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IMPULSIVE NOISE REDUCTION USING FUZZY FILTER IN GRAY IMAGES

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Abstract-In this paper, a two-stage fuzzy filter has proposed for impulse noise reduction in gray level images. In the first stage, it removes the impulsive noise and in the second stage, it sharpens the edges. The proposed methodology is based on fuzzy rules. The developed method has been implemented for gray level images and the results have been compared with conventional median based methods to show its superiority. The proposed filter is simple, easy to implement and effectively remove the impulsive noise while preserving the image details.
Key Words: Fuzzy filter, image enhancement, image processing, impulsive noise.

1. INTRODUCTION

Image enhancement is one of the major tasks in image processing. Improvement in the quality of image for a specific application by some process is known as image enhancement. The enhancement process basically increases the domain of required features. One of the applications of image enhancement is to remove impulsive noise without degrading the image details. The conventional median filters though have nice potential for removing the impulsive noise but also perform the processing of noise free pixels and causing the edge and texture blurring.

With the advancement in digital technology, the application area of image enhancement is growing and thus past few years, various research workers have shown interest in the development and application of soft computing based techniques. These techniques such as neural networks, fuzzy logic systems and neuro-fuzzy systems are now frequently being used for better results. Restricting to our domain of study to the application of fuzzy sets, as the fuzzy classifier in feature selection was studied by Bezdek and Castelaz [2]. Pal and King [7-8] first applied the fuzzy set theoretic approach in image enhancement by evolving an algorithm in for successive application of fuzzy operator. Shen [21] developed a fuzzy model for noise sequence and the possibility distribution for an estimate of the original image. Russo and Ramponi [10] considered a window based technique in which each pixel of an image is processed according to the luminance values of pixels in its neighborhood. In his study, an operator was presented to sharp the details of an image by applying fuzzy reasoning to the input luminance values. Peng and Lucke [9] used local statistics to train the membership function of a fuzzy filter for image processing to remove both Gaussian and impulsive noise. Further, Russo and Ramponi [11-15] made a significant contribution to the development of the windows based techniques for image processing using a fuzzy rule based system. Choi and Krishnapuram [3] proposed a fuzzy rule based image enhancement method. The proposed method was a combination of three filters, each responsible for different jobs of: removing impulsive noise, smoothing out non-impulsive noise and enhancing edges. Russo and Ramponi [16] proposed a multilevel DS-FIRE filter for the image enhancement by performing fuzzy reasoning at two different levels. Arakawa [1] proposed a filter obtained as the weighted sum of the input signal and output of the median filter, where the weight is set by fuzzy rules. Further, Russo [17-19] made a comprehensive study on Fuzzy Interface ruled by else action (FIRE) operators as a class of non-linear processing. The study was based on several experimental results and it showed that FIRE filters were significantly better than other filters. Farbiz et al. [4-5] proposed a fuzzy logic based filter with the ability to remove impulsive noise and smooth Gaussian noise, while preserving edges and edge details efficiently. Kam and Tan [6] proposed an efficient means to obtain the parameters for adaptation of a method to reduce impulsive noise. Schulte et al. [20] studied the case, when images have a mixture of impulsive noise and another type of noise and presented a fuzzy impulse noise detection and reduction method (FINDRM).

The Motivation of the present study is to develop a simple and easy to implement methodology with minimum fuzzy rules for keeping in view that methodology developed is robust and should perform the job of impulsive noise cancellation while preserving the image details. The work has been organized and presented in following sections: Section two, the next one, presents fundamentals in proposed filter along with its working rules. Section three discusses the experimental results of computer simulation. Section four presents the conclusions and the references used in the study.

2. DESIGN OF PROPOSED METHOD

The proposed filter is a two-stage filter. The first stage detects and removes the impulsive noise by applying fuzzy if then else approach. The second stage enhances the image details using the second stage of DS-FIRE filter [16]. A trapezoidal membership function is proposed in this paper. The methodology adopted is described in this section.

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2.1 Membership Functions:-

The trapezoidal membership function is used in the proposed design. The trapezoidal function needs four parameters and is defined as (1) and shown in Fig. 1. Two symmetrical trapezoidal membership functions POS and NEG [Fig. 2] are used for if action. In second stage processing two trapezoidal membership functions μ_{ME} and μ_{LA} are used in the second stage of Russo and Ramponi [16] DS-FIRE filter as given in Fig. 3.

$$\mu(x,a,b,c,d)=\begin{cases}0, & x<a, x>d\\ \dfrac{x-a}{b-a}, & a\le x\le b\\ 1, & b<x<c\\ \dfrac{d-x}{d-c}, & c\le x\le d\end{cases} \tag{1}$$

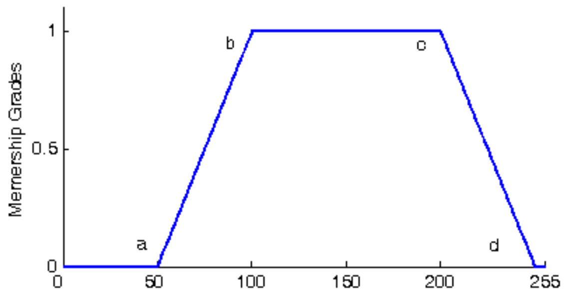


Fig. 1 Trapezoidal membership function
μ(x, 50,100,200,255).

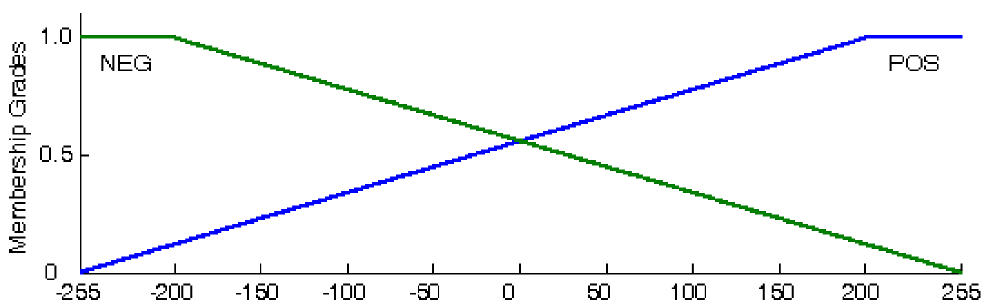
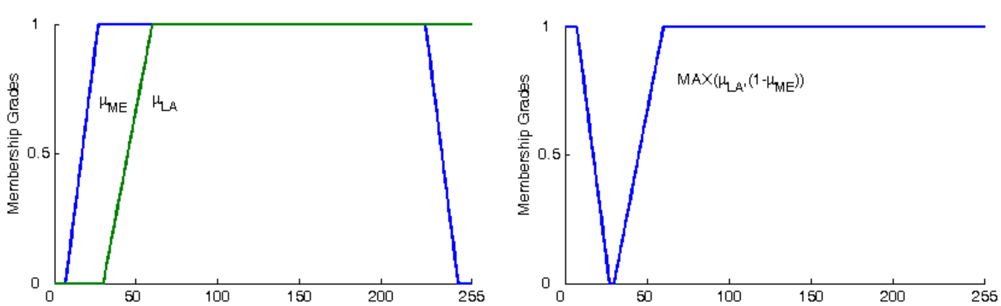


Fig. 2 Membership functions.



(a) (b)

Fig. 3 (a) Two trapezoidal membership functions μ_{ME} and μ_{LA} for 2nd stage filter (b) final fuzzy variable y calculating from μ_{ME} and μ_{LA} Membership functions.

2.2 Methodology:

This section presents the methodology of proposed filter. In this filter, we have adopted fuzzy if-then-else rule mechanism. The proposed filter has two steps, the first step removes the noise and second step sharpens the edges. The method takes eight if rules and one else rule (3). The POS and NEG trapezoidal membership functions can be symmetrically tuned to get the best result.

2.3 Fuzzy rules:

For each pixel P of an image, let us consider the group of neighboring pixels { P_j } which belongs to 3X3 window W centered at P, say {x_j} as given in Fig. 4, be the luminance differences $x_j = P_j - P$. Let us consider the image having L gray levels. The Domain D of input variables {x_j} takes integer values in the interval [-L+1, L-1]. Let y represent the output variable of the fuzzy processing. The processed pixel P' is represented by

$P' = P + y$ (2)

P is replaced by P' in original image after processing. The process is recursive in nature. The operator has two if rule and one else rule.

x_1	x_2	x_3
X_4	x_0	X_5
X_6	X_7	X_8

Fig. 4 A 3X3 luminance difference Window.

The following rules and membership functions, shown on Fig 2, are proposed for noise filtering.

R1-R8:

IF ((x_2 in POS) AND (x_3 in POS) AND (x_5 in POS) AND (x_8 in POS)) THEN (y in POS)
IF ((x_5 in POS) AND (x_8 in POS) AND (x_7 in POS) AND (x_6 in POS)) THEN (y in POS)
IF ((x_7 in POS) AND (x_6 in POS) AND (x_4 in POS) AND (x_1 in POS)) THEN (y in POS)
IF ((x_4 in POS) AND (x_1 in POS) AND (x_2 in POS) AND (x_3 in POS)) THEN (y in POS)
IF ((x_2 in NEG) AND (x_3 in NEG) AND (x_5 in NEG) AND (x_8 in NEG)) THEN (y in NEG)
IF ((x_5 in NEG) AND (x_8 in NEG) AND (x_7 in NEG) AND (x_6 in NEG)) THEN (y in NEG)
IF ((x_7 in NEG) AND (x_6 in NEG) AND (x_4 in NEG) AND (x_1 in NEG)) THEN (y in NEG)
IF ((x_4 in NEG) AND (x_1 in NEG) AND (x_2 in NEG) AND (x_3 in NEG)) THEN (y in NEG)
ELSE (y in ZERO) (3)

2.4 Rules Activity Degree Calculation

The activity degrees through R1 to R8 are computed by the following relationship:

$y_1=\text{MIN}(\mu_{pos}(x_2), \mu_{pos}(x_3), \mu_{pos}(x_5), \mu_{pos}(x_8))$ (4)
$y_2=\text{MIN}(\mu_{pos}(x_5), \mu_{pos}(x_8), \mu_{pos}(x_7), \mu_{pos}(x_6))$ (5)
$y_3=\text{MIN}(\mu_{pos}(x_7), \mu_{pos}(x_6), \mu_{pos}(x_4), \mu_{pos}(x_1))$ (6)
$y_4=\text{MIN}(\mu_{pos}(x_4), \mu_{pos}(x_1), \mu_{pos}(x_2), \mu_{pos}(x_3))$ (7)
$y_5= \text{MIN}(\mu_{neg}(x_2), \mu_{neg}(x_3), \mu_{neg}(x_5), \mu_{neg}(x_8))$ (8)
$y_6= \text{MIN}(\mu_{neg}(x_5), \mu_{neg}(x_8), \mu_{neg}(x_7), \mu_{neg}(x_6))$ (9)
$y_7= \text{MIN}(\mu_{neg}(x_7), \mu_{neg}(x_6), \mu_{neg}(x_4), \mu_{neg}(x_1))$ (10)
$y_8= \text{MIN}(\mu_{neg}(x_4), \mu_{neg}(x_1), \mu_{neg}(x_2), \mu_{neg}(x_3))$
$y_{POS}=\text{MAX}(y_1, y_2, y_3, y_4)$
$y_{NEG}=\text{MAX}(y_5, y_6, y_7, y_8)$

For the Else rule, we apply the following formula to evaluate the degree of activation

$y_0= \text{MAX}(0, 1-y_1-y_2)$ (14)

The first stage output from fuzzy rule given in (3), is calculated as

$y' = L^*(y_1-y_2)/(y_0+y_1+y_2)$ (15)

The second step: the output of first stage y' is further process in second step using (16) and a membership function as shown as in the Fig. 3.

$y=y' \text{ MAX}(\mu_{LA}(|y'|), 1- \mu_{ME}(P))$ (16)

3 EXPERIMENTAL RESULTS

Many computer simulations have been performed to analyze the performance of the proposed filter. The original image Lena of size 300X300 as shown in Fig. 5(a) has been considered for the study. This image is corrupted by 5% & 11% impulsive noise as shown in the Fig. 5(b), Fig. 5(c) respectively. For simulation, the parameters used are given in Table 1. The impulsive noise matrix generated using MATLAB routine. The program is tested on MATLAB. Symmetric padding (symmetric boundary value replication) is used in the filter for boundary condition.

(a) (b) (c)

Fig. 5 (a) Original Lena image, (b) image corrupted by 5% impulsive noise, (c) image corrupted by 11% impulsive noise.

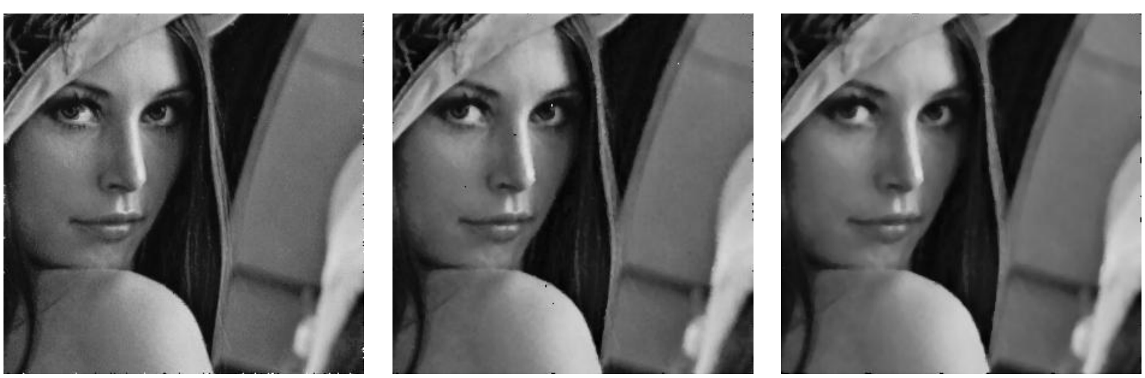
Table 1 Variable for membership function used in simulation.

	POS	NEG
a	-255	-255
b	240	-255
c	255	240
d	255	255

The results of proposed filter shown in the Fig. 6(a) and 7(a) have been compared with from 3X3 and 5X5 median filters and are shown in the Fig. 6(b), 6(b) and Fig. 7(c), 7(c) respectively.

(a) (b) (c)

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



(a) (b) (c)

Fig. 7 Results obtained by removing 11% impulsive noise using (a) proposed filter, (b) 3X3 median filter, (c) 5X5 median filter.

The performances of these filters are also compared by quantitative measurements using mean square errors (MSE) defined by (17) and peak signal to noise ratio (PSNR) in decibels defined by (18). As shown from the Fig. 8 & Fig. 9, the quantitative measurement justifies the performance of the proposed filter. The MSE for the proposed filter is much lower than 3x3 and 5x5 median filters, while PSNR is much better than median filters.

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M * N} \quad (17)$$

$$PSNR = 10 * \log_{10}(\frac{255 * 255}{MSE}) \quad (18)$$

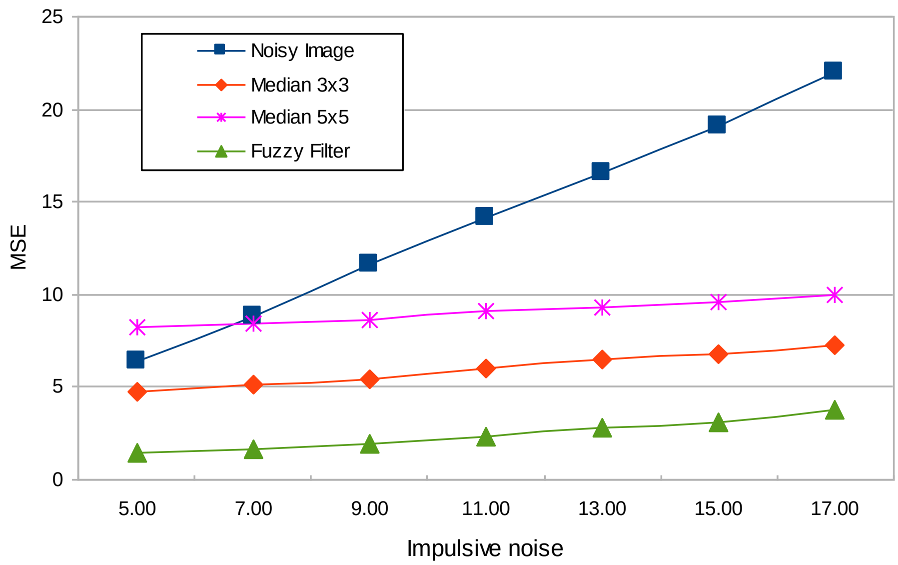


Fig. 8 Comparative MSE values for different filtering methods.

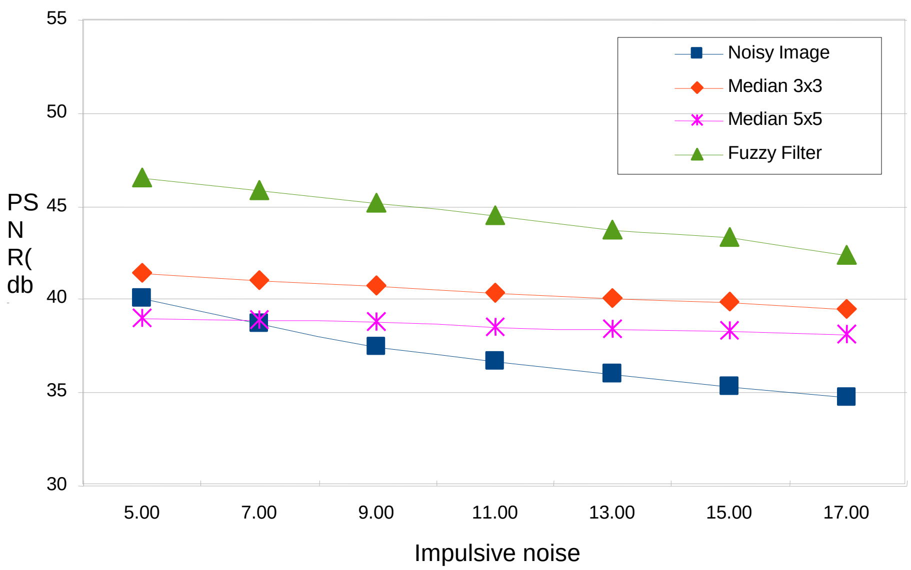


Fig. 9 Comparative PSNR values for different filtering methods.

4 CONCLUSIONS

The paper presents a simple fuzzy filter that 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 merits of the filter lie with the fact that it uses only eight rules for noise cancellation and easy to implement. It is highly efficient for the image up to 15% noise. Further, in case of noise more than 15%, a better result can be obtained by applying proposed filter twice.

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