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A Modified Switching Median Filter for Reduction of Impulse Noise

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Abstract*- This paper presents a new modified switching median filtering technique using fuzzy logic in image processing. This filter is able to remove impulse noise in digital images while preserving image details very well. The performances are compared with other filters such as median, center weighted median and traditional switching median filters for different levels of noise densities in terms of peak signal to noise ratio (PSNR). The subjective evaluations of the filters are also analyzed through various figures.*

Key words: salt-and-pepper noise, median filter, center weighted median filter, switching median filter, peak signal to noise ratio, fuzzy logic

1. INTRODUCTION

Image acquisition by the sensors on image capturing devices and/or the transmission of digital images through communication channels is often affected by impulse noise which is most commonly referred to as salt and pepper noise. When a digital image is contaminated by impulse noise, it hardly degrades the quality. In a motive to restore the images corrupted by impulse noise[1], the noise removal becomes an essential pre-processing step in digital image processing that usually enhances the quality of the image for further processing by machine vision systems. In an attempt to suppress the impulse noise from the corrupted image various kinds of noise removal filters have been proposed.

Among them, the median filter and its modifications are used widely because of their effective noise suppression capability. However, most of the median filters [3,6] are implemented uniformly across the image and thus tend to modify both noisy and noise-free pixels. Consequently, the effective removal of impulse noise is often accomplished at the expense of blurred and distorted features, thus removing fine details in the image. To avoid the damage of good pixels, the switching strategy was introduced where an impulse detector was used to determine whether a pixel should be modified. The switching median filters [12,8,9]have been shown to be simple and yet more effective than uniformly applied methods, such as median filter.

Recently, an efficient method in the removal of salt-and-pepper noise is introduced. With the growing appeal of fuzzy logic, employing fuzzy theories as an extension to the existing classical filters may prove useful and effective in the domain of noise removal in image processing. In this paper, a new algorithm [4,11,5]has been proposed to improve the filter performance in salt-and-pepper noise detection and cancellation. This new recursive filter is called the fuzzy switching median (FSM) filter. The FSM filter is composed of two semi-dependent modules, namely the salt and-pepper noise detection module and the fuzzy noise cancellation module. The fuzzy set used for noise cancellation does not require time-consuming tuning of parameters and thus no training scheme is required. This marked the simplicity of the proposed algorithm.

This paper is organized as follows: Section 2 describes the definition of salt and pepper noise. Section 3 describes the filtering scheme in response to the noise detection and reduction. Section 4 presents experimental results; the paper is concluded in Section 5 presents experimental results; the paper is concluded in section 5.

2. NOISE MODEL AND DIFFERENT RESTORATION FILTERS

Let us suppose we are dealing with grayscale digital image which intensity is stored in an 8-bit integer, giving a possible 256 gray levels in the interval [0, 255]. The noise can be either positive or negative. Positive impulse appears as white (salt) points with intensity 255 and probability *pw* in the image. Conversely, negative impulse appears as black (pepper) points with intensity 0 and probability *pb* in the image. In this paper, we define a low level salt-and-pepper noise as one having probability lies in the range 0 and up to $p = pw + pb = 0.25$, where $pw = pb$. If $p = 0.45$ or higher, the image is regarded as corrupted by high level of salt and-pepper noise. Otherwise, the image is said to be corrupted by a moderately high level of salt-and-pepper noise.

Median Filter

The standard median filter is a simple rank selection filter that attempts to remove impulse noise by changing the luminance value of the center pixel of the filtering window with the median of the luminance values of the pixels contained within the window. If we let {X(.,.)} and {Y(. , .)} be the input and output , respectively of the median filter then

$$Y(i,j) = median\{X(i-s, j-t) \mid (s,t) \epsilon W$$

Here W is the window that is defined in terms of the image coordinating in the neighborhoods of the origin. A (2N+1) × (2N+1) square window is given by

$$W = \{(s,t) \mid -N \leq s \leq N, -N \leq t \leq N$$

Weighted Median Filter

The weighted median (WM) filter [10] and the center weighted median filter are modified median filters that give more weight to the appropriate pixels of the filtering window.

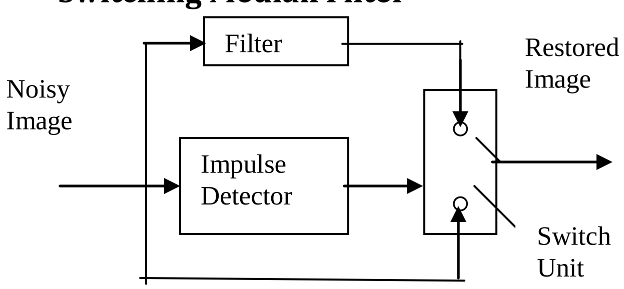
Center Weighted Median Filter

In center weighted median (CWM) filter [7] it gives more weight to the central value of a window. A WM filter with central weight h(0,0) = 2K+1 and h(s,t) =1 for each (s,t) not equals to (0,0) is called CWM filter Where K is a non negative integer. The output Y(i,j) is given by

$$Y(i,j) = median\{X(i-s, j-t),$$
$$2K \text{ copies of } X(i,j) \mid (s,t) \epsilon W$$

When K=0 the CWM filter becomes the median filter and when 2K+1 is greater than or equal to the window size 2L+1, it becomes the identity filter (no filtering).

Switching Median Filter



[Fig. 1 Block Diagram for SWM Filtering scheme]

The switching median filter (SWM) algorithm [12,2] uses the switching scheme which includes a procedure of preliminary impulse detection and a procedure of image filtering. The work of impulse detector is based on the comparison of a pixel value in the center of filtration window with maximum and minimum pixel values among all pixels within a window. If the pixel value is equal with maximum or minimum value within a filtration window then this pixel is considered to be a noisy pixel, otherwise a noise-free pixel. On the next step we run a procedure of image filtering itself, taking into account the information which we have obtained from the step of preliminary detection.

3. THE FUZZY SWITCHING MEDIAN FILTER

In case of FSM filter as long as X(i,j) equals any of the two salt-and-pepper noise intensities, the absolute luminance difference $g_{i+k,\ j+l}$ between the neighboring pixels and the central pixel in 3×3 window is calculated using

$$g(i+k, j+l) = |X(i+k, j+l) - X(i,j)|$$

$$with\ k, l \,\epsilon\, (-1,0,1)$$
$$and\ X(i+k, j+l) \neq X(i,j)$$

Next, the fuzzy input variable G(i,j) is determined. G(i,j) is the maximum fuzzy gradient value in the 3×3 filtering window and is given by:

$$G(i,j) = \max\{g(i+k, j+l)$$

It dictates that the maximum value of the absolute gradient among the eight neighboring pixels of X(i,j) in the 3×3 window W(i,j)will be used as the fuzzy input variable. The choice of selection on using the maximum operator over minimum operator will be explained later.

The fuzzy set (in Fig. 2) processes the neighborhood information represented by the input fuzzy variable G(i,j) to estimate a correction term which aims at canceling the noise. Mathematically, the fuzzy set f(i,j) is given by:

$$f(i,j) = \begin{cases} 0 & : 0 \leq G(i,j) < T1 \\ \dfrac{G(i,j) - T1}{T2 - T1} & : T1 \leq G(i,j) < T2 \\ 1 & : otherwise \end{cases}$$

where T1 and T2are the thresholds to perform partial correction as shown in Fig.

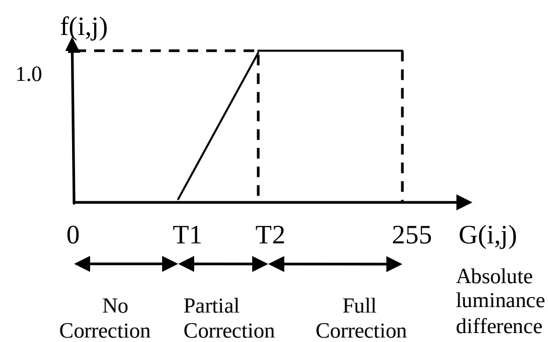


Fig.2. Fuzzy set adopted by the FSM filter

The correction term Y(i,j) for replacing the current pixel X(i,j). This correction term is also adopted by the median-based and SWM filters respectively.

$$Y(i,j) = (1 - f(i,j)X(i,j) + f(i,j)m(i,j)$$

where m(i,j) is the median of in the 3×3 window given by:

$$m(i,j) = median\{x(i-1, j-1), \ldots x(i,j),$$
$$\ldots x(i+1, j+1)\}$$

The corrected pixel Y(i,j) depends on a linear combination between X(i,j) and median m(i,j). The fuzzy membership value f(i,j) lends a weight on whether more of pixel X(i,j) or median pixel m(i,j) would be restored as the corrected pixel.

Similarly the corresponding pixels for 5×5 and 7×7 filtering window is calculated.

4. SIMULATION RESULTS

In experiments, the original test image (Lena face image) is degraded with 30% fixed valued salt-and-pepper. The size of the test image is 183×163. The Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) is used to evaluate the restoration performance in our experiment. The peak signal to noise ratio has been used for numeric estimation of algorithm's efficiency in this work. This criterion is shown in expression:

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

The MSE is defined as

$$MSE = \frac{\sum_{M,N}[F(i,j) - Y(i,j)]^2}{M \times N}$$

Here, R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R is 255, etc. M and N are the number of rows and columns in the input images. X(i,j) is the input noisy image image, F(i,j) is the original noise free image and Y(i,j) is the filtered image.

In this section, the performances of the Median Filter and its variants are compared. The FSM filter performs better as compared with other filters. The effect of thresholding T1 and T2 on the performance of FSM filter is not significant as long as T1 and T2 lies in a range that covers the switching of a pixel that is regarded as noisy or noiseless. The optimized value of T1 and T2 for the fuzzy set are T1=10 and T2=30

TABLE I
PSNR OF IMAGE DENOISING FILTERS FOR LENA FACE IMAGE UNDER DIFFERENT NOISE DENSITIES

Filter	Noise Density				
	10	20	30	40	50
LENA FACE IMAGE					
Median(3×3)	32.78	29.43	23.41	19.02	15.38
Median(5×5)	30.21	29.55	28.53	27.12	23.58
Median(7×7)	28.39	27.96	27.80	26.74	26.14
CWM(3×3)	37.68	36.16	31.80	25.47	22.22
CWM(5×5)	31.60	31.15	30.53	28.05	25.08
CWM(7×7)	28.85	28.64	28.19	27.47	26.13
SWM(3×3)	39.27	31.49	26.57	20.30	16.53
SWM(5×5)	39.01	35.69	32.54	29.05	24.99
SWM(7×7)	37.63	34.49	31.85	29.42	26.86
FSM(3×3)	39.87	33.18	26.01	20.31	16.69
FSM(5×5)	39.40	35.83	33.29	30.41	25.58
FSM(7×7)	38.36	34.46	32.28	30.93	29.49

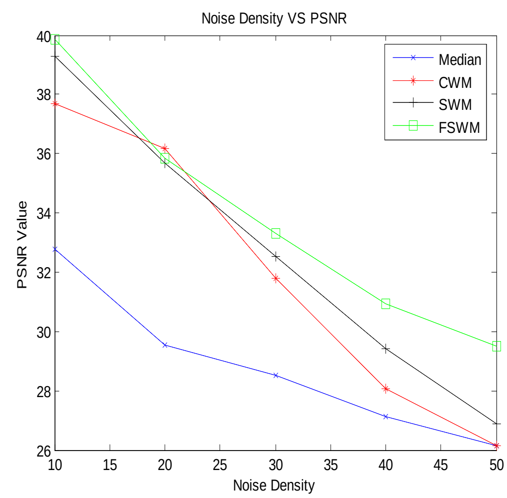
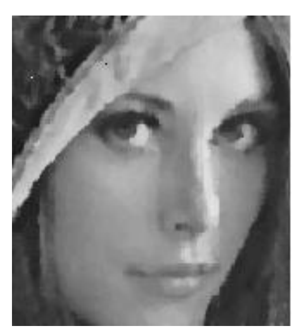


Fig.3. PSNR vs. Noise Density graph of filters

(a) (b)



(c) (d)




(m) (n)

(e) (f)


(g) (h)


(i) (j)


(k) (l)

Fig.4. (a) Original image (b) Noisy image with 30%SPN ;Filtered images by various filtered techniques (c) Median filter 3×3 (d) Median filter 5×5(e) Median filter 7×7 (f) CWM filter 3×3(g) CWM filter 5×5 (h)CWM filter 7×7 (i) SWM filter 3×3(j) SWM filter 5×5(k)SWM filter 7×7 (l) FSM filter 3×3 (m)FSM filter 5×5 (n)FSM filter 7×7

5.CONCLUSION

This paper presented a recursive fuzzy switching median filter which is an extension to the classical switching median filter by employing fuzzy inference mechanism. Simulation results show FSM could remove noise while preserving image details very well. Here we compared various denoising filters in terms of PSNR. The FSM filter out performs the median, CWM and SWM filter. It gives high PSNR as compared to other filters.

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