. PROPOSED WORK

Noise model:

Noise is the undesirable element produced in the image During image transmission, several factors are responsible for introducing noise in the image. Depending on e type of disturbance, the noise can affect the image to different extent. Generally researchers keep focus on to remove certain kind of noise. Therefore researchers identify certain kind of noise and apply different algorithms to eliminate the noise. Image noise can be categorised as Impulse noise (Salt-and-pepper noise),Amplifier noise(Gaussian noise),Shot noise, Quantization noise(uniform noise),Film grain, on-isotopic noise, Multiplicative noise(Speckle noise) and Periodic noise.

Noise tells unwanted information in digital images. Noise produces undesirable effects such as artefacts, unrealistic edges, unseen lines, corners, blurred objects and disturbs background scenes. To diminish these undesirable effects, prior knowledge of noise models is required for further processing. Digital noise may arise from various kinds of sources such as Charge Coupled Device(CCD) and Complementary Metal Oxide Semiconductor (CMOS) sensors. In some sense, points spreading function(PSF) and modulation transfer function (MTF) have been used for timely, complete and quantitative analysis of Noise models. Probability density function (PDF) is also used to design and characterise the noise models. 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 a to the base R,a to the base G and a to the base B be the probabilities of the impulse Noise corruption of the three components respectively.

y= x with probability 1-a

{n to the base R,x to the base G,x to the base B} with probability a.a to the base R

{x to the base R,n to the base G,x to the base B}with probability a.a to the base G

{x to the base R,x to the base G,n to the base B} with probability a.a to the base B

{n to the base R,n to the base G,n to the base B} with probability [1-(a to the base R,a to the base G,a to the base B)].a

x={x to the base R,x to the base G,x to the base B} and **y**={y to the base R,y to the base G,y to the base B} represents the original and the corrupted vector pixels respectively.And the impulsive Noise is represented by the random vector n={n to the baseR,n to the base G,n to the base B) which can be vector of 0 or 255 or both.

Noise or Edge Pixel detection:

The proposed impulse noise detector is based on adaptive fuzzy membership functions which are constructed using the concept of directional statistics and their mean deviations. Impulse detector constructs noise map, where corresponding pixels in the image are labeled as 0, 1 or 2 based on their classification as noise-free, noise pixel in smooth or detailed region respectively. Pixels classified as noisy in smooth or detailed regions becomes candidate for the noise filtering.

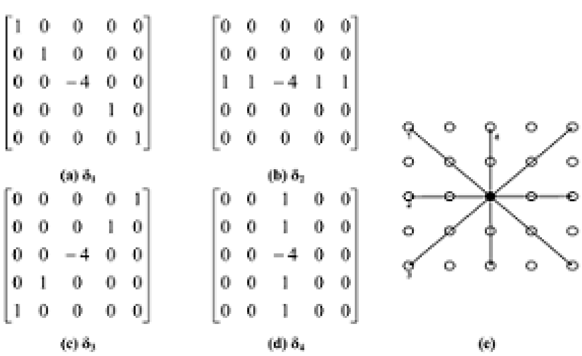

Fig. 2. (a)-(d) shows four directional kernels and (e) shows selected directions for directional indices.

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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:-

dxr(idx)=sum (s-x to the base i,j)/4, idx =1,2,3,4 -(1)

Sdir=sort(dir) -(2)

The 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 to the base d(i,j)= sum (X(i+l,j+m)-x(i,j))/(square(2M+1))-1 -(3)

l=-M to M

m=-M to M

Pixels that are corrupted and edge pixels usually result in large M to the base d(i,j) values. As edge pixels represent the detail present in the image, we can't mix them with the noisy pixels.

As directional indices, pixel aligned in certain direction will have very small ı and will always be less than $MIN_{k,l\in}\{-_{k,...,+k}\}$[M to the base $_d$(i + l, j + m)].

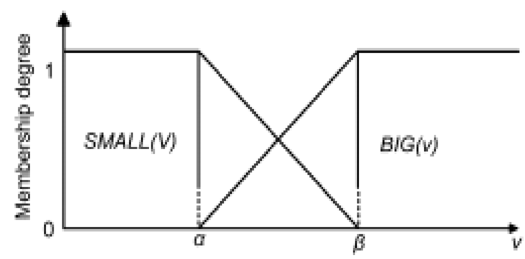


Fig. 3. Fuzzy membership functions BIG(*v*) and SMALL(*v*).

Fig. Fuzzy membership functions BIG(*v*) and SMALL(*v*).

Therefore, in order to differentiate the noisy pixels from the pixels containing detail information, mean deviation has been used for construction of adaptive fuzzy membership functions which lead to fuzzy inference system based noise detector.

Noise filtering:-

Alpha(i,j)= min(M to the base d(i+l,j+m)) -4(a)

l,m belongs to {-m to m}

Beta(i,j)=alpha(i,j)*0.2*alpha(i,j) -4(b)

The set of five fuzzy rules is as follows:

Rule-1 : R_1= BIG(dir^1)(alpha,beta) × BIG(dir^2)(alpha,beta)×BIG(dir^3)(alpha,beta)× BIG(dir^4)(alpha,beta)

Rule-2 : R_2= SMALL(dir^1)(alpha,beta) ×BIG(dir^2)(alpha,beta)×BIG(dir^3)(alpha,beta)× BIG(dir^4(alpha,beta)

Rule-3 : $R_{3=}$SMALL(dir^1)(alpha,beta) × SMALL(dir^2)(alpha,beta)×BIG(dir^3)(alpha,beta)×BIG(dir^4)(alpha,beta)

Rule 4:R_4=SMALL(dir^1)(alpha,beta)×SMALL(dir^2)(alpha,beta)×SMALL(dir^3)(alpha,beta)× BIG(dir^4)(alpha,beta)

Rule-5 :
R_5=SMALL(dir^1)(alpha,beta)×SMALL(dir^2)(alpha,beta)×SMALL(dir^3)(alpha,beta) × SMALL(dir^4)(alpha,beta)

where membership functions BIG and SMALL can be expressed mathematically as given below:

BIG(v)= 0,v<alpha
v-alpha/beta-alpha, alpha< or =v<beta
1,v> or =beta

SMALL(v)= 1,v< alpha
v-beta/beta-alpha, alpha< or =v<beta
0, v> or = beta

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 cre-ated which maintains the class labels of the corresponding pixel in input image as computed by the fuzzy inference system. Pixels are classified into three main classes namely: noise in smooth region, noise-free smooth or edge pixel and noise in detailed region. 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 R_1 , R_2 , R_3 , R_4 and R_5 is equal to R_1 then
$_{Nmap}$(i, j)=1

Else if maximum of R_1 , R_2 , R_3 , R_4 and R_5 is equal to R_2 or R_5 then
$_{Nmap}$(i, j)=0

Else
$_{Nmap}$(i, j)= 2

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

If Nmap(i, j)=1, then
y(i, j)= MED{x}
X€W

Else if Nmap(i, j)=0,then
y(i, j)=x(i, j)

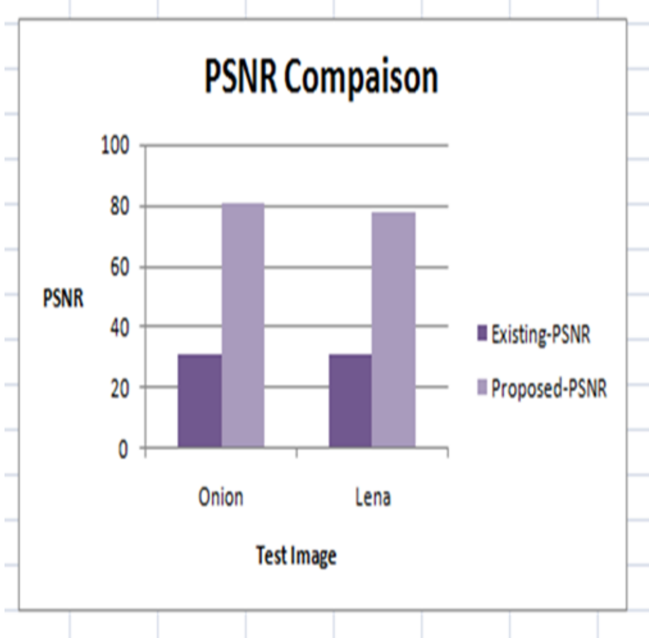
Else
y(i, j)= MED(xi,j,x) , if |dir^1-dir^2|> or equal to |dir^3-dir^4|
x£S tou(D^1)
MED(xi,j,x), if |dir^1-dir^2|<|dir^3-dir^4|
x£S tou(D^4)

IV. EXPERIMENT

System details:

System Name: Dell Inspiron 15R
Operating System: Windows 8.1
Processor: Intel(R) Core(TM)i5 CPU@ 1.80GHz
RAM: 4 GB
ROM: 1 TB
System Type: 64-bit Operating System

Graph 1:
The graph shows the peak signal-to-noise ratio of existing and proposed work of test images of onion and lena.



Snapshots of existing work 3(a) and proposed work 3(b) of onion image:

Test image of onion is shown: an input,10% noise is added to the image and the enhanced image.

3(a)

3(b)

The following table gives a representation of mean squared error and peak signal-to-noise ratio values of existing and proposed work for the given test images.

Test Image	Existing-MSE	Proposed-MSE	Existing-PSNR	Proposed-PSNR
Onion	52.734	6.24E-04	30.9205	80.2546
Lena	52.4237	0.0011	30.9656	77.8386

Table 1.

V. RESULTS AND DISCUSSIONS

The proposed work is compared with the existing work as seen in Table 1. We have given more emphasis on the signal content of the filtered image which is technically given by PSNR.The table showed that the proposed minimum square error(MSE) and power signal-to-noise ratio(PSNR) have better values than that of existed work where adaptive switching used.These switching filters use certain noise detection algorithms to identify the noisy pixels and tends to restore the original find details of the image. But if seen more precisely, even most of these switching filters are uneven in nature meaning that, they are good in lesser noise ratio but tends to work inefficiently in higher noise ratio. The proposed filter, Modified vector median filter might not give the highest PSNR at lower noise ratio, 10% is considered, though very close, but it is clearly seen that it even outperformed the switching method at higher noise ratio. This fact can be seen from the Table 1,Fig.3 showing the performance results of both works i.e.measured results are highlighted. The images of Onion, of existing are compared with the proposed one are shown in Figures 3(a) and 3(b).Images of the Figure 3(b) using the proposed filter, which has high signal content but a little blurry, which is because the noisy pixels are replaced by the mean of the fuzzy weighted pixels.

VI. CONCLUSION AND FUTURE WORK

In this paper, Vector Median filter, for random-valued impulsive noise removal that works well both in lower and higher noise ratio is introduced.The filter not only preserves the image's details efficiently but also maintains the chromaticity of the color image very well.Future work includes efficiency of the image can be improved further and Blurred nature of the image can be removed.

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