Noise Analysis and Removal Using Fuzzy Mean Filter with Triangular Membership Function

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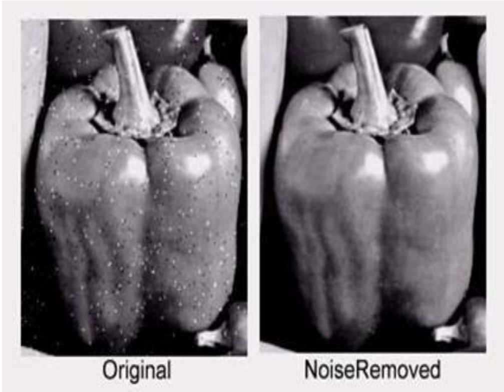
Abstract: ***In digital Image Processing, removal of noise is a highly demanded area of research. Impulsive noise is common in images which arise at the time of image acquisition or transmission of images. A lot of research works have been done on the restoration of images corrupted by impulse noise. However, due to some limitations of the filters under different conditions the edge preservable efficiency is less. In this paper, we propose an image filtering technique by using Fuzzy mean filter based on fuzzy entropy given by triangular membership function to remove impulse noise of corrupted images. The proposed method is based on noise detection, noise removal and edge preservation modules. The proposed algorithm is capable to reconstruct 90% of the damaged image. The results will be evaluated with various parameters such as PSNR, SSIM, NAE, NCC and SCC so that we can ensure about the quality of services and Fuzzy Mean Filter for Immense Impulse Noise Removal (FMIINR) proves to be very robust at immense noise level. The main advantage of the proposed technique over the other filtering techniques is its superior noise removal as well as features of image preserving capability.***

Keywords: Impulse Noise, Fuzzy mean filter, Triangular Membership function, fuzzy entropy

1.Introduction

Image denoising [1, 2] is the process of removing the noise from the digital images using some prior knowledge about the noise while retaining as much as possible important image features. A digital image is a representation of a two-dimensional image as a finite set of digital values called picture elements or pixels. The aim of digital image processing is to improve the potential information for human interpretation and processing image for storage transmission and representation for autonomous machine perception. Digital images are often corrupted by impulse noise in transmission error, malfunctioning of pixel elements in the camera, sensor's faulty memory locations, and timing error in the Analog to Digital conversion. The different types of noise occur during image processing and they affect the image and degrade the quality of the image. Image deploring and image denoising are the two sub areas of image restoration. The median filter was once the most popular non- linear filtering technique for removing impulse noise, because of its good denoising power band computational efficiency. However, the noise level over 60% some details and edges of the original image are smeared by the filter.The median filter is a nonlinear operator that arranges the pixels in a local window according to the size of their intensity values and replaces the value of the pixel in the result image by the middle value in this order. Enhancement of an image is one of the key steps in digital image processing. Noise filtering is used to filter the unnecessary information from an image. It is also used to remove various types of noises from the images.

Mostly this feature is interactive. Various filters like low pass, high pass, mean, median etc., are available. Fuzzy logic [3] provides way to detect the removal of noise. Fuzzy logic provides the fuzziness of the membership. Fuzzy entropy is the main measure to determine the fuzziness. Triangular membership function is one of the most used fuzzy membership functions.



(a) **(b)**

Figure 1.1: a) Noisy and b) Denoised Images

1.1 Fuzzy logic

Fuzzy provides a method to transact the fuzziness and randomness. The commonly used method of uncertainty reasoning is based on fuzzy set theory. The basis of fuzzy set theory is the membership function. The membership function is a one-point to one-point mapping from a space U to the unit interval [0, 1]. After the mapping, the uncertainty of an element belonging to the fuzzy concept becomes certain to the degree represented by a precise number The uncertain characteristics of the original concept are not passed on to the next step of processing at all. This is the intrinsic shortcoming of the fuzzy set theory.Fuzzy image processing[4] is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected Fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages: image Fuzzification, modification of membership values, and if necessary, image Defuzzification as shown in Figure1.2.The Fuzzification and Defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values). After the image data are transformed from gray- level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. Fuzzy logic is applied in many cases like Fuzzy Color Credibility Approach to Color Image Filtering, Vision Intelligence for Farming Using Fuzzy Logic Optimized Genetic Algorithm and Artificial Neural Network etc...

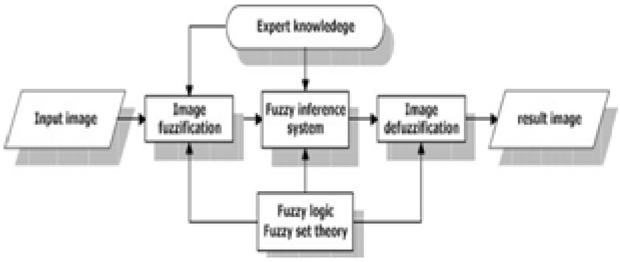


Figure 1.2: The general structure of Fuzzy image processing

1.2 Fuzzy Entropy

Fuzziness is one of the universal attributes of human thinking and objective things. Fuzzy set theory is one of the efficient means of researching and processing fuzzy phenomena in real world. It is the fuzzy sets that may describe fuzzy objects effectively so that fuzzy sets play more and more important functions in system modeling and system design. Therefore, the quantitative analysis of fuzziness in a fuzzy set is an important problem. Entropy is an important concept in Shannon information, in which entropy is a kind of measurement for describing the degree of no restrain of stochastic vectors. Fuzzy set theory makes use of entropy to measure the degree of fuzziness in a fuzzy set, which is called fuzzy entropy and thus has especial important position in fuzzy systems, such as fuzzy pattern recognition systems, fuzzy neural network systems, fuzzy knowledgebase systems, fuzzy decision-making systems, fuzzy control systems and fuzzy management information systems. In this paper, a novel filter with fuzzy entropy for impulse noise detection and removal has been proposed. It represents the uncertainties of the noise perfectly by using the fuzzy entropy, which is helpful in detecting and removing the noise.

2.Literature Survey

In this digital era one of the emerging fields of image processing is removal of noise from a contaminated image. Many researchers have suggested a large number of algorithms and compared their results. The main thrust on all such algorithms is to remove impulsive noise while preserving image details. Some schemes utilize detection of impulsive noise followed by filtering where as others filter all the pixels irrespective of corruption. An important non-linear filter that will preserve the edges and remove impulse noise is standard median filter. But if the noise density increases the median filter does not work well. Specialized median filters such as centre weighted median filter, weighted median filter, progressive switching median filter, and adaptive median filter remove low to medium density fixed value impulse noise but fail to preserve edges if noise density increases. K. S. Srinivasan and D. Ebenezer [5] proposed Decision Based Algorithm (DBA) in which pixel is processed only when its value is either 0 or 255 or else left unchanged. Even these method uses median as its tool. But in case the output of median will be 0 or 255 which is noisy. In such case, neighbouring pixel is used for replacement. Switching median filter proposed by H. L Engand and K. K. Ma [6] uses pre-defined threshold value for recovering corrupted image. The major drawback of this method is defining threshold value. Also, these method yields unsatisfactory results in preserving edge details at high noise densities. Modified Non-linear filter yields better results at very high noise density that is at 80% and 90% and gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF) values than the MDBUTMF and existing algorithms. To avoid this drawback, open close sequence filter has been proposed by Deng Ze Feng, Yin Zhou Ping and Xiong You Lou [7]. To overcome the disadvantages of the mentioned filtering techniques a two-stage algorithm has been proposed by R. H. Chan, to Solve the problem. C.W. Ho and M. Nikolova [8]. In this algorithm adaptive median filter is used in first stage to classify the values of the noisy and noise free pixels. In second stage regularization technique is used for noisy pixels to preserve the details and edges as much as possible. Images often corrupted by various noises during the process of generation and transmission. Mostly Images are corrupted by impulse noise. T.A. Nodes and N.C. Gallagher [9], Jr identified two types of impulses noise, they are salt and pepper noise and random valued noise. The salt and pepper noise corrupted pixels of image take either maximum or minimum pixel value. Several filters have been proposed for recovering images corrupted by impulse noise. Among these standard median filters is reliable and easy to implement. However, the major drawback of Median filter (MF) is that it works effectively only at low noise densities. At high noise densities image cannot be recovered and edge details of original image are not preserved. J. Astola and P. Kuosmaneen [10] proposed by Adaptive Median Filter (AMF) yields better results than median filter at low noise densities. Abreu.E et al [11] discussed A new framework for removing impulse noise from images in which the nature of the filtering operation is conditioned on a state variable defined as the output of a classifier that operates on the differences between the input pixel and the remaining rank-ordered pixels in a sliding window. This survey provided help to select and implement the better technique to remove impulse noise by preserving most of the important information of an image.

3.Existing System

Image restoration is imperative for successive tasks (e.g., edge detection, image segmentation, classification, parameter estimation, etc.) which are basically affected by the quality of the image. Capturing devices has become sensitive to the acquaintance of impulse noise due to more sensing elements per unit space are integrated on a single chip. To overcome this, digital camera manufacturing companies rely on restoration methods to enhance the visual quality of the image acquired. As a result, a number of methods have been proposed for the removal of impulse

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noise. Non-linear filters are superior to linear filter with their great execution to restoring the image from impulse noise, for instance, the median filter, could be a natural selection for suppressing impulse noise. The idea of a median filter is to replace the window pixel given by the median of the brightness in the window. The Median filter gives the better results at low noise levels (<10%) but it alters the image pixels even though it is not corrupted, this led to bad result at high noise levels (>10%), the key image details are also decorated. This problem has led to the development of various classes of filters, such as the weighted median-filters, adaptive filters and rank-ordered statistics, switching median filter and soft computing filters. By adapting these non-linear filters, the restoration quality significantly increases but the implementation and time complexity is multiplied and hardware cost also increases. The experimental results show the FEIND filter [12] is the good among the tested filters, compared with the traditional switching filters. No matter whether, in noise detection, the image details preservation or computational complexity, the FEIND filter makes a good improvement and has the higher performances. Even if the noise level closes to 90%, the texture, the details, and the edges of the images restored by the FEIND filter are preserved with good visual effectbut FEIND is not giving the positive results for low impulse noise levels below the 30 % we will address this problem in the proposed part of this paper. In this paper, we propose a new filtering mechanism for high impulse noise removal with less computational cost using fuzzy entropy. The proposed technique restored the digital image with less computational time and it simultaneously maintaining edge information compare with different existing filters.

3.1 Impulse Noise Detection Method Using Fuzzy Entropy Measure

A greater difference of the values among the evaluation pixels results in a higher fuzzy entropy and pixel values which are similar in the window results in lower fuzzy entropy. Using this underlying idea the pixels can be classified as corrupted or uncorrupted. To identify given pixel in the window of interest (WoI) is impulsive [13] or not, calculate the fuzzy entropy of processing pixel in the WoI and check whether the fuzzy entropy of pixel is greater than the given alpha cut value. If it is greater than the given alpha cut value then it is impulsive and submitted to correction phase.

Algorithm:

For every pixel P(i, j) image do
1) Get region R for image pixel pi, j by taking M=4; P_(i, j)^M={P_(i+a, j+b)│-M?a, b?M}
2) Calculate the Standard Deviation of the Region p
3) Calculate the fuzzy membership of the processing pixel pi, j, i.e.,

$$\mu(pi,j) = e^{-\left(p_{(i,j)}-p\right)2/2\sigma^2}$$

4) Calculate the fuzzy entropy of the processing pixel pi, j, i.e.,

$$E(\boldsymbol{\mu}(\boldsymbol{P}_{i,j}))=\boldsymbol{\mu}(\boldsymbol{P}_{i,j})\log2\boldsymbol{\mu}(\boldsymbol{P}_{i,j})\boldsymbol{\mu}(\boldsymbol{P}_{i,j})\log2(1-(\boldsymbol{P}_{i,j})),\ 0\leq\boldsymbol{\mu}(\boldsymbol{P}_{i,j})\leq\mathbf{1}$$

5) If E(μ(pi, j))<T then fuzzy weights of uncorrupted pixel is

$wi = \mu(pi,j)$ =e^(-(p((i, j)- p)^2/2σ^2)

6) Compute the fuzzy weighted mean of uncorrupted pixel, i.e.,

$$y_{i,\,j}=\sum_{i=1}^{n} p_{\,i*}\,\mu^{(p_i)}$$

where n= number of un-corrupted pixels in the region of interest.

The results of this study were shown in the below fig. 3.1, 3.2 & 3.3. The experimental results show the FEIND filter is the good among the tested filters, compared with the traditional switching filters. No matter whether, in noise detection, the image details preservation or computational complexity, the FEIND filter makes a good improvement and has the higher performances. Even if the noise level closes to 90%, the texture, the details, and the edges of the images restored by the FEIND filter are preserved with good visual effect. However FEIND is not giving the positive results for low impulse noise levels below the 30 % we will address this problem in proposed system of this paper.

Figure 3.1: Denoising corrupted image "Lena, " with 30% impulse noise density. (a) DBA (b) MDBUTMF (c) AMF (d) NAFSM (e) BDND (f) CM and (g) FEIND

Figure 3.2: Denoising corrupted image "Lena, " with 60% impulse noise density (a) DBA (b) MDBUTMF (c) AMF (d) NAFSM (e) BDND (f) CM and (g) FEIND

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Figure 3.3: Denoising corrupted image "Lena, " with 80% impulse noise density (a) DBA (b) MDBUTMF (c) AMF (d) NAFSM (e) BDND (f) CMand (g) FEIND

4.Proposed System

In the proposed system fuzzy mean filter (FMIINR) is considered for impulse noise removing. The design of filter comprises of two phases. One is detection of damaged pixels and second is its reconstruction. For the detection, we have used fuzzy triangular membership function and classic mean filter for reconstruction. The proposed algorithm is capable to reconstruct 90% damaged image. The results will be evaluated with various parameters PSNR, SSIM, NAE, NCC and SCC so that we can ensure about the quality of services and FMIINR proves to be very robust at immense noise level.

This proposed algorithm comprised of two phases:

a) Finding undamaged pixel
b) Algorithm for the reconstruction of noisy pixels.

We focus on image consistency for finding the damage area of the image-on-image. Damaged area of image contains high inconsistency corresponding to the surrounding pixel, with this approach we find the center location of damaged region and apply the mean filter for its reconstruction.

For every pixel at location (i, j) in the image, we take (2n +1) × (2n + 1) neighborhood region with at the center. Set of intensities of pixel in this region are called.

$$R^{M}_{ij}=\{Mi+k,\ j+l \mid -n \leq k,\ l<=n\} \qquad (1)$$

After that set of fuzzy is defined correspondence to every triangular member function

$$f(a{:}x, y, z)=\max(\min(a-x)/(y-z), (z-a)/(z-y)), 0) \qquad (2)$$

The key stages of our algorithm are as follows:

Define Parameters: The image de-noising can only be performed using minimum number of undamaged pixels in a matrix. We denoted this number as P. We are required to apply multiple iterations so that the value of minimum undamaged will get traced and at least, we obtain 90% undamaged pixel in an image. The analysis is only done in matrix form and the size of matrix is 3X3. For construction of undamaged pixels as well as finding we have used mean filter and triangular membership function.

Computation of Mean of non-damaged pixels: In this work, damaged pixels values are either 0 or 1 whereas non-damage pixels values lie between 0 and 1. By taking mean of this non-damage pixel, one can get the values of the damaged pixels easily. In this way, all the values can be calculated easily.

Triangular Membership Functions: Triangular Membership Functions [14] are specified by three parameters {x, y, z} as follows:

$$0,\ if\ a<x \qquad \frac{a-x}{y-x}\ if\ x \leq a \leq y$$

$$\text{Triangle (a:x, y, z)} = \left\{ \frac{z-a}{z-b}\ if\ y < a \leq z \right. \qquad 0 \text{ if } a>z$$

Here a is the variable which stores all the values of the parameters. The parameter x and z locate the "feet" of the triangle and the parameter y locates the peak.Triangular membership functions are easy to use and they are best to use for impulse noise removal.

If Tr (r : m, a, M) < T then the pixel is noise pixel else the pixel is image pixel. Threshold value is represented by T. Noise pixel can be obtained by using the triangular membership function and the correction term is added to the noise pixels where the image pixels are left alone so that the image can be enhanced efficiently.

Algorithm for the reconstruction of Noisy pixels

We focus on the non-damage image to find out the centre mean of the damage image.

1. Basic Method of Mean Filtering: Consider an image and its gray level pixels are stored in a 2-D arrays
2. Assume that data[0][0] contains first pixel and data [A-1][B-1] contains last pixels. When mean filter is applied over a rectangular neighborhood window, gray level of pixel data [row[col]over y * z neighborhood is calculated using replication of boundary rows and columns.

For row=0 to A-1
For Col=0 to B-1
*Sum= Sum +(y*z)*
pixel grey levels in the neighborhood centered at Data
*New data [row][col]=∑y*z*
End
End

Here new data [A] [B] is a 2-D array that contains average computing. The basic method is simple to device but it is ineffective due to pointless re-computations of additions and divisions both. The required number of additions is A*B*y*z that is the division of the value and these both are directly proportional to the image size and increase accordingly.

Main rules to follow while reconstructing the fully damaged image using Fuzzy denoising.

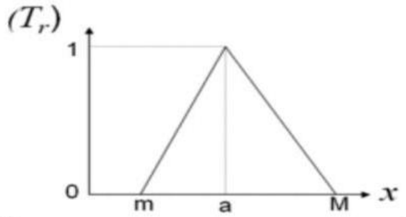

Figure 4.1: Triangular membership function membership function

Rule 1: First of all, target the matrix which is having at least 3 uncorrupted pixels starts from 3X3 matrix size and increase according to the steps. If it encounters any matrix in the entire image, it stops and reconstructs the central pixel of the image using basic Mean Filtering technique. Therefore, uncorrupted pixel is decided by fuzzy triangular membership function.

Rule 2: If Rule 1 doesn't encounter the matrix having at least 2 i.e. THRESHOLD VALUE of uncorrupted pixel then threshold of uncorrupted pixel is stepped down and one can find the matrix (according to rule 1). At this point it steps down the size of matrix as well. With the help of this approach, the centre pixel we are constructing can get better resemblance to its original value.

Rule 3: If Rule 2 gets failed we need to increase the size of the matrix to the extent that we at least find a matrix having maximum number of uncorrupted pixels and start reconstruction from this point.

5.Parameter Evolution

To analyze efficiency of more than an existing work, Peak Signal-to-Noise Ratio (PSNR), PR, SSIM, Normalize Cross Co- relation and Normalize Absolute error are taken as performance measures.

A) **PSNR: Peak Signal-to-Noise Ratio** (PSNR) is a accurate measure of image quality depends on the pixel difference between two images. PSNR is defined as

$$\text{PSNR}=10 \log \frac{s}{mse}^{2}$$

Where s = 255 for an 8-bit image. The PSNR is mainly the SNR when all pixel values are equal to the maximum possible value.

B) **Structural Similarity Index SSIM** is proposed as an improvement for UIQI. The mean structural similarity index is computed in two steps. Initially, the original and inaccurate images are categorized into b 8*8 block size and after these block are converted into vectors. Secondly two standard derivations, two means and one covariance value are computed from the images.

$$\text{SSIM}(x,y)=(2\mu^{x}\mu^{y}+C^{1})(2\sigma^{xy}+C^{2})/(\mu^{2x}+\mu^{2y}+C^{1})(\sigma^{2x}+\sigma^{2y}+C^{2})$$

C) **Normalize Absolute Error (NAE):** Opij is an output image and Oij is an original image.

Di= Output Image- Original Image

$$NAE = \sum_{i=0}^{n} D_{ij} / \sum_{i=0}^{n} O_{ij}$$

D) Normalized Cross Correlation

$$\text{NCC}=\sum O_{ij} * Op_{ij} / \sum O_{ij}^{2}$$

E) Structural Content Calculation (SCC):

$$ssc = O_{ij}^{2} / Op_{ij}^{2}$$

Table 4.1: Comparison table of restored images in PSNR (in decibels)

Image	**Noise Level**	**AM-EPR**	**FM**	**MMEM**	**CM**	**BDND**	**FMIINR**
Lena	50%	33.5	33.5	29.83	32.5	30.39	34.16
	60%	31.5	31.3	27.74	30.82	28.81	33.008
	70%	30.2	30.1	25.82	29.56	27.11	31.76
	80%	27.2	27.2	23.08	27.68	24.89	30.19

Table 4.2: Comparison of various parameters of image with different noise levels

Images	**Noise Level in %**	**PSNR**	**SSIM**	**NAE**	**NCC**	**SCC**
Lena	50	33.271	0.90381	0.02669	1.0015	0.99819
	60	31.6441	0.89376	0.02914	1.0011	0.9954
	70	30.453	0.87927	0.0421	1.0009	0.9952
	80	28.841	0.85232	0.037475	0.99988	0.9956
	90	26.991	0.79721	0.99834	0.0485914	0.99521
	97	22.761	0.68407	0.99255	0.07566	0.99585

6.Conclusions

FMIINR filter algorithm for effective removal of impulse noise is presented in this paper. This filter is able to suppress high density of impulse noise, at the same time preserving fine details, textures and edges. Extensive simulation results verify its excellent impulse detection and detail preservation abilities by attaining the highest PSNR and lowest NAE values across a wide range of noise densities.For de-noising of noisy images, few aspects are very important. First is exact estimation of noisy pixels. Second the reconstruction of damaged pixels should lie close to the original value and last is lower computation, complexity and greater efficiency along with this time complexity should be minimum. So that real time deployment of the filter makes possible. Handling all of these challenges, FMIINR excellent performance is being validated with experimental results. There are various filters which are not performing above 60% because they lost the original content of the image above this level whereas FMIINR can restore damaged pixel at 90% also.In addition, the relatively fast runtime and simplicity in implementation of the algorithm. The de-noising of filter is done with the triangular membership function and reconstruction is done by the classic mean filter. The surprising performance is being shown by the filter for 90% of damaged image. So we can say FMIINR filter can deploy for real time applications also.

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