JOURNAL OF COMPUTING TECHNOLOGIES

ISSN 2278 – 3814

Available online at www.jctjournals.com

Volume 1, Issue 3, July 2012

Image Noise Detection and Reduction Technique Using Fuzzy Filter

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Abstract

Image restoration using fuzzy filtering method is very active research area in the image processing. The detection of the presence of the noisy pixels in the image tells the performance of the image filtering system. Most of the impulse noise detection schemes assume presence of salt and pepper noise in the images. In order to detect noise efficiently a better detection and reduction process is used which gives better results. In this paper, a new algorithm is presented to improve the performance of other filters. This method consists of two stages: initially the detection stage will detect the noisy pixels in the corrupted image and these detected noisy pixels are then forwarded to the filtering stage where we employ fuzzy method to reduce the noise present in the corrupted image and this filter also used to preserve the image details. The MSE, PSNR, SSIM are the parameters to measure worth of image restored.

Keywords: - Median filter, salt and pepper noise, MSE, SSIM, MSSIM

I. INTRODUCTION

Filtering is an essential part of any signal processing system, which involves estimation of a signal degraded, in most cases, by salt and pepper or impulse noise. Several filtering methods have been discussed over the years, for various applications. A very large portion of digital image processing is devoted to image restoration. Major areas of image processing are: Image Representation and Modeling, Image Transform, Image Enhancement, Image Filtering and Restoration, Image Analysis and Recognition, Image Reconstruction, Image Data Compression, Color Image Processing, etc. Image restoration is the important branch of the image processing, which deals with the reconstruction of image by removing noise blurriness, and making them suitable for human perception. The contamination of image by salt and pepper noise is largely caused by error in the image acquisition or recording. One of the simplest way to remove salt and pepper noise is by windowing the noisy image with median filter but this filter restores each pixel with the median pixel in the filtering window weather it is a noisy pixel or non noisy pixel, so this will blur the restored images. So in this paper we proposed a new type of salt and pepper noise filter which enables the filter to expand the size of its filtering window according to noise rate. This will speed up the filtering process at the same time it also preserving the image details by selecting only noisy pixels for processing. In this fuzzy technique is used to produce an accurate correction term which deals with the uncertainty present in the local information.

II. LITERATURE REVIEW

Fuzzy techniques have already been applied in several domains of image processing e.g. filtering, interpolation and morphology. But the main problem with the many image processing techniques is that they cannot work well in a noisy environment, so that we require the preprocessing module which helps to remove the noise from the corrupted image. Already several fuzzy filters for noise reduction had been developed, e.g., the well-known FIRE operator from [1], the weighted fuzzy median filter from [2], and the iterative fuzzy control based filter from [3]. Most fuzzy techniques in image noise reduction mainly deal with fat-tailed noise like impulse noise. These fuzzy filters were able to outperform rank-order filter schemes (such as the median filter). Lee, in their reviews [4], had divided spatial image restoration techniques into two broad categories named conventional and blind image restoration. In the first category, the techniques are used to solve motion blur, system distortions, geometrical degradations and additive noise problems. Information about the degradation process is generally known in these cases. This known information can be used in developing a model which can be used to restore the corrupted image back to its original form. Unfortunately, details about the degradation process are unknown in most of the cases, which make the image restoration process more demanding. Recently, more focus has been placed on the second category of image restoration, where the image has to be restored directly from the degraded image without any prior knowledge. Pitas et al. [5] , Tukey [6], and Pujar et al. [7] had utilized median filtering to remove impulse noise from the corrupted images. Other filters for removal of impulse noise includes histogram based fuzzy filter (HFF) [8], Lee et-al.'s novel fuzzy filter (NFF) [9], genetic based fuzzy image filter (GFIF) [10], fuzzy impulse noise detection and reduction method (FIDRM) [11], fuzzy random impulse noise reduction method (FRINR) [12], Guo et-al. universal impulse noise filter based on genetic programming [13], a new directional weighted median filter for removal of random valued impulse noise (DWM) [14] and detail preserving fuzzy filter (DPFF) [15] were the examples of the most recent filters. In addition, the median filter has been intensively studied and used in promising approaches such as weighted median (WM) [16] and center weighted median (CWM) [17] filters. The WM filter used a set of weighting parameters to control the filter performance in order to preserve the image details. The CWM filter was a special case of the WM filter, where only the center pixel of the filtering window has a weighting factor. Eng et al. [18] present a noise adaptive soft-switching median (NASM) filter to achieve a much-improved filtering. Experimental results show that the NASM filter impressively outperforms other techniques. Still, performance advantages of these approaches can be achieved only when the noise probability is low. Furthermore, there are many other filters proposed for removing impulse noise based on machine learning techniques. FIDRM and FRINR were recently proposed methods for impulse noise reduction; however, they employ only random valued impulse noise. DPFF and MHFF remove salt & pepper and additive long tailed impulse noise respectively.

III. NOISE DETECTION AND REDUCTION METHOD

The intensity of the noisy pixel will be different from its nearest surrounding pixels. Based on this factor our proposed method focuses on noisy pixels detection technique. Our proposed technique is two phase filters in which the detection phase is followed by the filtering phase. It will perform the salt-and-pepper noise intensities detection before identifying the locations of possible noise pixels. When a "noise pixel" is detected, it is subjected to the next filtering stage in other case that pixel is a "noise free pixel". The filtering action is used to avoid altering any fine details and textures that are contained in original image. The steps include for proposed filtering method is:

- Get the image
- Add salt and pepper noise with rate 0.1-0.95
- Select window size according to different noise rate
- Separate salt and pepper noise
- Use noise detection and reduction operation
- Restore the image at receiving end

A. Noise Detection Phase

The proposed fuzzy filter is used to utilize the noisy image as to estimate the salt and pepper noise intensities. The image detection is based on the assumption that a noise pixel takes a gray value between 0 and 255 which is different from the neighboring pixels in the filtering window, whereas noise free regions in the image have locally smoothly varying gray levels separated by edges. This method is used to find the salt and pepper noisy pixels in the entire image. The search will end until all the noisy pixels are found. When the noise intensities are wrongly detected, the salt and pepper noise will be left unfiltered in the noisy image. A binary mask is used to mark the location of noise pixels as in equation (1)

$$F(i,j)=\begin{cases}0 & X(i,j)=N_{salt} or N_{pepper}\\ 1 & otherwise\end{cases} \qquad (1)$$

Where $X(i,j)$ is the pixel at location (i,j) with intensity X, $F(i,j)=1$ represents "noise free pixels" to be retained from the noisy image while $F(i,j)=0$ represents "noise pixels" given to the next filtering stage.

B. Noise Filtering Phase

This is the second phase of the fuzzy filtering method. In this phase we have used squaring filtering window $w_{2s+1}(i,j)$ with odd $(2s+1)*(2s+1)$ dimensions which are given as equation (2). In this method noisy pixels with $F(i,j)=0$ will be replaced by estimated correction term which will be find by the median of the noise free pixels in the selected window.

$$w_{2s+1}(i,j)=\{(i+m,j+n)\} \qquad (2)$$

where $m,n \in (-s,......0,.....,s)$.

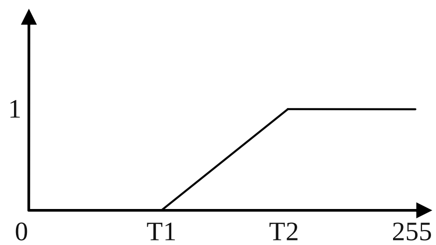


Figure 1. Fuzzy membership function

If selected window does not have minimum number of "noise free pixels" then that filtering window size will be expanded by one pixel at each of its four sides. The noise free pixels in the filtered window are selected to correct the noisy pixels. In one condition if no noise free pixel is detected although the window sixe for filtering process reaches 7*7 then in this case first four pixels in 3*3 window is selected and used to compute the median pixel. The noisy pixels are replaced by the median of the noise free pixels $M(i,j)$ in the selected window, given by equation (3)

$$M(i,j) = median\{X(i+m, j+n)\} \quad (3)$$

With $F(i+m, j+n) = 1$

firstly we compute the absolute luminance difference by using equation (4)

$$d(i+k, j+l) = |X(i+k, j+l) - X(i,j)| \quad (4)$$

With $(i+k, j+l) \neq (i,j)$.

Then the local information is found by maximum absolute luminance difference between in the selected window as in equation (5)

$$D(i,j) = \max\{d(i+k, j+l)\}. \quad (5)$$

From this luminance difference we can find maximum or minimum operator but the choice of using maximum absolute luminance difference rather than minimum is that in this operation "noise pixels will set to 255 while "noise free pixels" will assume other values in dynamic range. So with this in turn conveys local information such as image details, thins lines and noise free pixels for further processing. But minimum absolute luminance difference is even unable to find the difference between the noise pixels and noise free pixels [26]. Now fuzzy technique is used with this extracted value as in equation, where the local information is used as fuzzy input variable and two threshold values are used for optimal performance.

$$f(i,j) = \begin{cases} 0 & : \quad D(i,j) < T1 \\ \dfrac{D(i,j) - T1}{T2 - T1} & : \quad T1 \le D(i,j) < T2 \\ 1 & : \quad D(i,j) \ge T2 \end{cases} \quad (6)$$

At last the correction term to restore a detected "noise pixel" is a linear combination between the processing pixel and median pixel. The restoration term is given in equation (7)

$$Y(i,j) = [1 - f(i,j)].X(i,j) + f(i,j).M(i,j) \quad (7)$$

Where fuzzy membership value $f(i,j)$ puts a weight on whether more of the pixel $X(i,j)$ or $M(i,j)$ is to be used.

IV. SIMULATION RESULTS AND DISCUSSION

In this framework it is assumed an image corrupted with P% of salt and pepper noise is made up of 0.5% of salt and 0.5% of pepper noise. Two standard test images (boats, goldhill) are used are contaminated with salt and pepper noise ranging from 0.5-0.95 with increment steps of 1.0, which are to be used in simulations. In order to test the proposed algorithm corrupted images are restored at different level of noise on different image (boats, goldhill) of size 256*256. To evaluate the image restoration performance, MSE (mean square error), PSNR (peak signal to noise ratio), SSIM (structural similarity index module) and MSSIM (mean structural similarity index module) where

$$\text{MSE(F,O)} = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}[O(i,j) - F(i,j)]^2, \quad (8)$$

$$\text{PSNR(F,O)} = 10\log_{10}\frac{S^2}{MSE(F,O)} \quad (9)$$

$$SSIM(a,b) = \frac{(2\mu_a\mu_b + C_1)(2\sigma_{ab} + C_2)}{(\mu_a^2\mu_b^2 + C_1)(\sigma_a^2 + \sigma_b^2 + C_2)} \quad (10)$$

Where O is the original image, F is the restored image of size NM and S is the maximum possible intensity value. The SSIM indices measure the structural similarity between two images. Suppose a and b are two non-negative image signals, if one of the signals is considered to have perfect quality, the similarity measure can be used as a quantitative measurement of the quality of the second signal and computed by SSIM.

Table 1. MSE index for different images for different noise rate (0.1-0.95).

Noise Rate	MSE (Boats)	MSE (Goldhill)
0.1	11.1048	15.0761
0.2	27.8326	30.8454
0.3	45.9690	52.1851
0.4	101.3088	84.9667
0.5	138.3450	115.3638
0.6	198.6986	167.4313
0.7	254.9899	198.7192
0.8	320.8708	255.0907
0.9	427.7395	356.2520
0.95	619.3816	481.6242

Table 2. PSNR index for different images for different noise rate (0.1-0.95).

Noise Rate	PSNR (Boats)	PSNR (Goldhill)
0.1	37.6757	36.3479
0.2	33.6853	33.2389
0.3	31.5062	30.9553
0.4	28.0743	28.8383

0.5	26.7212	27.5101
0.6	25.1489	25.8924
0.7	24.0656	25.1484
0.8	23.0675	24.0639
0.9	21.8890	22.6132
0.95	20.2112	21.3037

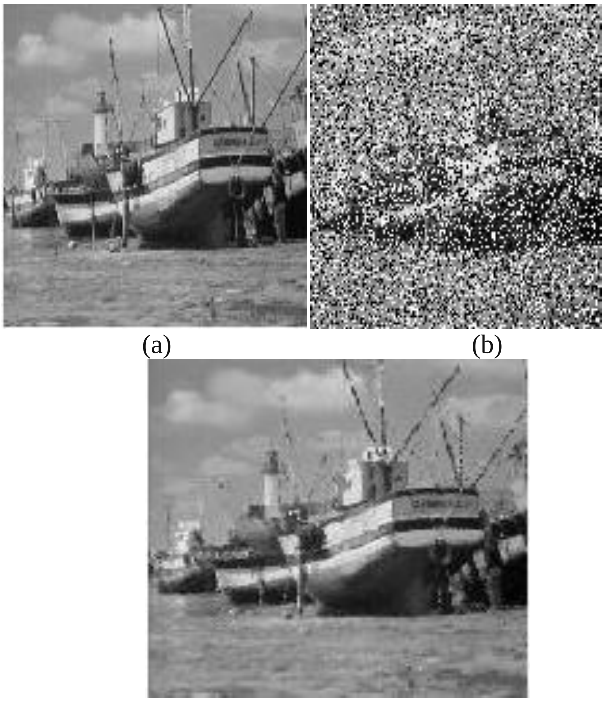
0.5	0.8510	0.8246
0.6	0.7838	0.7503
0.7	0.7335	0.6885
0.8	0.6710	0.6229
0.9	0.5794	0.5148
0.95	0.4971	0.4300

Table 3. SSIM index for different images for different noise rate (0.1-0.95).

Noise rate	Min. SSIM (Boats)	Max. SSIM (Boats)	Min. SSIM (Goldhill)	Max. SSIM (Goldhill)
0.1	0.5356	1	0.3742	1
0.2	0.4213	0.9999	0.5160	0.9999
0.3	0.2763	0.9998	0.3732	0.9992
0.4	0.1752	0.9935	0.2280	0.9997
0.5	0.0011	0.9979	0.1277	0.9975
0.6	-0.1678	0.9976	-0.0312	0.9966
0.7	-0.1853	0.9954	-0.2324	0.9901
0.8	-0.2825	0.9948	-0.4589	0.9870
0.9	-0.5359	0.9899	-0.3732	0.9865
0.95	-0.6194	0.9808	-0.5747	0.9838

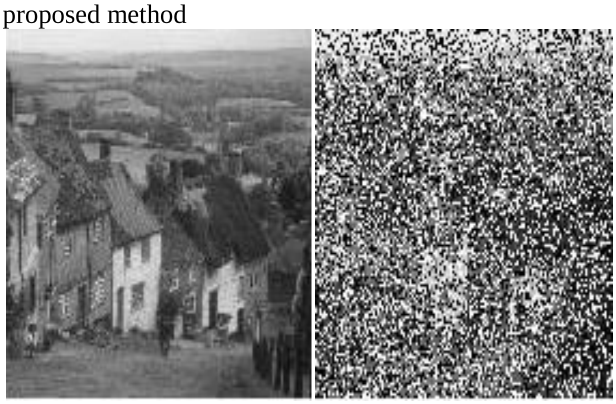
Table 4. MSSIM index for different images for different noise rate (0.1-0.95).

Noise Rate	MSSIM (Boats)	MSSIM (Goldhill)
0.1	0.9347	0.9759
0.2	0.9664	0.9499
0.3	0.9468	0.9166
0.4	0.8856	0.8675



(a) (b) (c)

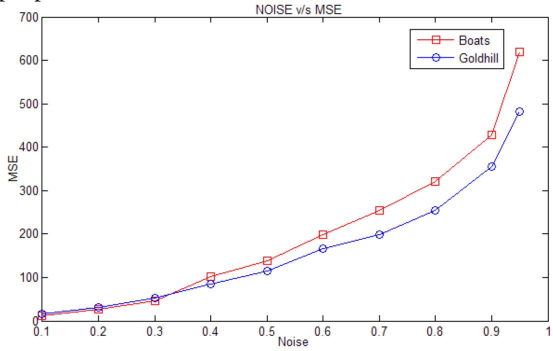
Figure 1 (a) Original “Boats” image (b) “Boats” image corrupted 0.4 of salt and pepper noise. (c) output of the proposed method



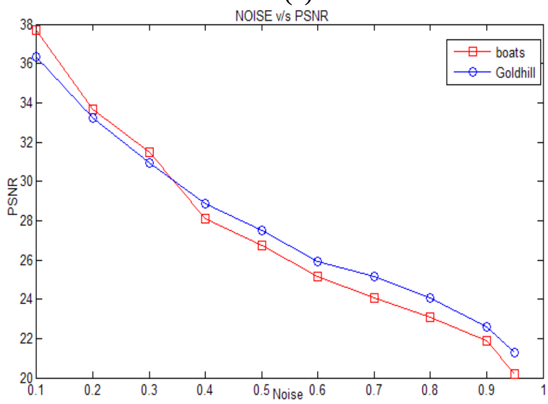
(a) (b)

(c)

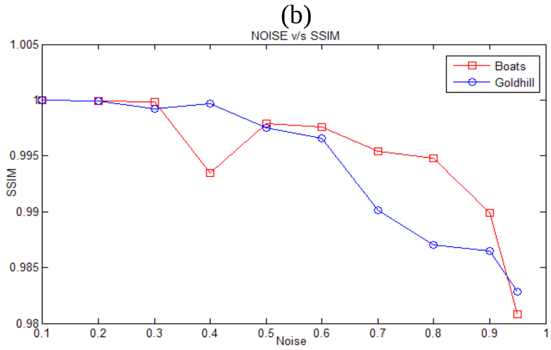
Figure 2 (a) Original “Goldhill” image (b) “Goldhill” image corrupted 0.5 of salt and pepper noise. (c) output of the proposed method



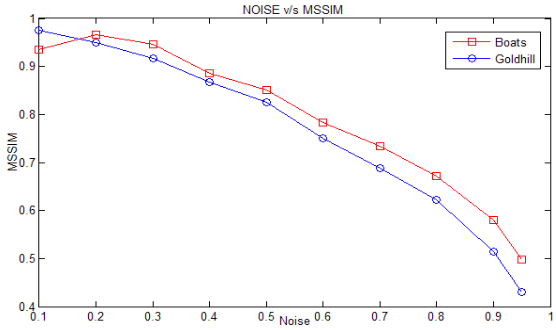
(a)



(b)



(c)



(d)

Figure 3. Comparison of proposed technique based on MSE, PSNR, SSIM and MSSIM with different salt and pepper noise corrupted images (boats, goldhill) (a) Comparison of proposed technique based on MSE with different salt and pepper noise corrupted images (0.1-0.9) (b) Comparison of proposed technique based on PSNR for salt and pepper noise corrupted different test images (0.1-0.9) (c) Comparison of proposed technique based on SSIM for salt and pepper noise corrupted different test images (0.1-0.9) (d) Comparison of proposed technique based on MSSIM for salt and pepper noise corrupted different test images (0.1-0.9).

V. CONCLUSION

From the experimental results we concluded that our proposed filter gives much better results than the other filtering techniques for high noise rate and also used to preserve the image details using fuzzy membership function. So we have improved image quality at the receiver end in terms of MSE, SSIM, PSNR and MSSIM and we have these improved results with the salt and pepper noise insertion rate (0.1-0.95).

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