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Adaptive Window Based Multi Stage Impulse Noise Detection for Removal of Random Valued Impulse Noise in Digital Images

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Abstract: Image denoising has an increasing importance in digital image processing as digital images are usually corrupted by different noises during amplification and transmission. Impulse noises are added due to the errors in the transmission channel and sensors in the path. In this study, a new method for the removal of Random Valued Impulse Noise (RVIN) is proposed. The entire process includes noise pixel detection and denoising. Corrupted pixels are detected in the four steps and the median filtering is applied for this noisy pixels. In each step, noisy pixels are detected based on the pre-defined threshold values and median filtering is applied in each step. Noisy pixels are removed in the successive steps. The simulation results show that the proposed method shows better performance over compared algorithms both in terms of peak signal to noise ratio and mean absolute error.

Key words: Random valued impulse noise, image denoising, adaptive window, median filter, image restoration

INTRODUCTION

Digital image processing has wide range of increasing applications like medical image processing, remote sensing, robotics and many security applications. The main sources of noises in images are transmission of digital image, acquisition and its amplification. Noise removal seems to be simple, but to preserve the image features along with the noise detection is a complex one. Impulse noises are generated in the noisy sensors and during the transmission through the communication channel. Random valued impulse noise model can be defined as follows:

$$x_{ij} = \begin{cases} O_{ij} & \text{with probability } 1\text{-}\rho \\ N_{ij} & \text{with probability } \rho \end{cases} \quad (1)$$

Where:

ρ = The noise probability

O_{ij} and N_{ij} = The original image pixel value and noisy image value at location (i,j)

Impulse noised pixel values ranges from 0-255. There are two types of impulse noise: Fixed Valued Impulse Noise (FVIN) and Random Valued Impulse Noise (RVIN). Fixed valued impulse noise is also called as salt and pepper noise. The noise value of the corrupted pixel will be equal to 0 or 255 which is called salt value (255) and pepper value (0). For random valued, noise value of the corrupted one will be uniformly distributed between 0 and 255. So, the removal of random valued impulse noise is challenging compared to the fixed valued noise. A variety of schemes have been proposed for removing impulse noise. One of the common methods is the median filtering. Even though, it has higher denoising capability it cannot properly remove the noise pixels when the noise density is above 50%. The edge details will be lost (Bovik, 2010). Some modified filters are introduced such as Center Weighted Median filter (CWM) (Ko and Lee, 1991). It effectively removed the impulse noise but blurring and some features are distorted. Number of noise removal methods has been introduced later which includes different noise detection schemes. These are used to remove the damage and information loss in the pixels. These methods include a noise detector and a noise reduction section. Ebenezer and Manikandan (2007) have been proposed a detail preserving neural median filter to reduce streaks and false alarm for noise reduction in images. Vasanth and Senthilkumar (2012) has proposed an unsymmetrical trimmed variants to detect the impulse noise. Tri State Median filter (TSM) (Chen *et al*., 1999) suppresses impulse noise and preserves pixel details. Adaptive Center Weighted Median filter (ACWM) (Chen and Wu, 2001). The difference between current pixel and CWM output with different center weight is utilised. Thirumurugan and Kumar (2013) proposed an edge preserving methodology to detect the impulse noise affected pixels using Cloud algorithm. In Switching Median filter (SM), a switching scheme was utilised before filtering. Progressive Switching Median (PSM) filter was proposed by Wang and Zhang (1999) consists of switching scheme with two stages of noise image

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processing. The Multistate Median (MSM) filter (Chen and Wu, 2000) is based on the switching median filter which used threshold logic for adaptively switching among different center weights of the MSM filter. It proposes a generalised frame work. Artificial intelligence based noise detection and reduction techniques have been introduced in the last few years. A simple and efficient method that separates image details from impulse and an iterative filtering based noise removal was proposed in PW-MAD (Crnojevic *et al*., 2004). An iterative weighted median filter (Ghanekar *et al*., 2010) which incorporates a nonlinear function to discriminate noisy and noise-free pixels effectively but it requires more computation time.

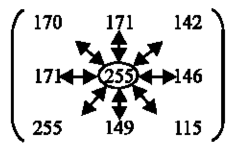
MATERIALS AND METHODS

In this study, a new method for the image denoising is introduced which is based similar neighbourhood criterion. Apart from fixed value impulse noise random valued noise is uniformly distributed over the image, hence number of similar pixels randomly changes. The detection is done using different steps. Each step includes detection of noise pixels, while preserves the pixel details. The proposed denoising method consists of four phases for the noise detection. For random valued impulse noise, noise pixel has random intensity values, hence it is better to have number of detection stage for preserving image details. There is no need of optimizing parameters and hence, the implementation is quite simple. The threshold values in each stage are determined based on the literature survey and trial and error method. The entire process includes two stages of operation; detection of impulse noise and impulse noise filtering.

Four phase detection of random valued impulse noise: The proposed detection method includes detection and four stages of denoising. The denoising is based on predefined threshold values. The method consists of four stages. In the first stage, the elements in a 3×3 window are considered. The center pixel is compared with every neighboring pixel in the window. Mean value of this absolute difference is calculated and is compared with a predefined threshold. If the mean value is greater than the threshold then pixel is found noisy. Let $X_{i,j}$ be the pixels considered in the 3×3 window centered at x and is given as the matrix value:

$$\begin{pmatrix} 170 & 171 & 142 \\ 171 & \textcircled{255} & 146 \\ 255 & 149 & 115 \end{pmatrix}$$

The center pixel value is 255. Center pixel is compared with remaining eight pixels. Absolute difference between 255 and other pixel value is calculated for each pixel y∈X, d_{xy} denotes the absolute difference between the intensity values of the center pixel and neighbor pixel. Hence, eight difference values are obtained:



The matrix below shows absolute difference d_{xy} between the center pixel 255:

$$\begin{pmatrix} 85 & 86 & 113 \\ 86 & 0 & 109 \\ 0 & 106 & 140 \end{pmatrix}$$

The mean value of this absolute difference is taken for determining whether the pixel is noisy or not. The mean value of these d_{xy} is denoted as S_1:

$$S_1 = \frac{1}{8}\sum_{i=1}^{n} d_{xy} \quad (2)$$

If the S_1 is greater than the predefined threshold value of the first stage then the test pixel is considered as noisy. A nominal value of 90 is taken as the threshold value (T_1) for the first phase.

If $S_1 > T_1$, pixel is noisy; the noisy pixel is eliminated from the window using median filtering and it is replaced by the median luminance value of the remaining pixels. Intensity value of the corrupted pixel can be quite similar to the neighbors as the impulse noise can take any value. Therefore, these corrupted pixels considered as original pixels until they are found noisy in the proceeding stages with lower threshold values.

In the second stage, 5×5 window is considered with lower threshold value. The center pixel is compared with remaining twenty four pixels. The S_2 is calculated by taking the mean value of the difference between each pixel:

$$S_2 = \frac{1}{24}\sum_{i=1}^{n} d_{x,y} \quad (3)$$

The threshold value in the stage is lower than the first stage in order to avoid more noisy pixels. Threshold value of 85 is taken for the second phase. If S_2 is greater than threshold it is considered as noisy and median filtering is applied. In the third and fourth phases, similar operations performed in the first and second steps are repeated for lower threshold values. This is for the detection of the noisy pixels which were missed in the first and the second stages. When, the noise density is low, detection of the all noisy pixels is completed after the one or two stages. Threshold value for the third and fourth phase is taken as 80. When, the noise density is high detection of the all noisy pixels requires three or four stages.

Filtering stage: The detected noisy pixels are eliminated from the window. The value of the noisy is replaced by the median luminance of the remaining pixel in the window. Median filtering is applied after each phase. If the center pixel is found noisy, it is eliminated from the window. This is shown in the above figure and the noisy pixel is replaced by median value of the remaining. If center pixel value 255 is noisy, it is replaced with 149. Median filtering is applied after other three phases also. First, detection phase is to detect any pixel that has a dissimilar value amongst other pixels in the window selected. Corrupted pixels are uniformly distributed between 0 and 255 for RVIN. So, in high noise densities most similar pixels of the any noisy pixel in 3×3 sliding window may be all corrupted and also luminance values will be similar to the tested pixel. In this case, mean value of the differences between neighboring pixel will be small, although the tested pixel is corrupted. In order to prevent missing of the noisy pixels at high noise density and low noise density conditions the threshold values for first phase must be selected as big enough. Peak Signal to Noise Ratio (PSNR) and Mean Absolute Error (MAE) are used to compare the performance of the proposed and existing method.

RESULTS AND DISCUSSION

The test images used are Lena and flowers. The simulation results are compared and analysed with other existing schemes for their performance in terms of peak signal to noise ratio and mean absolute error:

$$\text{PSNR}=10\log_{10}\left(\frac{255^2}{\text{MSE}}\right)\text{dB} \tag{4}$$

Where, Mean Squared Error (MSE) is defined by:

$$\text{MAE}=\frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left|o(i,j)-r(i,j)\right| \tag{5}$$

Simulation results: The restoration results for Lena and flowers e corrupted with 50 and 30 % impulse noise are illustrated in Fig. 1 and 2, respectively. The proposed method output is compared with Adaptive Center Weighted Median filter (ACWM), Pixel Wise MAD (PWMAD) and Contrast Enhancement Filter (CEF). It is clearly seen from Fig. 1 and 2 the proposed filter preserves edge sharpness and shows better performance in noise detection compared to other filters.

The proposed method gives better PSNR and MAE with other filters. It shows better tradeoff between impulse noise detection and enhancement.

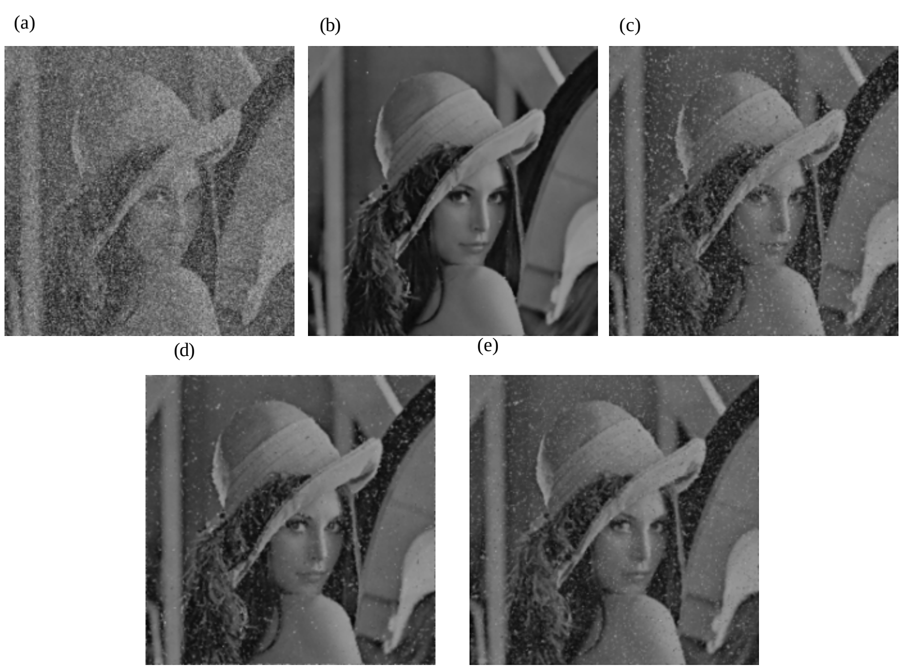


Fig. 1: Output images from different filters for the 50% corrupted Lena image: a) Noisy Lena image; b) Proposed method (PA); c) ACWMF; d) PW-MAD; e) CEF

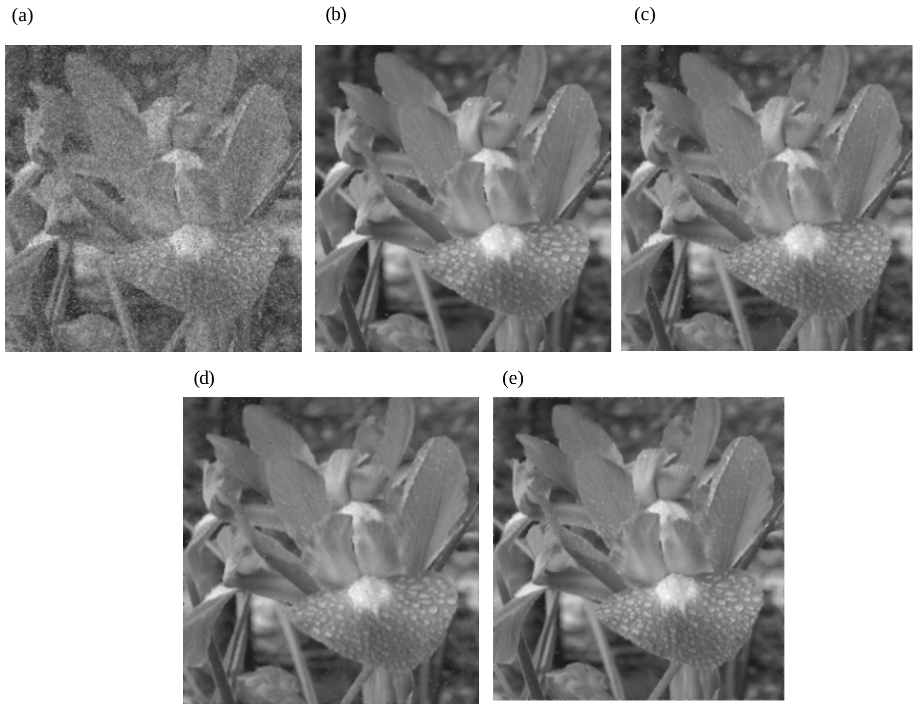


Fig. 2: Output images from different filters for the 30% corrupted flower image: a) Noisy flower image; b) Proposed method (PA); c) ACWMF; d) PW-MAD; e) CEF

Table 1: The PSNR (dB) comparison for Lena and flower images

	Lenan (%)						Flower (%)					
Methods	10	20	30	40	50	60	10	20	30	40	50	60
ACWMF	36.06	29.75	24.30	20.76	17.88	15.78	30.65	29.78	25.22	21.11	19.27	16.65
PW-MAD	34.08	31.87	28.39	25.17	22.37	19.45	32.59	29.98	26.62	23.03	20.43	16.59
CEF	34.36	31.03	28.80	26.16	22.90	19.67	34.91	30.51	28.49	26.79	24.56	22.26
PA	40.84	38.65	35.90	34.75	28.65	25.62	40.62	39.54	32.73	32.36	28.00	24.55

Table 2: The MAE ccomparison for Lena and flower images

	Lenan (%)						Flower (%)					
Methods	10	20	30	40	50	60	10	20	30	40	50	60
ACWMF	1.41	2.41	4.83	8.79	14.82	22.27	1.69	2.56	4.17	7.06	10.97	16.41
PW-MAD	2.52	3.07	4.18	6.19	9.46	15.20	3.36	3.87	4.67	5.97	7.97	10.86
CEF	0.72	1.49	2.49	4.10	7.21	12.69	1.06	1.97	2.90	4.20	6.23	9.38
PA	0.26	0.34	0.48	0.86	1.48	2.24	0.36	0.41	0.53	0.78	1.20	1.81

Performance analysis: The simulation results obtained are compared with the existing methods in terms of parameters such as PSNR and MAE values. The test images lena and flower are analyzed in different noise density condition. The PSNR and MAE values for different noise density input images are calculated. Table 1 and 2 shows the PSNR and MAE value comparison between the proposed method and existing methods. It is clear from the Table 1 that the proposed method produce better denoised image with high PSNR while compare to other filters. The PSNR value decreases for high noise density input images. High PSNR is obtained when the noise density is low. Even though, the proposed method produces better denoised image than other filters both in high and low noise density.

CONCLUSION

In this study, a new random valued impulse noise removal method is proposed which is based on similarity between neighbor pixels. Four stage method is utilizes to detect the corrupted pixels. The performance of the proposed method for different test images can be easily shown from Table 1-2. It is clear, from the analysis result is that the PSNR and MAE values of the proposed method are better than that of the ACWM, PWMAD and CEF. Proposed method gives absolutely better restoration results compared with other methods.

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