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Modified Adaptive Median Filter for Salt & Pepper Noise

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Abstract: In this paper, an image denoising filter for salt & pepper noise is proposed. We introduced a ROAD (Rank Order Absolute Difference) statistics in this filter to identify the noisy pixels in image corrupted with salt & pepper noise. ROAD statistics values quantify how different in intensity the particular pixels are from their most similar neighbours. After identify the presence of impulse noise, adaptive window filtering concept is used to filter the salt & pepper noise. To evaluate the performance of proposed filter, both quantitative and qualitative techniques are used and a comparison is carried out between proposed filter and other standard filters, it is observed from experimental results that proposed filter performs remarkably well in filtering and preserving the image detail as compared to well known standard filters.

Index Terms: Adaptive window, Impulse noise, Median, PSNR, ROAD,UQI.

I. Introduction

Digital images get contaminated by impulse noise during image acquisition/transmission. The intensity of impulse noise has the tendency of being either relatively high or relatively low. Thus, it could severely degrade the image quality and cause great loss of information details. So it becomes important to suppress this noise in the images before some subsequent processing, such as edge detection/extraction, image segmentation and object recognition. In the literature, various filtering techniques have been proposed for removing impulse noise and it is well-known that linear filters could produce serious image blurring. As a result, nonlinear filters have been widely exploited due to their much improved filtering performance, in terms of impulse noise attenuation and edge/details preservation. One of the most popular nonlinear filters is the standard median (SM) filter [1], which exploits the rank-order information of pixel intensities within a filtering window and replaces the center pixel with the median value. Due to its effectiveness in noise suppression and simplicity in implementation, various modifications of the SM filter have been introduced, such as the weighted median (WM) [2] filter and the center weighted median (CWM) [3] filter. Conventional median filtering approaches apply the median operation to each pixel unconditionally i.e. without considering whether it is uncorrupted or corrupted. As a result, even uncorrupted pixels are filtered, and this causes image quality degradation. A better solution to overcome this problem is to implement an impulse-noise detection mechanism prior to filtering; hence, only those pixels identified as "corrupted" would undergo the filtering process, while those identified as "uncorrupted" would remain intact. In this paper, an adaptive window based salt & pepper noise removal filter is proposed. In this filter, ROAD statistics is introduced to quickly identify the noisy pixels.

II. Impulse Noise

Impulse noise affects image pixel by pixel and not the whole area of an image. This noise is introduced due to acquisition/transmission errors. Impulse noise can be of two types:

- Random Values Impulse Noise (RVIN)
- Salt & pepper noise

The Salt and Pepper (SP) noise is also called as fixed valued impulse noise, it will take a gray level value either minimal (0) or maximal (255) (for 8-bit monochrome image) in the dynamic range (0-255). It is generated with the equal probability. In the case of salt and pepper noise, the image pixels are randomly corrupted by either 0 or 255. That pixel is replaced by either white value (255) or black value (0) that's why it is called as salt & pepper noise.

For each image pixel at location (i,j) with intensity value O(i,j), the corresponding pixel of the noisy image will be X(i,j), in which the probability density function of X(i,j) is

$$p(x)=\begin{Bmatrix} \frac{p}{2} & for\ x=0 \\ 1-p & for\ x=o_{i,j} \\ \frac{p}{2} & for\ x=255 \end{Bmatrix} \tag{1}$$

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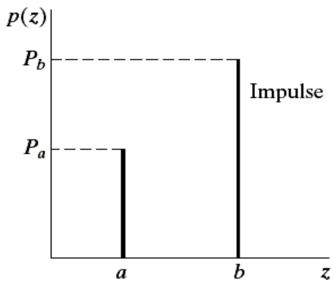

Fig. 1: Probability density function of impulse noise

Random Valued Impulse noise (RVIN) is also called as variable type impulse noise which also replaces some pixels with random values like salt & pepper noise but in the range [0 255](in case of 8 bit gray scale image).

III. MEDIAN FILTER

The best known order statistic filter is the median filter which replaces the value of the pixel by the median of the gray levels in the neighbourhood of that pixel [1] i.e.

$$Z_{(x,y)} = \mathrm{median}_{(s,t)\in S_{xy}}\{g(x,y)\} \qquad (2)$$

The value of the pixel at (x,y) is included in the computation of the median. Since the median value must actually be the value of one of the pixels in the neighbourhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason, the median filter is much better in preserving sharp edges than the mean filter. These advantages aid median filters in suppressing the uniform noise as well as other noises.

IV. RANK –ORDERED ABSOLUTE DIFFERENCE (ROAD) STATISTICS

Rank – Ordered Absolute Difference (ROAD) Statistics [11] is a local image statistics proposed to detect outliners in image in 2005. It provides a measure of how close a pixel value is to its M most similar neighbors in intensity. Let x be the central pixel of its (2N+1) × (2N+1) neighborhood in the input image. For each pixel $y\epsilon\Omega$, we define $d_{(x,y)}$ as the absolute difference in intensity between x and y :

$$d_{(x,y)} = |\, I(x) - I(y)| \qquad (3)$$

Then we sort the eight $d_{(x,y)}$ values, and the smallest m values together to form the Rank – Ordered Absolute Difference (ROAD) Statistics:

$$\mathrm{ROAD}_m(x) = \sum_{i=1}^{m} r_i(x) \qquad (4)$$

Where $2\le m\le 7$, and $r_i(x)$ = i th smallest $d_{(x,y)}$ for $y\epsilon\Omega$. In Proposed Filter, m=4 is taken.

V. BILATERAL FILTER

The bilateral filter is non linear filter proposed by Aurich and Weule, Smith and Brady and Tomasi and Manduchi to smooth images. It has been adopted for filtering additive white Gaussian noise (Tomasi and Manduchi). The rationale of bilateral filter is that, two pixels are close to each other not only if they occupy nearby spatial locations but also if they have some similarity in the photometric range. The weight $W_s(x,y)$ of each neighbour combines a spatial weight component $W_R(x,y)$ that penalizes pixels with different weight between the intensities of central pixel I(x) and its neighbouring pixel I(y).

$$I_{out}(x) = \frac{1}{k(x)}\sum_{y\epsilon\Omega} w_s(x,y)\, w_R(x,y) I(y) \qquad (5)$$

$$K(x) = \sum_{y\epsilon\Omega} w_s(x,y)\, w_R(x,y) \qquad (6)$$

$$W_s(x,y) = e^{\frac{|\, x-y\, |^2}{2\sigma_s^2}} \qquad (7)$$

$$W_R(x,y) = e^{\frac{|\, I(x)-I(y)\, |^2}{2\sigma_R^2}} \qquad (8)$$

VI. PROPOSED FILTER

In this algorithm, ROAD (Rank Ordered Absolute Difference) statistics has been introduced to inspect the presence or absence of salt & pepper noise in the acquired image; the calculated ROAD value for a particular window decides that whether window is corrupted or not. if the ROAD of the selected window is greater than the predefined threshold, this shows that window is noisy; then adaptive median filter works on the selected window to denoise it from salt & pepper noise; otherwise selected window is retained as it is, and filter select the next window for detection and suppression of the salt & pepper noise.

VII. EXPERIMENTAL RESULTS

We have extensively tested the performance of our algorithm and compared the results with some existing methods. Evaluation Parameters PSNR (dB) and UQI are presented in this paper to validate the filtering performance of PF.

Calculation of PSNR (dB) and UQI:

To calculate the PSNR and UQI, Let the original noise-free image, noisy image and the filtered image be represented by f (x, y), g(x, y) and $\tilde{f}(x, y)$, respectively. Here, x and y represent the discrete spatial coordinates of the digital images. Let the image be of size M×N pixels, i.e. X=1,2,3,…,M, and Y=1,2,3,…,N.

(a) Mean Absolute Error (MAE)

Mean Absolute Error (MAE) gives measure of image dissimilarities between original image and restored image respectively.

$$\mathrm{MAE} = \frac{1}{M\times N}\sum_{i=1}^{m}\sum_{j=1}^{n} \mathrm{abs}(f(x,y - \tilde{f}(x,y)) \qquad (9)$$

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(b) Image Enhancement Factor (IEF)

Image Enhancement Factor (IEF) gives a measure of image quality restored.

$$\mathrm{IEF} = \frac{\sum_{i,j}(g(x,y)-f(x,y))^2}{\sum_{i,j}(\tilde{f}(x,y)-f(x,y))^2} \quad (10)$$

Experimental Results:

To evaluate the results of different approaches and to compare the quality of filtered images; various tests were conducted with PF and other standard filters. In all these tests, salt & pepper noise with variance values ranging from 0.1 to 0.5 was added in the Lena image to get the test image. This test image was used for simulation purpose to obtain a thorough evaluation of the proposed algorithm and standard filters. A comparison has been made amongst Mean filter, Median filter, Wiener filter, Adaptive median filter, Bilateral filter, Double Bilateral filter and Trilateral filter. To demonstrate the filtering performance of all filters; results of various tests in terms of MAE and IEF are shown graphically in fig.3 and fig.4.

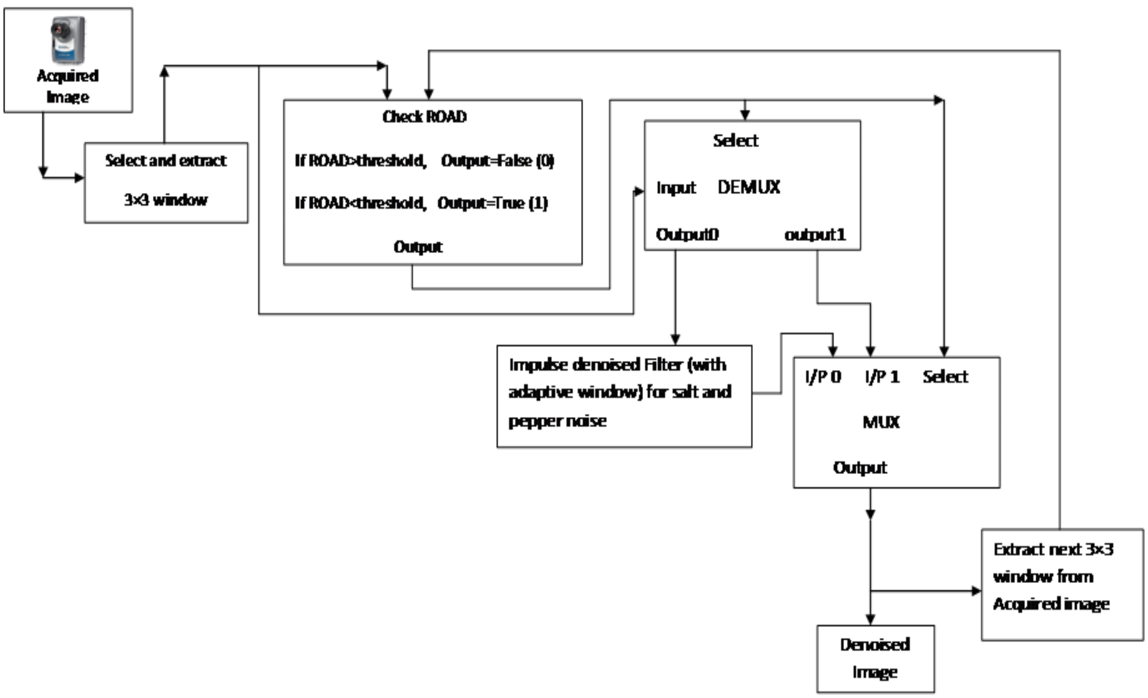

Fig.2: Architecture of Proposed Filter

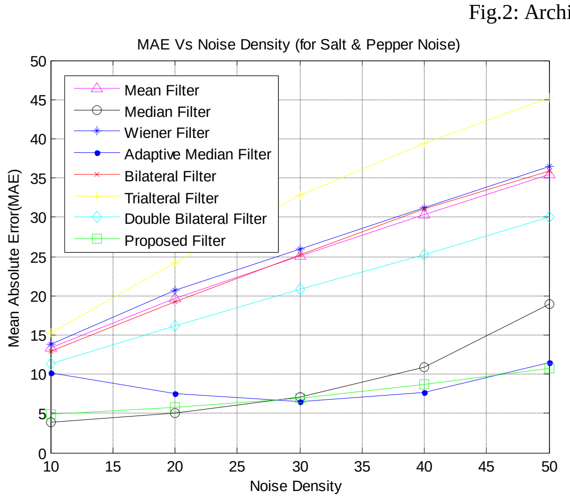

Fig. 3: Performance comparison of various filters in terms of MAE, calculated on Test Image containing different noise levels of salt & pepper noise.

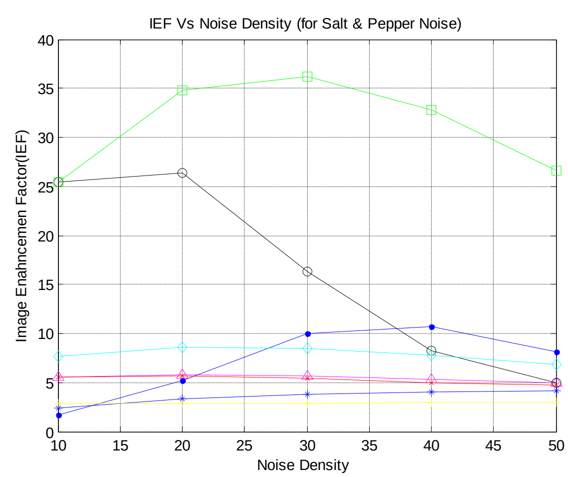

Fig.4: Performance comparison of various filters in terms of IEF, calculated on Test Image containing different noise levels of salt & pepper noise.

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It is observed from fig.3 and fig.4 that at lower noise density i.e. (σ_g =0.1 or 10%),the performance of Wiener filter in terms of MAE is better than proposed filter but as density of noise increased; performance of PF improves and becomes better than Wiener Filter and other standards filters. Similarly, at low and moderate noise densities, performance of Median filter and Bilateral filter in terms of IEF (Image Enhancement Factor) is approximately equal to IEF value of proposed filter but these filters are unable to retain their performance for highly corrupted images and at higher noise densities (i.e. at σ_g =0.3 to 0.5), PF has highest IEF value than other filters. So it is clear from these performance measures that the filtered image of proposed filter is more similar to uncorrupted image; in other words, image quality of output image of PF is better as compared to other filters.

VIII. CONCLUSION

In this paper, we proposed a modified adaptive median filter to remove the salt & pepper noise. In the proposed filter, we introduce a ROAD statistic in some neighborhood of a pixel to process impulse pixels and edge pixels differently. In other words, Rank-Ordered Absolute Differences (ROAD) statistic is used to detect the presence of impulse noise in corrupted image because it works in both domains i.e. geometric domain and intensity domain. At the end, to check the filtering performance of the proposed filter; various tests were conducted by taking various salt & pepper noise corrupted gray scale images as test images. It is observed from quantitative analysis in terms MAE and IEF as shown in fig.3 & fig.4 that the proposed filter performed better than other standard filters at all noise densities. Subjective evaluation/ Visual comparison shown in fig.5 conclude that PF is more capable to preserve the image detail as compare to other denoising methods.

VISUAL COMPARISON

(a)Original Lena Image

(b)

(c)

(d)

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(e)


(f)


(g)


(h)


(i)


(j)

Fig.5: Performance of Various Filters for Lena Image corrupted with salt & pepper noise (σ_I(standard Deviation) = 30%) (a) Original image (b) Noisy image (c) –(j): Results of various filtering schemes (c) Output of Mean Filter (d) Output of Median Filter (e) Output of Wiener Filter (f) Output of Adaptive Median Filter (g) Output of Bilateral Filter (h) Output of Double Bilateral Filter (i) Output of Trilateral Filter (j) Output of Proposed Filter.

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