국부 통계 특성을 이용한 임펄스 노이즈 영상의 적응적 노이즈 검출 및 변형된 형태의 Gaussian 노이즈 제거 기법

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An Adaptive Noise Detection and Modified Gaussian Noise Removal Using Local Statistics for Impulse Noise Image

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요약

본 논문에서는 국부 통계 특성을 이용한 임펄스 노이즈 영상의 적응적 노이즈 검출 및 변형된 형태의 Gaussian 노이즈 제거 기법에 대해 제안한다. 노이즈 검출을 위한 제약 조건을 결정을 위하여 국부 평균, 국부 분산 그리고 국부 최대값을 이용하였다. 또한 검출된 노이즈 제거를 위한 변형된 형태의 Gaussian 필터를 사용하기 위해 노이즈 정도를 조절하기 위한 튜닝 매개변수(tuning parameter)를 사용하였다. 실험 결과를 통해 제안된 방식이 기존 방식보다 효과적으로 노이즈 검출 및 제거 되었음을 확인할 수 있었다.

키워드 : 노이즈 검출, 노이즈 제거, 국부 통계 특성, 임펄스 노이즈, Gaussian 필터.

Abstract

In this paper, we propose an adaptive noise detection and modified Gaussian removal algorithm using local statistics for impulse noise. In order to determine constraints for noise detection, the local mean, variance, and maximum values are used. In addition, a modified Gaussian filter that integrates the tuning parameter to remove the detected noises. Experimental results show that our method is significantly better than a number of existing techniques in terms of image restoration and noise detection.

Keyword : Noise detection, Noise removal, Local statistics, Impulse noise, Gaussian filter.

1. INTRODUCTION

Images are often corrupted by impulse noise comes from noise sensors, communication channels, recording process, or any combination of these. It is important to eliminate noise in the images before some subsequent processes, such as edge detection, image segmentation and object recognition. Thus, many approaches have been proposed for this purpose.

In the two past decades, the mean filter (MF) [1] and the standard median filter (SMF) [2] was initially proposed to remove impulse noise, in which, the mean and median value of all pixel values inside the filter window are used, respectively. Due to its effectiveness in noise suppression 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 mean filter (ATM) [5]. However, the details, e.g. step edges and thin lines, are easily to lost since they operate uniformly all pixels across the entire image.

In order to overcome these drawbacks, the noise detection stage 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, in the ENDHAQ [8] and DBA methods [9], the corrupted and uncorrupted pixels are detected by checking the pixel value against the maximum and minimum values in the window selected.

In this paper, we proposed an adaptive noise detection bases on the important characteristic of Gaussian distribution. If one pixel value satisfies the proposed condition, it will be judged belong to the corrupted pixel and removed by using the modified Gaussian filter. This paper is organized as follows. Section II describes the proposed noise detection and removal algorithm. In Section III, the experimental results and analysis will be showed to demonstrate ability of the proposed algorithm. Finally, the conclusions are drawn in the Section IV.

2. PROPOSED ALGORITHM

A. An Adaptive Noise Detection

In general, the degradation model is described by

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

where y, x and n represent, respectively, the degraded, original image and the additive noise. The local mean and the local standard deviation in Gaussian distribution can be obtained [10], respectively, as:

$$\mu(i,j) = \frac{\sum_{m=-1}^{1}\sum_{n=-1}^{1} a(m,n)y(i+m,j+n)}{\sum_{m=-1}^{1}\sum_{n=-1}^{1} a(m,n)}, \tag{2}$$

$$\sigma(i,j) = \frac{\sum_{m=-1}^{1}\sum_{n=-1}^{1} a(m,n)\times|y(i+m,j+n)-\mu(i,j)|}{\sum_{m=-1}^{1}\sum_{n=-1}^{1} a(m,n)}. \tag{3}$$

where the weighted 3×3 matrix $a = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$. By the following comparison insides the filtering window W, if the process pixel y_{ij} is greater than the sum of mean μ and $\sigma/Max(W)$, or less than the difference of them, y_{ij} will be decided to be a noise pixel y_{noise} otherwise y_{ij} is an original pixel $y_{original}$, as:

$$y_{det} = \begin{cases} 1, & y_{ij} > \mu + k.\frac{\sigma}{Max(W)} \text{ or } y_{ij} < \mu - k.\frac{\sigma}{Max(W)} \\ 0, & otherwise. \end{cases} \tag{4}$$

where $Max(W)$ is the maximum pixel value in the current filtering window W and the coefficient k is used to control the term $\sigma/Max(W)$ depends on the noise distribution level. Particularly, k and $Max(W)$ value vary in direct proportion. The pixel that is detected as a noise one is flagged as 1 in a binary image f. On the other hand, 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.

B. Modified Gaussian filter

By the efficient combination with the Tuning Parameter T, local mean μ and local standard σ, the coefficients h of the modified Gaussian are defined

$$h(i,j) = \frac{1}{Z}\exp\left(\frac{T\sigma^2(i^2+j^2)}{\sqrt{\mu+1}}\right) \tag{5}$$

Each noise pixel that flagged as 0 will be kept the same into the output image whereas the noise one will be restored by replacing as.

$$\hat{x}(i,j) = \frac{\sum_{m=-1}^{1}\sum_{n=-1}^{1} h(m,n)y(i+m,j+n)}{\sum_{m=-1}^{1}\sum_{n=-1}^{1} h(m,n)}, \quad m,n \in W \tag{6}$$

III. EXPERIMENTAL RESULTS

The performance of proposed algorithm has been compared with several other methods, including MF, SMF, ATM, ENDHQ and DBA. The test images in the simulation are of size 256×256 pixels and the size of filtering window is 3x3. It clearly outperforms others at medium to high noise densities. Results for the subjective visual qualities are shown for Lena image in Fig.1

(a) (b) (c) (d)

(e) (f) (g) (h)

Fig. 1. Various results images of corrupted *Lena* image: (a) Original, (b) Noise image, (c) MF, (d) SMF, (e) ATM, (f) ENDHQ, (g) DBA, (h) Proposed method.

In the Table 1, 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.

TABLE I. DETECTION PERFORMANCE COMPARISON OF VARIOUS FILTERS FOR CORRUPTED LENA IMAGE.

Method	30dB		20dB		10dB	
	False	*Miss*	*False*	*Miss*	*False*	*Miss*
ENDHQ	3866	30293	2058	37187	1027	41228
DBA	2696	36279	1108	46228	2227	50702
PSM	2503	31528	2152	36356	2095	35169
Proposed	2495	30212	1159	39568	7136	27912

In addition, the PSNR (Peak Signal to Noise Ratio) is also used as an objective measurement of the restored image quality. For MxN size 8 bit image, it is defined as,

$$PSNR = 10\log\frac{MN\times 255^2}{\| x-\hat{x} \|^2} \tag{7}$$

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

TABLE II. COMPARISON OF VARIOUS METHODS TERMS OF PSNR FOR CORRUPTED LENA IMAGE.

Method	PSNR[dB] - Lena Image		
	30dB	20dB	10dB
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

IV. CONCLUSION

In this paper, a new effective detection algorithm has been proposed for impulse 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 Gaussian noise, resulting in satisfactory visual quality.

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