Adaptive Noise Detection and Removal Algorithm Using Local Statistics for Salt-and-Pepper Noise

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Abstract – **In this paper, an adaptive noise detection and removal algorithm using local statistics for salt-and-pepper noise are proposed. In order to determine constraints for noise detection, the local mean, variance, and maximum value are used. In addition, a weighted median filter is employed to remove the detected noise. The simulation results show the capability of the proposed algorithm removes the noise effectively.**

Key words – *noise detection*; *removal*; *local statistics*; *salt-and-pepper noise*

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1 Introduction

When an image is formed or recorded by an imaging system, the image may be degraded by the additive noise which comes from the image formation process, transmission medium, recording process, or any combination of them. As pointed out, the typical image obtained by image formation system represents the degraded and noisy version of an original image. Therefore, noise detection algorithm need to improve the visual quality and to remove the noise. The noise is very visible when the additive noise is salt-and-pepper.

There have been a number of exploitations to detect and to remove the noise[1-9]. The Mean Filter (MF)[1] and Standard Median Filter (SMF)[2] use the mean and median value of all pixel values inside the current window, respectively. Due to its effectiveness in noise supression and simplicity in implementation, different variants of the SMF have been introduced, such as the Weighted Median Filter (WMF)[3] and the Center Weighted Median filter (CWMF)[4]. Or the number of data values which are dropped from the average is controlled by the trimming parameter alpha in Alpha-Trimmed filter (ATM)[5]. Generally, these filters operate uniformly across the entire image and thus tend to modify both noise and noise-free pixels. Thus, edge and details degradation is inevitable. A noise detection process to discriminate between noisy and noise-free pixels prior to applying other filters is highly desirable. The PSM method[6] includes the switching scheme and progressive methods were applied through several iterations, whereas Srinivasan and Ebenezer proposed a fast decision-based algorithm[7] that removes only noisy pixel by the median value or by its neighboring pixel value. Very recently, the ENDHAQ[8] and DBA methods[9], the corrupted and uncorrupted pixels are detected by checking the pixel element value against the maximum and minimum values in the window selected.

In this paper, we proposed an adaptive noise detection and removal algorithm based on the important characteristic of Gaussian distribution. If one pixel's value is far from the proposed condition, it will be judged belong to the corrupted pixel. After the pixel's detection, we used the weighted median filter. This paper is organized as follows. Section 2 describes the proposed noise detection algorithm for salt-and-pepper and noise removal algorithm. In section 3, the experimental results and analysis will be presented to demonstrate ability of the proposed algorithm. Finally, the conclusions are drawn in the section 4.

2 Proposed algorithms

2.1 An adaptive noise detection

In general, the degraded model can be written as

$$y = x + n, \tag{1}$$

where y and x represent the degraded and the original image, respectively. Also, n denotes the additive noise.

By the following comparison insides the filtering window W, if the process pixel y_{ij} is greater than the sum of μ and $\sigma/\mathrm{Max}(W)$, or less than the difference of

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them, y_{ij} will be decided to be a noise pixel y_{noi} otherwise, it is an original pixel y_{org} , as

$$y_{Det} = \begin{cases} 1, & y_{ij} > \mu + k\dfrac{\sigma}{\mathrm{Max}(W)} \text{ or } y_{ij} < \mu - k\dfrac{\sigma}{\mathrm{Max}(W)}; \\ 0, & \text{otherwise.} \end{cases} \quad (2)$$

Where Max(W)is the maximum pixel valued in the current filtering window W and the parameter k is used to control the term $\sigma/\mathrm{Max}(W)$ depends on the noise distribution level. In addition, k and $\sigma/\mathrm{Max}(W)$ value vary in direct proportion. The pixel that is detected as a noise one is flagged as 1 in a binary image, f . And the pixel that is detected as a noise-free one is flagged as 0. Then the window W moves to the next pixel to perform the same method for all pixels in the image.

2.2 A noise removal

In this work, the normal distribution describes the data clustering around the mean value. For noise removal, we defined the impulse response as

$$H(x) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right), \quad (3)$$

where μ is the mean and σ is the standard deviation.

Each noise pixel that was flagged as 1 in binary image will be filtered as our proposed method. Using the above results, the filtering value $\hat{y}_{ij}$ can be written as

$$y_{ij} = \{y_{i-s,j-t} \mid -1 \leqslant s,t \leqslant 1, (s,t) \neq (0,0)\},$$
$$\hat{x}_{ij} = (1-f_{ij})y_{ij} + f_{ij}H(y_{ij}), f_{ij} = \{0,1\}. \quad (4)$$

3 Experimental results

The performance of proposed algorithm was compared with several other methods, including MF, SMF, ATM, ENDHQ and DBA. A number of experiments have been conducted with various images. Among of them, 256×256 "Lena" and 256 × 256 "Cameraman" images were used and the size of filtering window is 3×3. For evaluation the performance of the algorithm, PSNR (Peak Signal to Noise Ratio) was utilized. For $M \times N$ size 8 bit image, it is defined as

$$\mathrm{PSNR} = 10\log\frac{MN \times 255^2}{\| x - \hat{x} \|^2}, \quad (5)$$

where $\| \cdot \|$ is the Euclidean norm, and x and $\hat{x}$ represent the original image and the restored image, respectively.

It clearly outperforms others at medium to high noise densities. The corrupted images are shown in Fig. 1 and the results for the subjective visual qualities are shown in Fig. 2 and 3. From these results, we confirmed that the noise is removed effectively.

In the Tab. 1 and 2, the noise free pixels that are detected as noise pixels (False) and the noise pixels that are detected as noise free pixel (Miss). It shows a best detection performance with other detectors. In addition, the PSNR is also used as an objective measurement of the restored image quality. From Tab. 3 and 4, those are observed that the proposed algorithm is comparable to the competitive methods.

Fig. 1 Corrupted images by salt-and-pepper: (a) 256×256 Lena, (b) 256×256 Cameraman

Fig. 2 Various result images of corrupted "Lena" image : (a) MF, (b) SMF, (c) ATM, (d) ENDHQ, (e) DBA, (f) Proposed Method

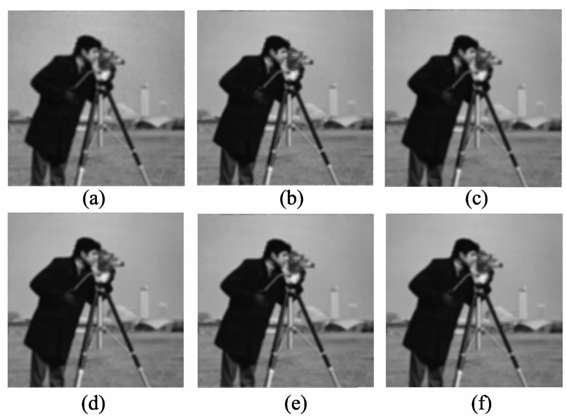

Fig. 3 Various result images of corrupted "Cameraman" image : (a) MF, (b) SMF, (c) ATM, (d) ENDHQ, (e) DBA, (f) Proposed Method

Tab. 1 Detection performance comparison of various filters for corrupted Lena image

Method	30 dB		20 dB		10 dB	
	False	Miss	False	Miss	False	Miss
ENDHQ	3 866	30 293	2 058	37 187	1 027	41 228
DBA	2 696	36 279	1 108	46 228	2 227	50 702
PSM	2 503	31 528	2 152	36 356	2 095	35 169
Prposed	2 495	30 212	1 159	39 568	7 136	27 912

Tab. 2 Detection performance comparison of various filters for corrupted cameramen image

Method	30 dB		20 dB		10 dB	
	False	Miss	False	Miss	False	Miss
ENDHQ	1 652	42 513	1 200	44 748	768	42 054
DBA	5 624	39 248	4 290	56 390	358	60 580
PSM	6 102	35 116	5 603	41 352	1 036	40 152
Prposed	7 351	15 035	4 939	16 625	3 262	37 020

Tab. 3 Comparison of various methods in terms of PSNR for corrupted Lena image

Method	PSNR(dB)-Lena image		
	30 dB	20 dB	10 dB
MF	23.24	23.20	23.89
SMF	23.66	23.62	23.56
ATM	24.09	23.74	23.98
ENDHQ	24.73	24.04	24.64
DBA	24.98	24.68	24.90
Proposed	25.82	25.73	25.51

Tab. 4 Comparison of various methods in terms of PSNR for corrupted cameraman image

Method	PSNR(dB)-Cameraman image		
	30 dB	20 dB	10 dB
MF	24.12	23.65	23.15
SMF	24.80	23.89	23.81
ATM	24.93	24.07	23.86
ENDHQ	25.31	24.35	23.90
DBA	25.56	24.86	23.98
Prposed	26.34	25.69	24.25

4 Conclusion

In this paper, a new effective detection algorithm has been proposed for salt-and-pepper noise. The adaptive noise detection is introduced, where the local statistics and window are incorporated into filtering process.

From the experimental results, it observed that PSNR gain and effective noise detection can be obtained. Also, it is verified that the proposed algorithm effectively removes the salt-and-pepper noise, resulting in satisfactory visual quality.

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