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A New Concept of Reduction of Gaussian Noise in Images Based on Fuzzy Logic

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Abstract

Image filtering is a technique to preserve important signal elements such as edges, smoothing the details of the image to make images appear clear and sharpener. Among all the non linear concepts to suppress Gaussian noise,the fuzzy logic based approaches are important as they are cabable of reasoning with vague and uncertain informations. In this study, we present a new method for the noise reduction of images contaminated with Gaussian noise by using fuzzy image filter with the help of fuzzy rules which make use of membership functions. In this article, fuzzy derivative concept is also applied to perform fuzzy smoothing. This method provides better input for further image processing techniques and also it increases the contrast of the images, fine details and sharpening the edges as well. In this study, comparison is also made with the existing noise reduction methods by numerical measures and visual inspection.

Keywords: Gaussian Noise, image denoising, fuzzy image processing system, membership functions, fuzzy derivative

Introduction

Noise is any undesired signal that contaminates an image,which is the result of errors in the image acquisition process that result in pixel values not reflecting the true nature of the scene. During acquisition,transmission,storage and retrieval processes ,an image signal gets contaminated with noise.An image which is being sent electronically from one place to another place is contaminated by a variety of noise sources. Noise can be caused in images by random fluctuations in the image signal The main objective of the image processing is to extract clear information from the images corrupted by noise. Such technique for noise removal is called filtering or denoising. An image gets corrupted with different types of noise .Noise may be classified as SUBSTITUTIVE NOISE(impulsive noise:salt and pepper noise,random valued impulse noise,etc.) and ADDITIVE NOISE (e.g.additive white Gaussian noise)In many occasions,noise in digital images is found to be additive in nature with uniform power in the whole bandwidth with Gaussian probability distribution.such a noise is referred to as additive white Gaussian noise(AWGN).The AWGN IS mathematically represeted by,η

$$N_{AWGN}(t)= \eta_G(t)\sigma$$

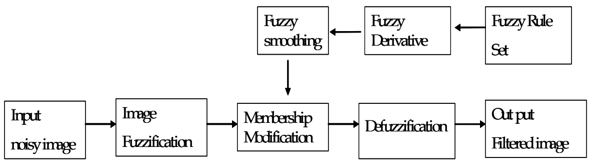
$$f_{AWGN} =f(x,y)+ \eta_{G(x,y)}----(1)$$

Where $\eta_G(t)$ is a random variable that has a Gaussian probability distribution .It is an additive niose that is charactrsed by its variance σ^2.In (1),the noisy image is represented as a sum of the original uncorrupted image and the Gaussian distributed random noise $\eta_{G.}$ When the variance of the random noise η_G is very low, $\eta_{G(x,y)}$ is zero or very close to zero at many pixel locations.Under such circumstances,the noisy image fAWGN is same or very close to the original image f(x,y) at many pixel locations(x,y). . Gaussian noise is generated during film exposure and development of the image.

In this study each pixel in the output image is computed as a function of one or several pixels in the original image, usually located near the location of the output pixel [1-2]. The best solution for noise reduction or filtering is to process the image by its individual pixels based upon the appearance of its immediate neighbour pixels [3]. Image filtering improves the quality of the image by the way of enhancement of edges of the images. So many techniques such as mean filter, median filter and some other denoising techniques have been developed to suppress Gaussian noise [4-7]. In this study, we focus on fuzzy techniques for denoising the Gaussian noise. Among all other filters, fuzzy image filter is very effective [9] and it can manage vague and uncertainty information efficiently. This article presents a new Fuzzy image filtering using fuzzy rules which make use of membership functions.

Fuzzy Image Processing Scheme

Fuzzy image processing scheme is a collection of different fuzzy approaches to image processing [8]. It has three main stages. They are (i) Image fuzzification (ii) Membership modification (iii) Image defuzzification.



Basic structure of denoising image by using Fuzzy logic Algorithm.

The Concept of a Fuzzy Processing scheme is to map the original image into the fuzzy domain, applying a fuzzy operator to the fuzzy image and defuzzification of the image to return to the original domain.

New Concept of Grouped mean fuzzy derivative filtering algorithm

In this study, we are going to deal with gray scale images. By this algorithm, the gray values of the neighbourhood pixels (nxn window) are stored in an array and then sorted in ascending or descending order. Then membership values are assigned to the neighbourhood pixels.

The neighbourhood of a central pixel (x y) in 3 x 3 window of pixels is given by

NW	N	NE
W	XY	E
SW	S	SE

Now mean value of pixel values of NW, XY, SE; N, XY, S; NE, XY, SW; W, XY, E are calculated. After finding the mean values of each group, grouped mean of all these groups is found. Now membership value ‘1’ is assigned to the pixel having the grouped mean. The membership value ‘0’ is assigned to the lowest and highest gray values. Now we consider only 2 x k + 1 pixels in the sorted pixels and they are the median gray values in the sorted list.

For example, consider a 3 x 3 window of pixels as follows:

102	124	185
107	126	190
109	119	192

Mean value of pixels
NW, XY, SE : 140

Mean value of pixels
N, XY, S : 123

Mean value of pixels
NE, XY, SW : 140

Mean value of pixels
W, XY, E : 141

Mean value of all groups : 136
Original value : 126
Median value : 124
Range value : K = 2
Sorted order: 101, 104, 109, 119, 124, 126, 185, 187, 192
Membership value: 0.0, 0.03, 0.16, 0.56, 0.76, 0.79, 0.05, 0.03, 0.00
Selected value : 126

Next stage we apply the fuzzy derivative concept for the pixel which has the highest membership value in the image and compute the fuzzy derivative for the selected pixel.

Computation of Fuzzy derivatives

Fuzzy derivative is the difference between the pixel and its neighbour in the direction D. [10] The derivative value of the central pixel (xy) denoted

∇_D (xy) is given by

$\nabla_N (xy) = I(x,y-1) - I(xy)$

$\nabla_{NW}(xy) = I(x\text{-}1, y\text{-}1) - I(x,y)$

The fuzzy rule used to compute the fuzzy derivative $\nabla_{NE} F(xy)$ for the Pixel (x,y) in the NW direction is as follows:

If (∇_{NE} (x,y) is small AND ∇_{NE} (x-1, y+1) is small) OR

(∇_{NE} (x,y) is small AND ∇_{NE} (x+1, y-1) is small) OR

(∇_{NE} (x-1, y+1) is small AND ∇_{NE} (x+1, y-1) is small)

Then $\nabla_{NE} F$ (x,y) is small

Eight such rules are applied, each computing the degree of membership of the fuzzy derivatives $\nabla_D F$ (x,y), $D \in$ dir.

A Small fuzzy derivative is caused by noise, while a large fuzzy derivative is caused by an edge in the image. In the next stage, maximum gray value pixel is subtracted with other pixel. The maximum gray value pixel is considered to be positive and other pixel is considered to be negative. Then we perform fuzzy smoothing taking these fuzzy derivatives as an input by weighting the contributions of neighbouring pixel values which make use of membership functions.

Fuzzy Smoothing

Fuzzy smoothing of the pixel can be achieved with the help of fuzzy rules for each direction of the pixel by using AND – operator and OR – operator Defuzzification of the given image is the next stage in the fuzzy smoothing. To compute the correction term ΔS for the processed pixel within the luminance component, a pair of fuzzy rules for each direction will be used. The idea behind the rules is the following:

(i) if, no edge is assumed to be present in certain direction (ii) the derivative value in that direction will be used to compute the correction term (ΔS)

(For eg) Let us consider the direction (NE).

Using the values λ_{NE}^{+} and ∇_{NE} (xy)., the following two rules are fired:

$\lambda^{+}{}_{NE}$: If ∇_{NE} F (xy) is small AND ∇_{NE} (xy) is positive then C is positive.

λ^{-} NE : If ∇_{NE} F (xy) is small AND ∇_{NE} (xy) is negative then C is negative.

Where C is the output of the rules ($\lambda^{+}{}_{NE}$) and ($\lambda^{-}{}_{NE}$).

In this article, fuzzy smoothing is performed on selected pixel values. Now convert negative pixel to positive pixel by fuzzy smoothing to provide the quality image having better enhancement of edges.

Results and Discussion

A new method of fuzzy image filtering technique using the concept of fuzzy logic is presented and implemented in this research. This proposed fuzzy filtering technique is applied to satellite lena image of dimensions 256 x 256 pixels. The effectiveness of this new method has been tested with different noisy and corrupted image after adding gaussian noise of different levels.

Fig 1 is the original satellite lena image compared with different filtering techniques and proposed filtering technique in terms of the visual quality of the image.

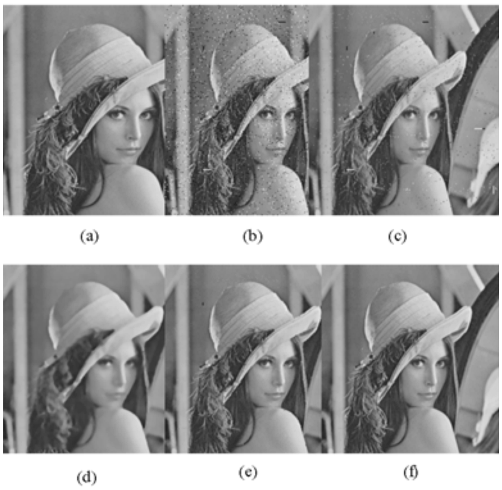


Fig. 1 The input image with additive noise and the output images with different filtering methods.

a) Original image
b) Image after adding 20% mixed Gaussian noise
c) Denoised image using mean filter
d) Denoised image using median filter.
e) Denoised image using Non Local mean method.
f) Denoised image using proposed fuzzy filter

The filter performances are usually compared in terms of PSNR,MSE and mean absolute error(MAE).These are simply mathematically defined image metrics that take care of noise power level in the whole image.Larger values of PSNR and small values of mse indicate less noise power in an image irrespective of the degradations undergone.PSNR

(Peak signal Noise Ratio) and MSE (Mean square Error) are used to test the effectiveness of the proposed algorithm with different filtering techniques.

Mean Square Error (MSE)

MSE is given by

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}[f(x,y)-f'(x,y)]^2$$

Where f(x,y) – M x N initial image

f^1 (x,y) - Noised image

Peak Signal Noise Ratio (PSNR)

PSNR is defined as

PSNR = 10 $\log_{10}$ (255^2/MSE) dB.

If PSNR value is high or MSE value is low THEN image quality is better.

Table 1: Comparison of the MSE'S of restored images between different image filtering techniques:

Filters	MSE
Mean filter (3 x 3)	382
Median filter (3 x 3)	245
Non Local Mean method	125
Proposed filtering technique	112

Conclusion

In this article, an innovative technique of denoising the Gaussian noise using the concept of grouped mean and fuzzy derivatives has been presented and implemented effectively. Fuzzy rules are applied to consider every direction around the processed pixel.It is easy and fast to implement and can suppress Gaussian noise with a varying degree of success.A numerical measure such as MSE and visual observation for Lena image show convincing results. Experimental results show the feasibility of the new filter and yield convincing results. This new proposed technique improves the quality of the image by enhancing and sharpening the edges

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