International journal of Advances in Electronics Engineering
Vol:1 Issue:1 ISSN 2278 - 215X

Analysis of Advanced Fuzzy Filters for Image Denoising

Nidhi Kharb
Deptt of EECE
ITM University
Gurgaon,haryana
nidhikharb1@gmail.com

Amanpreet Kaur
Deptt of EECE
ITM University
Gurgaon,haryana
amanpreet@itmindia.edu

***Abstract*- Image denoising algorithms may be the oldest in image processing. A first pre-processing step in analyzing such datasets is denoising, that is, estimating the unknown signal of interest from the available noisy data. There are several different approaches to denoise images. To remove noise several techniques and image denoising filters are used. This paper shows a comparative study and analysis of image denoising techniques relying on fuzzy filters. First is the fuzzy impulse noise detection and reduction method (FIDRM) and second is noise adaptive fuzzy switching median filter for salt and pepper noise reduction (NAFSM). The comparative analysis shows that the NAFSM filter is better then the FIDRM filter in terms of execution time, peak signal to noise ratio (PSNR) and mean square error (MSE).**

***Keywords*-Fuzzy reasoning, salt and pepper noise, noise histogram, noise reduction.**

I. INTRODUCTION

Image denoising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images. This paper describes different methodologies for noise reduction giving an insight as to which filter should be used to find the most reliable estimate of the original image data. Several fuzzy and non fuzzy filters have been developed for denoising of images [1-8]. They perform much better then classical filters as they are able to preserve images in a more comprehensive means [2]. This letter analysis such two fuzzy filters. The rest of the paper is structured as follows. Section II introduces the fuzzy impulse noise detection and reduction (FIDRM) filter and section III introduces the noise adaptive fuzzy switching median (NAFSM) filter. Experimental results and conclusion are given in sections IV and V.

II. FUZZY IMPULSE NOISE DETECTION AND REDUCTION METHOD

The FIDRM filter is a two step filter. First is the detection step which uses fuzzy rules to know that the pixel is corrupted with impulse noise or not. [2].

A. *DETECTION STEP*

A 3 X 3 neighbourhood window is used for each pixel (i,j) of the image (not a border pixel) . If A is the input image, then we define the gradient $\nabla_{(k,l)}A(i,j)$ as the difference

$\nabla_{(k,l)}A(i,j)=A(i+k,j+l)-A(i,j)$ with $k,l\in\{-1,0,1\}$ (1)

Where (i,j) is the center of the gradient and pair (k,l) corresponds to one of the eight directions. So the eight gradient values corresponding to the eight directions are called basic gradients. As shown in the table, there is one basic and two related gradients corresponding to each direction. The two related gradients in the same direction are determined by the centres making a right angle with the direction of the basic gradient [2].

TABLE I INVOLVED GRADIENT VALUES

R	BASIC gradient	RELATED GRADIENT
NW	$\nabla_{NW}A(i,j)$	$\nabla_{NW}A(i+1,j-1), \nabla_{NW}A(i-1,j+1)$
N	$\nabla_{N}A(i,j)$	$\nabla_{N}A(i,j-1), \nabla_{N}A(i,j+1)$
NE	$\nabla_{NE}A(i,j)$	$\nabla_{NE}A(i-1,j-1), \nabla_{NE}A(i+1,j+1)$
E	$\nabla_{E}A(i,j)$	$\nabla_{E}A(i-1,j), \nabla_{E}A(i+1,j)$
SE	$\nabla_{SE}A(i,j)$	$\nabla_{SE}A(i-1,j+1), \nabla_{SE}(i+1,j-1)$
S	$\nabla_{S}A(i,j)$	$\nabla_{S}A(i,j-1), \nabla_{S}A(i,j+1)$
SW	$\nabla_{SW}A(i,j)$	$\nabla_{SW}A(i-1,j-1), \nabla_{SW}A(i+1,j+1)$
W	$\nabla_{W}A(i,j)$	$\nabla_{W}A(i-1,j), \nabla_{W}A(i+1,j)$

Now the fuzzy gradient value $\nabla_R^F A(i,j)$ for each of the eight directions is calculated by the following fuzzy rule:

If $|\nabla_R\ A(i,j)|$ is large AND $|\nabla'_R\ A(i,j)|$ is small OR

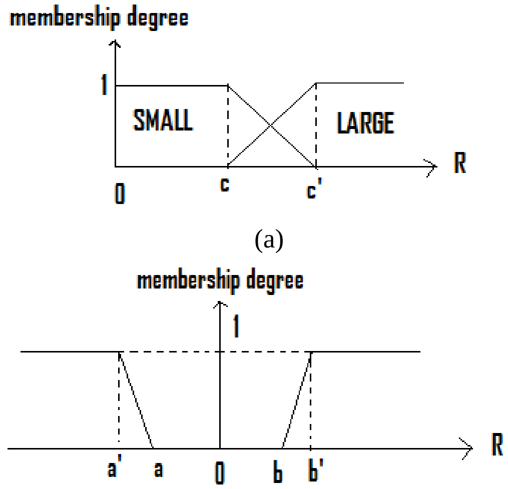
If $|\nabla'_R\ A(i,j)|$ is large AND $|\nabla''_R\ A(i,j)|$ is small OR

$\nabla_R A(i,j)$ is big positive AND $\nabla'_R\ A(i,j)$ AND $\nabla''_R A(i,j)$ are big negative OR

$\nabla_R\ A(i,j)$ is big negative AND $\nabla'_R\ A(i,j)$ AND $\nabla''_R A(i,j)$ are big positive

THEN $\nabla_R^F A(i,j)$ is large

Where $\nabla_R A(i,j)$ is the basic gradient value and $\nabla'_R A(i,j)$ is the first related gradient and $\nabla''_R A(i,j)$ is the second related gradient. The terms "large", "small", "big negative" and "big positive" can be represented as fuzzy sets. Fuzzy sets are represented by a membership function as shown in figure.



(a)

(b)

Figure I Membership functions (a) SMALL respectively, LARGE (b) BIG NEGATIVE, respectively, BIG POSITIVE

To determine if a central pixel (a nonborder pixel) is an impulse noise pixel, the following fuzzy rule is employed:

IF most of the eight $\nabla_R^F A(i,j)$ are *large* THEN the central pixel $A(i,j)$ is an impulse noise pixel.

If a pixel (i,j) is detected as an impulse noise pixel, then the corresponding grayscale value is stored in a histogram as shown in result section [2].

B. *FILTERING STEP*

Now, calculate five peak values in the noise histogram i.e. the corresponding gray scale value where maximum is reached (five p_k) and four parameters (a_k, b_k, c_k, d_k) which are used to construct the fuzzy set more or less impulse noise.

$$a_k = p_k - THR_a, \quad b_k = p_k - THR_b$$

$$c_k = p_k + THR_c, d_k = p_k + THR_d$$

$$THR_b = \frac{2}{3}THR_a, THR_c = \frac{2}{3}THR_d \qquad (2)$$

and

$THR_a = THR_d = \min(25, [\sigma])$, where $[\sigma]$ is the largest integer value smaller than the variance .These four parameters are used to construct the fuzzy set more or less impulse noise as shown in figure below.

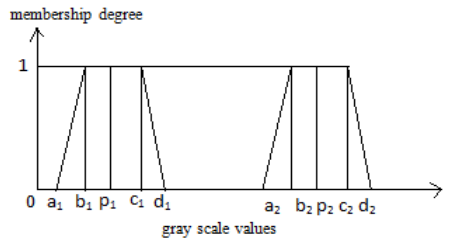


Figure II Membership function representing the fuzzy set "more or less impulse noise".

The first iteration of filtering is performed now according to the algorithm given below.

INPUT: A: The noisy image with impulse noise. $\mu(A(i,j))$: The membership degree for the fuzzy set more or less impulse noise.

F: the output image.

Steps:

(1) FOR each non-border pixel (i,j)∈A

(2) IF A(i,j) ∈ supp("more or less impulse noise")

(3) $F(i,j) = \frac{\sum_{h=-1}^{1}\sum_{l=-1}^{1} 1-\mu(A(i+h,j+l))\, A(i+h,j+l)}{\sum_{h=-1}^{1}\sum_{l=-1}^{1} 1-\mu(A(i+h,j+l))}$

(4) ELSE

(5) F(i,j) = A(i,j)

(6) END IF

(7) END FOR

It is possible that even after the first iteration the impulse noise is clustered around one or more pixels. So, second iteration is performed which is similar to the first one. In each iteration we use the modified image (the output image) of the previous performed iteration as the input image and window size will also increase by one. Modification of the membership function "more or less impulse noise" (for the m^{th} iteration) is also done by changing the parameters as follows[2].

$$a_k^m = \frac{1}{2}(a_k^{m-1} + p_k), b_k^m = \frac{1}{2}(b_k^{m-1} + p_k)$$

$$c_k^m = \frac{1}{2}(c_k^{m-1} + p_k), d_k^m = \frac{1}{2}(d_k^{m-1} + p_k) \qquad (3)$$

III. NOISE ADAPTIVE FUZZY SWITCHING MEDIAN FILTER

The NAFSM filter is a recursive, two stage filter. The first stage is the detection stage, it will detect the intensities of salt and pepper noise.

A. *Detection Stage*

In the detection stage the two peak intensities in noise histogram are searched, i.e. the two local maximums, L_{salt} and Lpepper[8] . Then a binary noise mask N(i,j) will be created to mark the location of "noise pixels" by using the equation

$$N(i,j) = \begin{cases} 0, & X(i,j) = L_{salt} \text{ or } L_{pepper} \\ 1, & otherwise \end{cases} \quad (4)$$

Where X(i,j) stands for the pixel at location (i,j) with intensity X.

B. Filtering Stage

After the creation of binary noise mask N(i,j) , "noise pixels" marked with N(i,j) =0 will be replaced by an estimated correction term. The NAFSM filter uses a square filtering window $W_{2s+1}(i,j)$ with odd (2s+1) x (2s+1) dimensions, given as below

$$W_{2s+1}(i,j) = \{ X(i+m,j+n)\} \text{ where } m,n \in (-s,\ldots,0,\ldots,s). \quad (5)$$

In the filtering window $W_{2s+1}(i,j)$, the number of noise free pixels $G_{2s+1}(i,j)$ are counted using

$$G_{2s+1}(i,j) = \sum N(i+m,j+n), \text{ where } m,n \in (-s,\ldots,0,\ldots,s) \quad (6)$$

The filtering window will be expanded by one pixel at each of its four sides (i.e., $s \leftarrow s+1$), until the criterion of $G_{2s+1}(i,j) > 1$ is achieved. These "noise-free pixels" are used for selecting the median pixel, M(i,j), given by

$$M(i,j)=\text{median}\{X(i+m,j+n)\} \text{ with } N(i+m,j+n)=1 \quad (7)$$

Then , the absolute luminance difference d(i,j) is computed:

$$d(i+k,j+l) = | X(i+k,j+l) - X(i,j) | \quad \text{With } (i+k,j+l) \neq (i,j) \quad (8)$$

After that, the maximum absolute luminance difference is calculated in the 3x3 filtering window.

$$D(i,j)=\max\{d(i+k,j+l)\} \quad (9)$$

Then the fuzzy reasoning is applied to D(i,j).

$$F(i,j) = \begin{cases} 0, & : D(i,j) < T_1 \\ \frac{D(i,j)-T_1}{T_2-T_1} & : T_1 \le D(i,j) < T_2 0, \\ 1, & : D(i,j) \ge T_2 \end{cases} \quad (10)$$

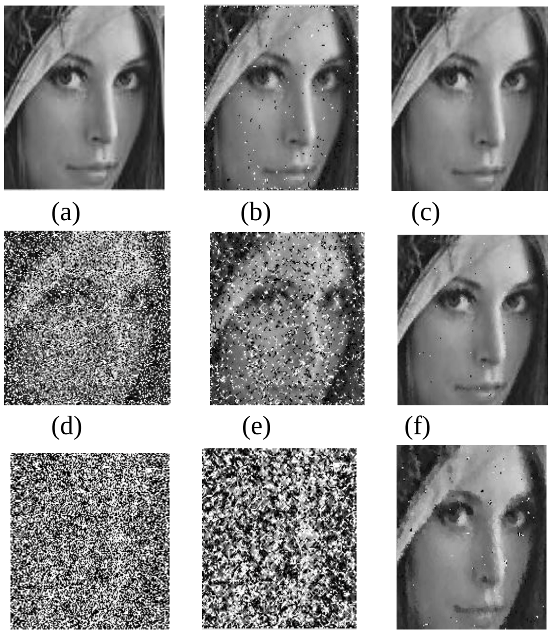
where D(i,j) is the local information used as input variable, and the two threshold values T1 and T2 are set to 10 and 30, respectively, for optimal performance [8].

Lastly, the correction term for restoring corrupted pixels is computed by using the equation given below.

$$Y(i,j) = [1-F(i,j)] \cdot X(i,j) + F(i,j) \cdot M(i,j) \quad (11)$$

IV. SIMULATION RESULTS AND DISCUSSIONS

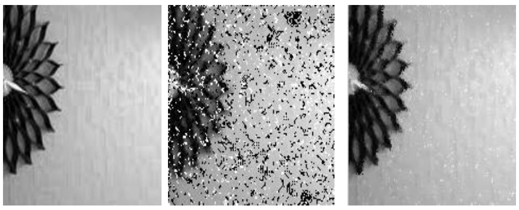
In this section the simulation results of FIDRM filter are compared with the NAFSM filter. A standard test image (Lena) frequently used in literature is contaminated with salt-and-pepper noise ranging from 5% to 95% with increment steps of 5%. The restoration results for "Lena" image, corrupted with salt-and-pepper Noise are shown in figure III.



(g) (h) (i)

Figure III (a)Original "Lena" image. (b)FIDRM filtered image for 20% impulse noise, (c) NAFSM filtered image for 20% impulse noise, (d) "Lena" image corrupted with 50% of salt-and-pepper noise. Simulation results (in PSNR) obtained using: (e) FIDRM, (f) NAFSM, (g) "Lena" image corrupted with 80% of salt-and-pepper noise. Simulation results (in PSNR) obtained using: (h) FIDRM, (i) NAFSM

The restoration results for "flower" image, corrupted with 50% of salt and pepper noise are shown in figure IV.NAFSM filter shows best results.



(j) (k) (l)

Figure IV (j)Original "flower" image. Filtered image for 50% impulse noise using (k)FIDRM (l) NAFSM

The restoration results for "my" image, corrupted with 50% of salt and pepper noise are shown in figure V.

Figure V Original "my" image. Filtered image for 50% impulse noise using (b)FIDRM (c) NAFSM

The graphs below shows the comparison of the two filters on the basis of peak signal to noise ratio i.e. PSNR(db), processing time and mean square error (MSE).

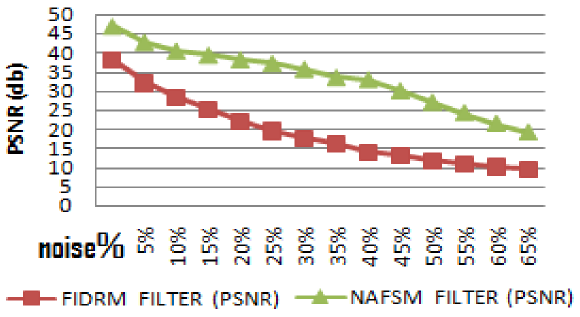


Figure VI Graph of PSNR(db) versus salt and pepper noise percentage(%)

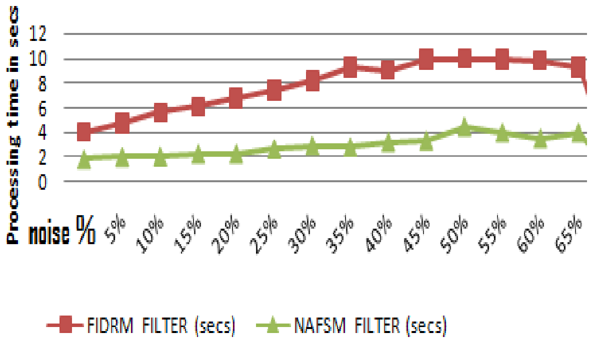


Figure VII Graph of processing time (seconds) versus salt-and-pepper noise percentage (%)

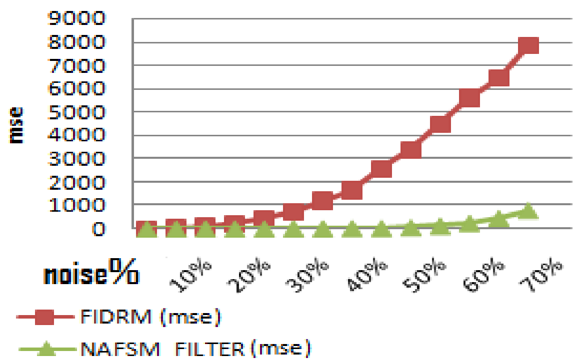


Figure VIII Graph of MSE (mean square error) versus salt-and-pepper noise percentage(%)

V. CONCLUSION

The analysis of FIDRM and NAFSM filter shows that NAFSM is able to outperform FIDRM filter in terms of PSNR, execution time and MSE. The NAFSM filter is able to suppress high-density of salt-and-pepper noise, at the same time preserving fine image details and edges.

The NAFSM filter is able to yield good filtering results with efficient processing time even at high percentages of salt and pepper noise. Future research should focus on further shortening of the processing time of NAFSM filter by estimating the local information adaptively based on fuzzy inference.

REFERENCES

[1] M. Nachtegael, D.Van der Weken and E. E. Kerre, "Fuzzy techniques in image processing: three cast studies," *Int, J.Comput Anticipatory Syst.*, vol. 12,pp. 89-104, Aug. 2002.

[2] S. Schulte, M. Nachtegael, V. D. Witte, D. Van der Weaken, and E. E. Kerre, "A fuzzy impulse noise detection and reduction method," *IEEE Trans. Image Processing.*, vol. 15, no. 5,pp. 1153-1162, May 2006.

[3] W. Luo, "Eficient removal of impulse noise from digital images," *IEEE Trans. Consumer Electron.*, vol. 52, no. 2, pp. 523–527, May 2006.

[4] Z. F. Deng, Z. P. Yin, and Y. L. Xiong, "High probability impulse noise-removing algorithm based on mathematical morphology," *IEEE Signal Process. Lett.*, vol. 14, no. 1, pp. 31–34, Jan. 2007.

[5] K. K. V. Toh, H. Ibrahim, and M. N. Mahyuddin, "Salt-and-pepper noise detection and reduction using fuzzy switching median filter," *IEEE Trans. Consumer Electron.*, vol. 54, no. 4, pp. 1956–1961, Nov. 2008.

[6] P. Y. Chen and C. Y. Lien, "An efficient edge-preserving algorithm for removal of salt-and-pepper noise," *IEEE Signal Process. Lett.*, vol. 15,pp. 833–836, 2008.

[7] X. Zhang and Y. Xiong, "Impulse noise removal using directional difference based noise detector and adaptive weighted mean filter," *IEEESignal Process. Lett.*, vol. 16, no. 4, pp. 295–298, Apr. 2009.

[8] K. K. V. Toh and N. A. M. Isa, "Noise adaptive fuzzy switching median filter for salt and pepper noise reduction," *IEEE Signal Process. Lett.*, vol. 17, no. 3, pp. 281–284, Mar. 2010.