AN ENHANCEMENT OF FUZZY-BASED IMAGE DENOISING FOR GAUSSIAN NOISE

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Abstract- In the process of image acquisition and transmission, it is hard to avoid the interference of different types of noises. Image denoising is important because various kinds of images are used as source of information for interpretation and analysis in many applications. Among the various types of noise, impulse noise and Gaussian noise are the most common. Most of the existing fuzzy based filters are keen on impulse noise because Gaussian noise is difficult to distinguish local variation due to noise and due to image structure such as edge, line or curve. In this paper, fuzzy based Gaussian filter is proposed to distinguish between noises and edges. In this system, fuzzy derivatives values for eight directions within a kernel are computed to detect the target pixel is whether noise or edge using a thresholding value. For the noise pixel, the fuzzy based filtering is operated to remove Gaussian noise by using these fuzzy derivatives values, positive and negative truthiness. This filtering process is iteratively according to the remaining of the noise level. Finally, the performance of the proposed filtering technique is compared with the Non-local means filter by calculating the PSNR value.

Index Terms- fuzzy based filtering, membership function, fuzzy derivatives, fuzzy sets, derivative neighborhoods

I. INTRODUCTION

Digital images are valuable sources of information in many research and application areas including astronomy, biology, medicine, remote sensing, material science, etc. In the process of imaging and transmission, it is hard to avoid the interference of different kinds of noises. Noise decreases image quality and causes loss of information. Although there are many types of noises, impulse noise, Gaussian noise and multiplicative noise are the most common noises appeared in images. Impulse noise corrupts some portion of images and leaving the remaining pixels unchanged. Salt and pepper noise is a special case of impulse which is randomly distributed and appeared as alternative color on an image. Gaussian noise is statistical noise which obeys Gaussian distribution when a certain distribution is added to each image pixel. Speckle noise is multiplicative noise which is the image dependent. It is difficult to remove due to the intensity of noise varies with the image intensity. In many occasions, Gaussian 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). Efficient removal of Gaussian noise from image data is difficult in digital image filtering because the intensity value of the guassian noise is almost near with the intensity value of neighborhood pixels. So,it is a difficult task to distinguish noise and image structure such as edge because the denoising operator is imposed with the requirement of preserving useful information in the image while it is removing noise.

The filtered image at a given location is a function of values of the input image in a small neighborhood of the same location. Assuming that images vary slowly over space, near pixels are likely to have similar values. But this assumption fails at regions that contain edges and image details (e.g. corners, lines, end of lines etc.) Most of the classical linear filters like the averaging low pass filters tend to blur and destroy the lines, edges and other fine image details. Hence, to remove more noise without disturbing on image structure, fuzzy based filtering techniques are being researched in not very soon. These fuzzy techniques are not only eliminating noises but also more detail in image structures. The proposed method of the paper is one of the fuzzy based filtering techniques. The proposed paper is composed with five sections. Section II reviews the related fuzzy filters for the noise. Our algorithm is presented in Section III. The experimental results and comparisons are provided in Section IV and Section V concludes the paper.

II. RELATED FUZZY BASED IMAGE FILTERING FOR GAUSSIAN NOISE

Several fuzzy filters for noise reduction have already been developed as fuzzy filters can mange the vague and grayness ambiguity in an image.The reduction of Gaussian noise is a very difficult problem; as it does not distinguish between local variation due to noise and image structure such as edge. Recently, to remove, any sort of grayness ambiguity, geometrical uncertainty present in an image and to modify the pixel in an image without distorting the image structure such as edges, fuzzy based approach is used.

Hamed Vahdat Nejad (1) designed a new fuzzy filter for noise reduction of image corrupted with additive noise. It uses the output of the previous fuzzy system to perform fuzzy smoothing by weighting the contributions of neighboring pixel values. In fuzzy noise estimation stage, this system used a fixed threshold for number of similar pixels in a neighborhood. Stefan Schulte (2) presented the reduction of additive noise for digital color images. The filter consists of two subfilters. The first subfilter computes fuzzy distances between the color components of the central pixel and its neighborhood. The goal of the second subfilter is to correct the pixels where the color components differences are corrupted so much that they appear as outliers in comparison to their environment. Mahesh T R (3) presented noise reduction by using fuzzy image filtering. The system first estimates a "fuzzy derivative" in order to be less sensitive to local variations due to image structures such as edges. Second, the membership functions are adapted accordingly to the noise level to perform "fuzzy smoothing." Both stages are based on fuzzy rules which make use of membership functions. The filter can be applied iteratively and effectively reduce heavy noise. In particular, the shape of the membership functions is adapted according to the remaining noise level after each iteration, making use of the distribution of the homogeneity in the image.

Fabriozio Russo and Giovanni Ramponi (4) showed that rule based fuzzy operators are a novel class of operators specifically designed in order to apply the principles of approximate reasoning to digital image processing. This paper showed how a fuzzy operator that is able to perform detail sharpening but is insensitive to noise can be designed. The results obtainable by the proposed technique in the enhancement of a real image are presented. An effective method for image enhancement was presented by Versha Yadav and Kapil K. Nagwanshi (5) which was controlled by tuning of one parameter. In this paper, a filter is introduced which will remove the noise and improve the contrast of the image. The objective of image restoration is to reconstruct the image from degraded one resulted from system errors and noises and so on. Another is called image enhancement, that is, constructing digital filters to remove noises to restore the corrupted images resulted from noises.

M. Hari Krishnan and R. Viswanathan (6) presented 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. It is easy and fast to implement and can suppress Gaussian noise with a varying degree of success.

A fuzzy filter is constructed from a set of fuzzy IF-THEN rules; these fuzzy rules come either from human experts or by matching input-output pairs which is presented by the author Sridevi.Ravada (7).

According to the above techniques, a fuzzy based image filtering for noise reduction Gaussian noise is implemented .In the proposed method, there are two sub processes. The first is edge detection within a kernel. Focus pixel (centre pixel) of the kernel is decided whether it is noise or edge. If it is edge, the pixel is skipped and kernel is moved for next pixel. If it is noise, our proposed denoising method is performed by using neighbour derivatives and fuzzy rules.

A. Non-local Means Filter

Nonlocal mean filter is one of the random additive noise removals (8). The main concept of this filer is that the

adjacent pixels are edge if adjacent neighbourhood pixels are similar and non-adjacent neighbour pixels are also similar. The following Fig.1 show three pixels p,q1,q2 and their respective neighborhoods. Self similarity is used to displayed as the following Fig1.

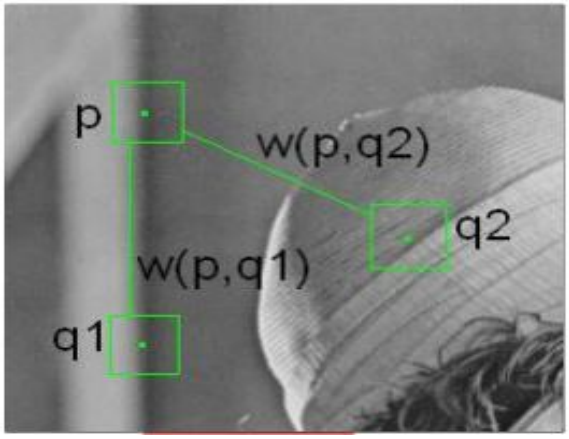


Figure 1. The self-similarity of neighborhood pixels in an image.

The neighborhood pixels p and q1 are similar,but the neighborhood pixels p and q2 are not similar. Adjacent pixel are similar but the non-adjacent pixels are similar when there is image structure. Pixel with similar neighborhood can be used to determine the denoised value of a pixel.

Noise reduction is detected by checking the similarity of the adjacent neighbours. The output modified pixel can be computed by the following equations (1) and (2). Given a discrete noisy image v= {v(q)} for a pixel I the estimated value of NL[v](p) is computed as weighted average of all the pixels i.e.

$$NL[V](p) = \sum_{q \in V} w(p,q)v(p) \qquad (1)$$

where {w(p, q)}j = the family of weights depend on the similarity between the pixels p andq

The similarity between two pixels p and q depends on the similarity of the intensity gray level vectors v( ) and v( ). Let Ni be the square neighborhood centered about pixel i with a user-defined radius Rsim. To compute the similarity between two neighborhoods as

a formula $\|v(N_p) - v(N_q)\|^2_{2,a}$ where a > 0 is the standard deviation of the Gaussian kernel.

$$w(p,q) = \frac{1}{z(p)} e^{-\frac{\|v(Np)-v(Nq)\|^2_{2,a}}{h^2}} \quad (2)$$

where Z(p) is the normalizing constant, the parameter h acts as a degree of filtering and a is the neighborhood filter with radius Rism.

The parameter h controls the decay of the exponential function and therefore the decay of the weights as a function of the Euclidean distances.

The weights of parameter a are computed as the following equation (3);

$$a = \frac{1}{\text{Rism}} \sum_{i=m}^{Rsim} \frac{1}{(2 * i + 1)^2} \quad (3)$$

Where m is the distance the weight is from the center of the filter and Rism is a user defined radius.

The Non-local Means compares not only the gray level in a single point but also the geometrical configuration in a whole neighborhood. The filter can give blurred result depending on the parameter h and kernel size.

III. PROPOSED FUZZY BASED DEONOSIGN TECHNIQUE

The general idea behind the filter is to smooth a pixel using its neighborhood pixels, but it is important to take care of the image structure such as edge. Most of the existing filters have problem for assuming edges as noise pixels. Fuzzy based approach can manage the grayness ambiguity and uncertain present in an image. In this paper, a fuzzy based image denoising for Gaussian noise is proposed. The main idea of proposed filter is to distinguish noise and edge.

In this system,before fuzzy crisp value and rules are applied, threshold estimation is firstly calculated because the threshold value is essential for determining the small fuzzy derivatives. The threshold value is estimating by the following steps.

The threshold value is estimated by the following steps:

Within a kernel,

(1)Find the value of the parameter h; h is calculated as

$$h = 1 - \frac{\text{Maximum gray value of pixel - Minimum gray value of pixel}}{255}$$

(2)Find the standard deviation (std) for the given kernel

(3)Record the no; of kernel which pass through over a given image

Within a given image,

(4)Calculate the mean of all h by

meanh = sum of all h / no; of kernel

(5)Calculate the mean of all standard deviation by

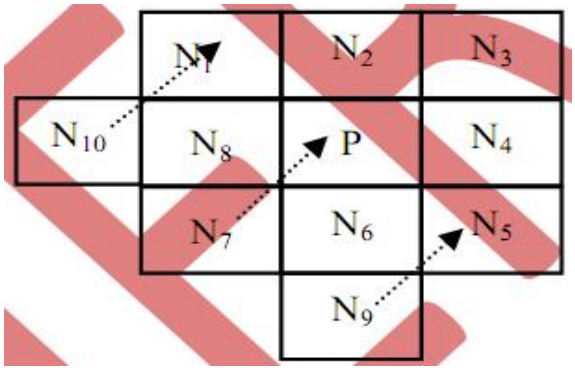
meanStd = sum of all std / no; of kernel

(6)Threshold value is estimated by

Threshold = α ((1-meanh)*meanStd)

Where, α is the amplification factor of denoising process or speed booster. By using the above steps, the threshold value to select small derivative can be estimated.

Hence, within a kernel, if most of neighbour derivative and perpendicular derivative values of a particular direction are larger than a threshold value, the neighbour pixels along the direction contain the edge region so they are omitted from our noise reduction process. For example, within a 3x3 kernel, there are one neighbour derivative and two perpendicular derivatives for a particular direction. If at least two derivative values are larger than the threshold value, the pixels along the direction can be said the edge pixels. If derivative values deviate from this assumption, they may be noises and need to modify. The neighbour derivative values (x) are estimated by subtracting centre pixel of a kernel from each neighbour. It can be demonstrated as shown in Fig. 2.



Neighbor derivative = N7– P

Perpendicular derivative 1 = N10- N1

Perpendicular derivative 2 = N19- N5

Fig. 2 Demonstration of derivative estimations for Sourth West (SW)direction

After that, as shown in the above Fig 2, is derivative value among centre pixel and each neighbour. For a given 3x3 kernel, fuzzy derivative value is defined by using the following fuzzy rules for a particular direction.

To define the fuzzy set values, the following fuzzy rules and fuzzy membership function are used as shown in Fig. 2. Among fuzzy set values, minimum fuzzy set value is used to calculate correlation term as shown in equation (4).

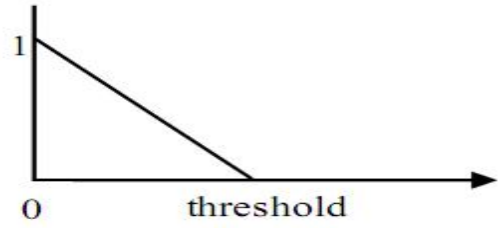


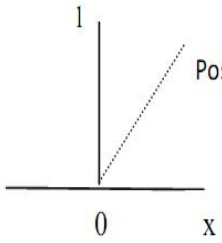
Fig. 2 Description of membership function and fuzzification for small derivatives

$$\varphi_i = \begin{cases} 1 - \frac{|\nabla|}{threshold} & if\ |\nabla| \le threshold \\ 0 & \text{else} \end{cases} \quad (4)$$

Each rule is applied on 3□3 kernel. Depend on each rule, the fuzzy derivative values are evaluated which determine noise or edge pixel.

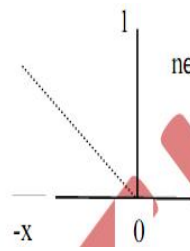
IF (neighbour derivative is small AND perpendicular1 is small) or (neighbour derivative is small AND perpendicular 2 is small) or (perpendicular1 is small AND perpendicular2 is small)

Then for the direction is minimum of all small values
If the derivative value is larger than the threshold value, this pixel is noise. Otherwise, this pixel is edge. There will be eight derivative values in a kernel. For the positive derivative value, positive rule is applied as shown in Equation 5. For the negative derivative value, negative rule is applied as shown in Equation 6.



$$\nabla F^{+} = \begin{cases} \frac{x}{L} & if\ x > 0 \\ 0 & else \end{cases} \quad (5)$$

IF is small and + is positive THEN positive truthness is the minimum of them.



$$\nabla F^{-} = \begin{cases} \frac{x}{L} & if\ x < 0 \\ 0 & else \end{cases} \quad (6)$$

IF is small and is negative THEN negative truthness is the minimum of them.

Where, L is the maximum gray value of the image and x is neighbour derivative value. The defuzzification for corrected term is estimated by the sum of the subtracted results of the positive truthness and negative truthness. It can be formulated by the following equation (7);

$$y(i,j) = I(i,j) + \left(\frac{255}{8} * \sum (positive\ truthness - negative\ truthness)\right) \quad (7)$$

Where, at the coordinate of i,j, I(i,j) is the centre pixel to modify and y(i,j) is the output denoised pixel to replace on I(i,j). According to equation (7), the corrected term is adaptive value to original centre pixel. Using the above equations and fuzzy rules, the centre pixel is denoised by shifting kernel in line fashion.

IV. RESULTS AND DISCUSSION

In this section, the performance of proposed method is presented comparing with nonlocal mean filter. Peak Signal to Noise Ratio (PSNR) is used to measure the performance. In this experiment, α is used as 5% and L is 255 or the maximum gray value of a given image. The experiments are performed at various Gaussian noise densities with the σ values of 5%, 35%and 75% Furthermore, these experiments are taken on the bitmap images. At each noise density, the performance of the proposed filter is measured and recorded comparing with Non-local Mean Filter. The results are tested on pepper.bmp as shown in Fig 3.

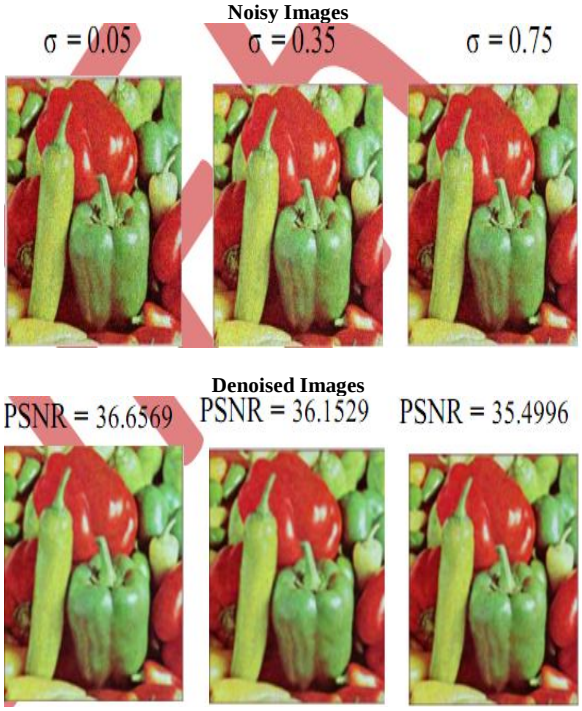


Fig. 3 Description of denoised image at various noise densities

The results of proposed filter for pepper.bmp images are presented as shown in Fig. 3. Next, the performance of proposed method is measured at various noise variances which are tested on lena.bmp 20%,40%,60%,80% comparing with Nonlocal Mean Filter as shown in Table 1 and Fig. 4.
To measure the quality of output denoised image, Peak Signal to Noise Ratio (PSNR) is used. The PSNR is the measure of how much the recovered image is similar with original. The PSNR value is calculated by equation (8).

$$PSNR\ (dB) = 20log_{10} \frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(B'(i,j) - B(i,j))^2}} \quad (8)$$

From the above equation (8), M and N are the numbers of row and column of the images; B(i,j) and B'(i,j) are the original image pixel and the denoised pixel at coordinate (i,j). Note that higher PSNR value, the denoised image will be more corrected.

TABLE I: PSNR VALUE COMPARISON AT VARIOUS NOISE DENSITIES

Noise density	PSNR of Nonlocal Mean Filter (dB)	PSNR of Proposed Filter (dB)
20%	31.5314	37.5830
40%	31. 4828	36.0511
60%	31.4610	35.7344
80%	30.4398	35.4333

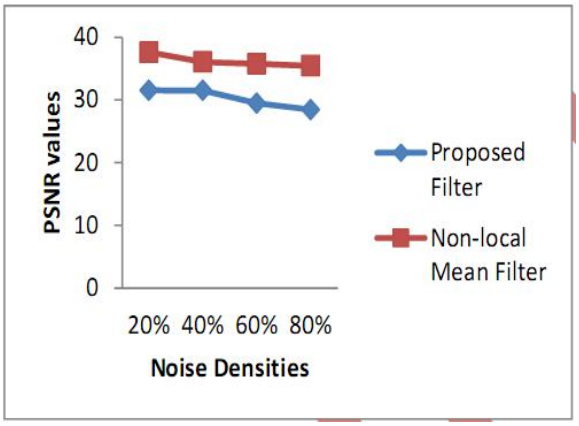


Fig.4 PSNR Values Comparison at Various Noise Densities

CONCLUSION

Fuzzy based image denoising filter for Gaussian noise is proposed in this paper. Most of the previous filter faces a problem which is to avoid the miss of image structure for filtering. In this proposed filter, edge or noise detection is firstly determined within a kernel by using fuzzy derivative values and fuzzy rules in eight different direction. To detect the edge, threshold value is calculated. The idea is to cancel out one of two derivatives is small than threshold value, it is assume that noise is present in the consider direction and filtering is performed in this direction. Fuzzy rules and fuzzy derivative values are used to consider eight directions around the processed pixel. The positive truthness and negative truthness within a kernel is used to determine new modified pixel. Moreover, the membership function is adapted according to the remaining of noise level after each filtering is performed. The input image is bitmap colour image. The experimental results show that the fuzzy based Gaussian filter has better results than Non-local mean filter. This system is emphasized on Gaussian noise only. This system can extend by modifying more fuzzy fules and fuzzy derivatives value to eliminate not only the impulse noise but also the gaussian noise.

REFERENCES

[1] Hamed Vahdat Nejad, Hameed Reza Pourreza, and Hasan Ebrahimi, "A Novel Fuzzy Technique for Image Noise Reduction", World Academy of Science, Engineering and Technology ,vol 21,pp 134-139,2006.

[2] Stefan Schulte, Valérie De Witte, and Etienne E. Kerre, "A Fuzzy Noise Reduction Method for Color Images", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 16, NO. 5, MAY 2007

[3] Mshesh T R, Prabjanjan s, Mvinaybabu, "Noise Reduction by using Fuzzy Image Filtering", Vol.15,No.2, pp 114-119,31May 2010.

[4] Fabrizio Russo and Giovanni Ramponi, "A Fuzzy Operator for the Enhancement of Blurred and Noisy Images", 1057-7149/95$04,00 0 1995 IEEE

[5] Versha Yadav and Kapil K. Nagwanshi, "A Fuzzy based Approach for Image Restoration", Vol. 1,Issue 2,pp87-89, July-Dec. 2011

[6] M. Hari Krishnan and R. Viswanathan, " A New Concept of Reduction of Gaussian Noise in Image Based on Fuzzy Logic", Applied Mathematical Sciences, Vol. 7, no. 12, pp 595-602, December 2013.

[7] Sridevi Ravada, Vani Prasanna Kanakala and Ramya Koilada, " Distinguishing the Noise and Image Structures for Detecting the Correction Term and Filtering the Noise by using Fuzzy Rules", International Journal on Computer Science and Engineering, Vol.3, pp 2754-2764, July 2011

[8] Westley Evan, "Image Denoising with Non-local Mean Algorithm" CS766 Homework #4 Fall 2005

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