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Research Article

A FUZZY MEDIAN FILTER (FMF) FOR IMPULSIVE NOISE REDUCTION

Ashish Mehta*

Department Of Computer Science, DSB Campus, Kumaun University, Nainital-263001

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ABSTRACT

In this paper, a fuzzy based median filter is proposed for impulse noise reduction in gray level images. The proposed fuzzy median filter (FMF) is a two-stage filter. In the first stage, it removes the impulsive noise using a combination of fuzzy if then else rule and median filter and in the second stage, it sharpens the edges. It uses two rules for impulsive noise removing. The developed method has been implemented for gray level images and the results have been compared with the conventional median filter and show its superiority. The proposed filter is very effective to remove noise up to 35%.

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INTRODUCTION

One of the applications of image enhancement is to remove impulsive noise without degrading the image details. In image enhancement, the noise smoothing and edge enhancement are conflicting to each other. As smoothing of a region may destroy its edges, while sharpening of edges may lead to generate undesired noise. The conventional median filters can remove the impulsive noise from the noisy pixel but it also distorted the noise free pixels that cause edge and texture blurring.

Bezdek and Castelaz [2] studied fuzzy classifier in feature selection. Goetcherian [6] uses fuzzy min and max operators in image enhancement. Pal and King [8-9] applied fuzzy operator "contrast intensification" in handwritten English script. Shen[24] developed a smoothing filter based on the maximum possibility criteria using fuzzy set theory and possibility theory. Russo[12] developed window based fuzzy operator for image enhancement. Pengand Lucke [10-11] developed fuzzy filters to remove Gaussian noise as well as impulsive noise using LMS(least mean square) and multi-level adaptive fuzzy(MLAF) filter respectively. Choi and Krishnapuram [3] demonstrated fuzzy rule-based image enhancement filter based on weighted least mean square method. The proposed method removing impulsive noise, smoothing out the non-impulsive noise and enhancing edges. Russo and Ramponi[13-15] studied on various Fuzzy Interface ruled by else action (FIRE) fuzzy rule-based filters for removing impulsive noise. Further, Yang and Toh [26] modified the multilevel median filter with an adaptive fuzzy multilevel median filter for better results. Russo and Ramponi [17] presented DS-FIRE filter for noise cancellation. The filter uses 50 fuzzy rules for noise cancellation. Arakawa [1] proposed a fuzzy based median filter based on weighted sum of the input signal and output of the median filter. Russo [16,18-20] made a significant study on FIRE operators as a class of non-linear filter for removing impulsive noise. Farbiz *et al* [4-5] proposed fuzzy logic control based filter that preserve the edges while removing impulsive noise and also smooth non-impulsive noise. Russo [21] presented a recursive neuro-fuzzy filter for removal of noise in an image. Xu *et al*. [25] presented an adaptive fuzzy switching filter using fuzzy logic approach for the enhancement of images corrupted by impulsive noise. Russo [22] considered a new technique for reduction of Gaussian noise present in the images. It adopted multi-pass processing based on a simple piecewise linear filter. Schulte *et al*. [23] presented a fuzzy impulse noise detection and reduction method (FINDRM) for removing a combination of impulsive noise and other types of noise. Yüksel *et al*. [27-30] have made significant works in the neuro-fuzzy system to remove impulsive noise. They also worked on the development of a hybrid system for restoring noisy digital images, while preserving edges, lines and other details. Li *et al*. [7] proposed a robust neuro-fuzzy network

Corresponding author:* **Ashish Mehta
Department Of Computer Science, DSB Campus, Kumaun University, Nainital-263001

approach for impulse noise filtering for color images. The method takes two stages: the first stage is a detection of a noisy image and the second stage uses a novel robust neuro-fuzzy approach.

The goal of a filter design is that it removes only the corrupted image pixel while leaving the noise free pixel unaffected to avoid blurring. Thus, the proposed fuzzy median filter (FMF), effectively removes the impulsive noise by applying fuzzy if then else rule in the median filter. The paper is organized is as follows: Section 2 presents the fuzzy filter. Section 3 shows the algorithm for FMF. Section 4 shows some experimental results of computer simulations. Section 5 reports the conclusions and references used in the study are places at the end.

The Fuzzy Median Filter (FMF)

The proposed method consists of two stages. In a first stage, it removes the impulsive noise by combining the fuzzy rules in the median filter. The second stage preserves the image details using the second stage of DS-FIRE filter. A trapezoidal membership function is used for fuzzification. Two symmetrical trapezoidal function NEG and POS are used for removing impulsive noise in the first stage and two trapezoidal function μ_{ME} and μ_{LA} are used in the second stage from Russo and Ramponi DS-FIRE filter [17].

METHODOLOGY

In the first stage two if rules and one else rule are used for noise cleaning. The rules fire only when the noise is presented. For each pixel P in an image, let W be a 3X3 window centered at P and the group of neighboring pixels $\{P_j\}$shown on {Figure 1}. The luminance difference is calculated as $x_j = P_j - P$. Let L be the maximum gray levels in an image. The range of $\{x_j\}$ takes integer values in the interval [-L+1, L-1]. Let y represent the output variable of the fuzzy processing.

The final pixel P' is represented by

$$P' = P + y \tag{1}$$

The following membership functions {Figure 2}andrules, shown on are proposed for noise filtering.

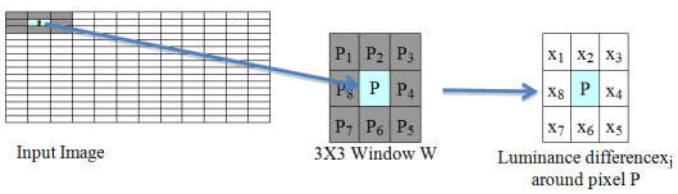


Figure 1 A 3x3 luminance difference window around image pixel P

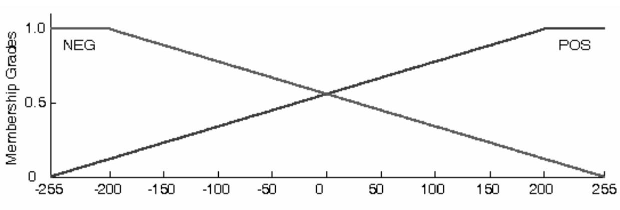


Figure 2 Membership functions for FMF.

R1: IF ((x_1 in POS) AND (x_2 in POS) AND (x_3 in POS) AND (x_4 in POS) AND (x_5 in POS) AND (x_6 in POS) AND (x_7 in POS) AND ($x_8$in POS)) THEN (y in POS)

R2: IF ((x_1 in NEG) AND ($x_2$in NEG) AND (x_3 in NEG) AND ($x_4$in NEG) AND (x_5 in NEG) AND ($x_6$in NEG) AND (x_7 in NEG) AND (x_8 in NEG)) THEN (y in NEG)

$$\text{ELSE } (y \text{ is } y_0) \tag{2}$$

The rules R1 and R2 are computed by the following formula:

$$y_1 = \text{median}(\mu_{pos}(x_1), \mu_{pos}(x_2), \mu_{pos}(x_3), \mu_{pos}(x_4), \mu_{pos}(x_5), \mu_{pos}(x_6), \mu_{pos}(x_7), \mu_{pos}(x_8)) \tag{3}$$

$$y_2 = \text{median}(\mu_{neg}(x_1), \mu_{neg}(x_2), \mu_{neg}(x_3), \mu_{neg}(x_4), \mu_{neg}(x_5), \mu_{neg}(x_6), \mu_{neg}(x_7), \mu_{neg}(x_8)) \tag{4}$$

For the else rule, we apply the following formula

$$y_0 = \text{MAX}(0, 1 - y_1 - y_2). \tag{5}$$

The first stage output from fuzzy rule given in (2), is calculated as

$$y' = L * (y_1 - y_2)/(y_0 + y_1 + y_2) \tag{6}$$

The second step: the output of first stage y' is further process in second step using (7).

$$y = y' \text{ MAX}(\mu_{LA}(|y'|), 1 - \mu_{ME}(P)) \tag{7}$$

The working of FMF, with its results, is shown in Figure 3. The input Lena image is corrupted by 10% impulsive noise is shown in Figure 3(a), in the first stage it removes impulsive noise is shown in Figure 3(b) and in the second stage, it sharpens the image is shown in Figure 3(c).

Figure 3 Example of filtering using FMF (a) image corrupted by impulsive noise (10%), (b) Noisy cleaning by first stage FMF, (c) edge sharpening by second stage filter.

Algorithm

1. Create symmetric padding around the input image.
2. For every pixel in the original image, select a 3x3 neighboring window, a luminance differences window obtained by subtracting the central pixel value form every element of the windows:
3. $x_j = P_j - P$.
4. Obtain fuzzy membership values of POS and NEG from luminance differences window.
5. Calculate y_1, y_2 and y_0 from rule based (3), (4) & (5).
6. Calculate the first stage output y' from (6).
7. Obtain y from (7).
8. Calculate the noise free pixel P' using (1).
9. Replace the original pixel P with modified noise free pixel P'.
10. Repeat the process recursively until the last pixel is processed.
11. Extract the noisy free image from padded image.

Experimental Results

The computer simulations show the performance of proposed filter (FMF). The original image Lena Figure 4(a) is corrupted by 15% and 20% impulsive noise as shown in Figure 4 (b) and

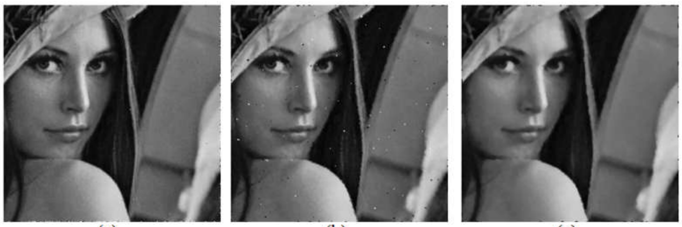
Figure 4(c) respectively. The results of proposed filter (FMF) are shown in Figure 5(a) and 6(a) respectively, and have been compared with traditional median filter of size 3x3 and 5x5 for removing 15% and 20% impulsive noise shown in Figure 5(b), 6(b), and Figure 5(c), and 5(c) respectively. For image boundary condition Symmetric padding (symmetric boundary value replication) is used in FMF.

(a) (b) (c)

Figure 4 (a) Original Lena image, (b) Image corrupted by 15% impulsive noise, (c) Image corrupted by 20% impulsive noise.

(a) (b) (c)

Figure 5 Results obtained by removing 15% impulsive noise using (a) proposed FMF, (b) 3X3 median filter, (c) 5X5 median filter.



(a) (b) (c)

Figure 6 Results obtained by removing 20% impulsive noise using (a) proposed FMF, (b) 3X3 median filter, (c) 5X5 median filter.

The performance of these filters is also verified by quantitatively. The mean square errors (MSE) defined by (8) and the peak signal to noise ratio (PSNR) defined by (9) is calculated. As shown in Figure 7, the quantitative measurement justifies the performance of the proposed filter (FMF). The MSE for the proposed filter is much lower than 3x3 and 5x5 median filters, while PSNR is much better than median filters.

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \quad (8)$$

$$PSNR = 10 * \log_{10}\left(\frac{255 * 255}{MSE}\right) \quad (9)$$

Table 1 shows that quantitative measures of FMF being applied repetitively. It also exhibits the performance of the FMF,it effectively removes the noise when applying twice where the impulsive noise level is more than 20%. Figure 8 also shows the result of FMF, when repeating twice. The results show that the quality of the image filter by FMF.

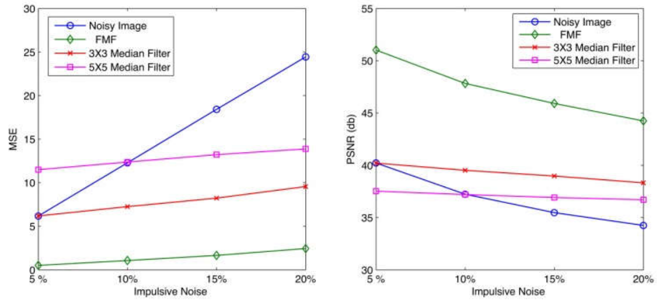


Figure 7 Comparative MSE &PSNRvalues for different filtering methods

Table 1 MSE values for repeated FMF

Noise	MSE			PSNR		
	FMF Applied once	**FMF Applied twice**	**FMF Applied thrice**	**FMF Applied once**	**FMF Applied twice**	**FMF Applied thrice**
5%	0.479	0.519	0.544	51.329	50.981	50.773
10%	1.044	1.076	1.098	47.942	47.814	47.726
15%	1.747	1.766	1.786	45.709	45.660	45.613
20%	2.542	2.535	2.550	44.079	44.092	44.065
25%	3.298	3.283	3.290	42.948	42.968	42.959
30%	4.314	4.279	4.284	41.782	41.817	41.812
35%	5.499	5.429	5.436	40.728	40.784	40.778

(a) (b) (c)

Figure 8 (a) Noisy image (35%), (b) Result yield by FMF, (c) Result yield by applying FMF twice.

CONCLUSION

The study exhibits that the developed FMF can remove impulsive noise effectively while preserving the image details. The performance of the proposed filter is better than the median filters in both qualitative and quantitative measures. The computer simulation confirms that, the algorithm performs better then the median filter without degrading the image details. The results show the proposed filter(FMF) outperform the median filter.

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