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다단계 기반 수정된 미디언 필터

(Modified median filter based on multi-step)

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(Young-Ro Kim and Sung-Soo Dong©)

요 약

본 논문에서는 임펄스 잡음을 제거하는 수정된 미디언 필터를 제안한다. 다단계를 기반으로 하는 제안 방법은 먼저 잡음 영상에서 잡음과 화소를 분리하고 잡음으로 판단된 화소를 미디언 필터링한다. 이때 필터링에 사용하는 주변 화소들을 에지에 따라 방향을 조절하여 필터링하는 선형필터링 한 값으로 대체한다. 따라서 제안하는 방법은 에지를 유지할 뿐 아니라 일정한 지역에서 잡음을 효과적으로 제거한다. 실험결과, 제안하는 방법이 기존 수정된 미디언 필터 보다 향상된 결과를 보인다.

Abstract

In this paper, we propose a modified median filter for impulse noise reduction. The proposed method based on multi-step finds noisy pixels from the corrupted image and applies filtering on the noisy pixels. Neighbor pixels for filtering are filtered by linear filter which adjusts filtering direction according to an edge. Thus, our proposed method not only preserves edge, but also reduces noise in uniform region. Experimental results show that our proposed method has better quality than those by existing modified median filtering method.

Keywords : Multi-step, impulse noise, mdified median filter, linear filter.

Ⅰ. Introduction

One of the most important image enhancement techniques is noise reduction. Enhanced images after reducing noise are used in various area such as recognition, storage, movie contents, etc. Noises of various types such as impulse and Gaussian are observed in an acquired image. Thus, many methods are proposed to reduce noise[1]-[5]. Most of all, median filter has attracted much attention because of its effective impulse noise reduction capability. Conventional median filtering methods apply median operation to each pixel unconditionally without considering edge direction and whether the pixel is corrupted or not. Thus, the image edges and details are smoothed and the image quality is degraded. To overcome these problems, methods of impulse noise detection are proposed prior to median filtering[6]-[9]. The modified median filtering methods have problems that the noisy vicinity pixels for filtering are replaced by median values without edge information. Thus, edges and details of the images are smoothed and degraded.

In this paper, we propose a modified median filter based on multi-step. In the first step, noisy pixels are identified. In the second step, pixels in vicinity for median filtering are replaced with linear filtering according to the edge direction. Finally, noisy pixels are filtered by median filtering method.

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Ⅱ. Existing modified median filtering methods

In existing modified median filtering methods, they proposed filtering methods which are generally consist of two stages. In the first stage, they detect noise for filtering only noisy pixels. The corrupted pixels are either set to 255 by positive impulse or set to 0 by negative impulse. The noise is quantified by the percentage of pixels which are corrupted as follows

$$y_{i,j} = \begin{cases} 0, & with\,probability\,\frac{p}{2} \\ 255, & with\,probability\,\frac{p}{2} \\ x_{i,j}, & 1-p \end{cases} \quad (1)$$

where i,j are vertical and horizontal locations of an image, respectively. For each pixel $y_{i,j}$, if $y_{i,j}=0$ or $y_{i,j}=255$, they detect the pixel as a noisy pixel. Otherwise, $y_{i,j}$ is considered as a noise free pixel.

If the pixel is identified as an impulse noise, the pixel should be filtered by median filtering. Otherwise, its pixel value is not filtered. Fig. 1 shows the steps of the modified median filtering method.

In modified median filtering[7], the noisy pixels if they are classified as noisy pixels are replaced by median value using their vicinity pixels which are median filtered. Fig. 2 shows the filtering windows and positions.

However, the modified median filtering methods

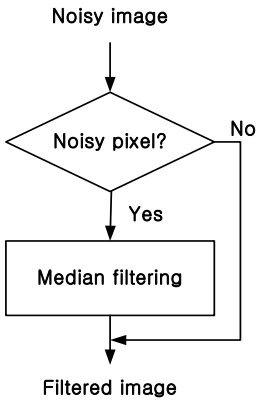


그림 1. 수정한 미디언 필터링
Fig. 1. Modified median filtering.

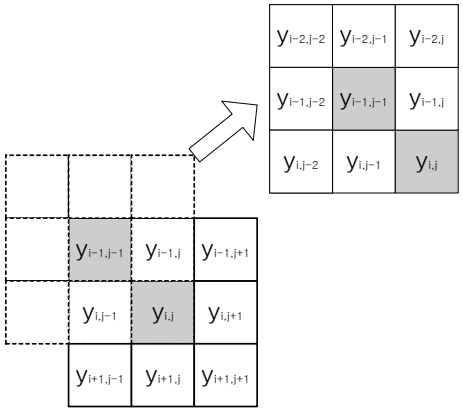


그림 2. 필터링 윈도우들
Fig. 2. Filtering windows.

have problems that the noisy pixels are replaced by median values in their vicinity without edge information. Thus, edges and details of the images are smoothed and degraded.

Ⅲ. Proposed modified median filtering method

The proposed modified filtering algorithm is based multi-step and considering local features such as edge and patterns. It has three steps. Fig. 3 shows the flowchart of the proposed modified median filtering method.

First, noise detection is performed. According to the value of the pixel in Eq. (1), we classify pixels

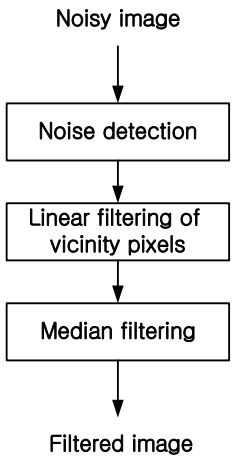


그림 3. 제안하는 수정한 미디언 필터링 알고리즘의 블록다이어그램
Fig. 3. Block diagram of the proposed modified median filtering algorithm.

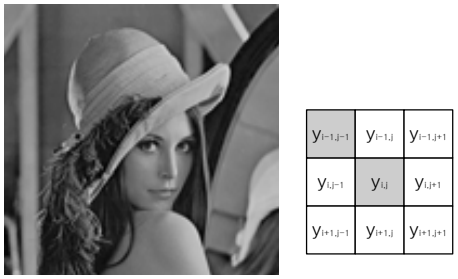


그림 4. 입력 테스트 영상과 필터링을 위한 윈도우
Fig. 4. Input test image and window for filtering.

A	B	C
D	E	F
G	H	I

그림 5. 래셔널 선형 필터링을 위한 화소들
Fig. 5. Pixels for a rational linear filtering.

as noisy pixel or noise-free pixel as shown in Eq (2).

$$\text{if} \quad y_{i,j} = 0 \text{ or } 255,\ y_{i,j} \text{is noisy pixel}$$
$$\text{else } y_{i,j} \text{ is noise-free pixel} \tag{2}$$

In our proposed algorithm, 3x3 window size is used for computational efficiency. Fig. 4 shows an input test image and an window for filtering.

Second, the proposed algorithm reduces noise of vicinity pixels by linear filtering according to the edge direction and patterns. We modify rational linear filtering method[10]-[11] and operate the filtering. In the rational linear filter, the four directions of input pixels as shown in Fig. 5 are investigated with the absolute differences as follows

$$\begin{aligned}\Delta_{AI} &= |A - I|,\\ \Delta_{BH} &= |B - H|,\\ \Delta_{CG} &= |C - G|,\\ \Delta_{DF} &= |D - F|.\end{aligned} \tag{3}$$

These values are sorted as follows

$$\delta_0 < \delta_1 < \delta_2 < \delta_3. \tag{4}$$

Using these sorted data, we decide pixel E as an edge in these cases:

$$\begin{aligned}&\text{case 1: } \delta_1 - \delta_0 > T_1\\ &\text{case 2: } T_2 < \delta_1 - \delta_0 \leqq T_1\\ &\text{case 3: } \delta_1 - \delta_0 \leqq T_2 \text{ and } \delta_2 - \delta_1 > T_2\\ &\text{case 4: } \delta_1 - \delta_0 \leqq T_2,\ \delta_2 - \delta_1 \leq T_2,\\ &\qquad \text{and } \delta_0 < T_3\\ &\text{case 5: } \delta_1 - \delta_0 \leqq T_2,\ \delta_2 - \delta_1 \leq T_2,\\ &\qquad \text{and } \delta_0 \geq T_3\end{aligned} \tag{5}$$

where T_1, T_2, and T_3 are threshold values to define edge. We have adopted values as $T_1 = 32$, $T_2 = 16$ and $T_3 = 16$, experimentally. In case 1, the pixel E is in the presence of a detail of the image because it is oriented in a direction. We assume that it is on the sharp and strong edge. In case 2, the pixel E is in the presence of a detail of the image and it is oriented in a direction but it is not so sharp and weak. In case 3, the pixel E is in the direction which is intermediate between two directions. It is not on a sharp edge. In case 4, the pixel has no particular direction. In case 5, the pixel is quite different from the other vicinity pixels. According to different cases, linear filtering are performed by the rational linear filtering method. Thus, we replace vicinity pixel value y by rational linear filtered value $y'_{i,j}$.

Finally, in proposed algorithm, median filtering operations are performed if the pixel y is classified as a noisy pixel.

$$y''_{i,j} = Median\left\{y'_{i-k,j-l}, \ldots, y, \ldots, y'_{i+k,j+l}\right\}$$

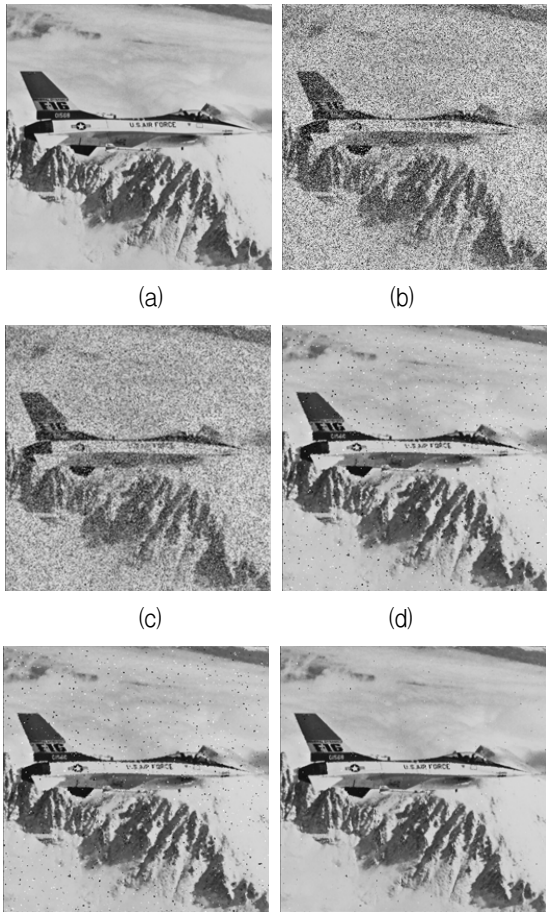
where k, j is the width and height sizes of a filtering window, respectively.

Ⅳ. Experimental results

In this section, the proposed algorithm and existing modified median filtering algorithm[7] are simulated on several test images, and the results are compared.

Fig. 6~Fig. 10 show experimental results of test images: "Airplane", "Baboon", "Boat", "House", and "Lena".

In Fig. 6~Fig. 10, noisy images are corrupted by 30% impulse noise. Our proposed method considers local features and patterns. Thus, as shown in Fig. 6(f)~Fig. 10(f), our modified median method preserves edges better than conventional methods.



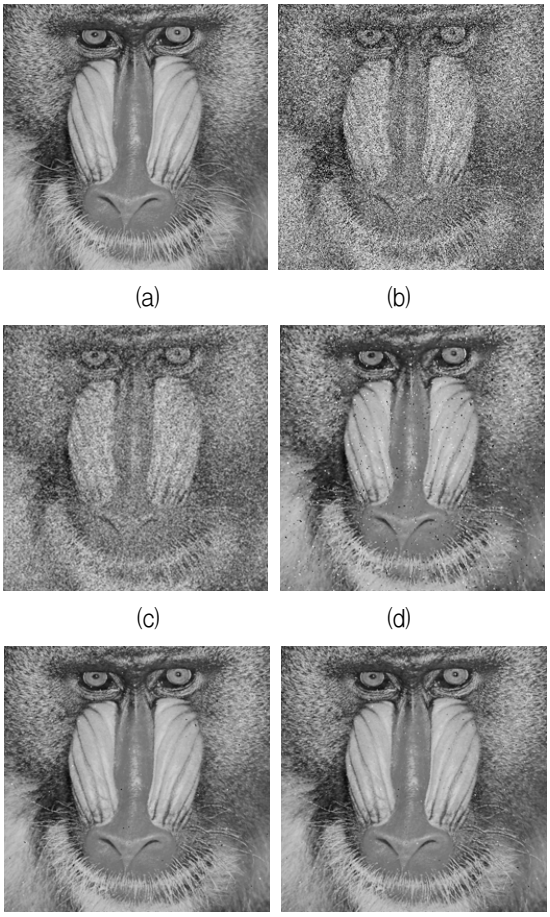
(a) (b)

(c) (d)

(e) (f)

그림 6. Airplane 테스트 결과.
(a) 원 영상, (b) 잡음 영상, $p = 30\%$,
(c) AF, (d) MF, (e) MMF, (f) 제안하는 방법

Fig. 6. Test results of Airplane.
(a) Original image, (b) Noisy image, $p = 30\%$,
(c) AF, (d) MF, (e) MMF, (f) Proposed method



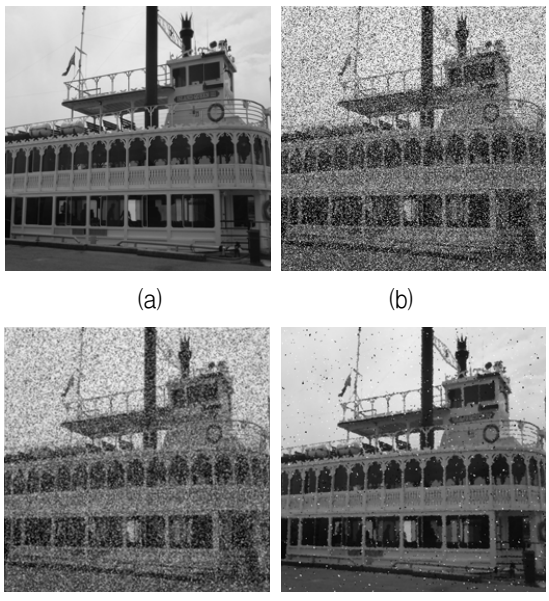
(a) (b)

(c) (d)

(e) (f)

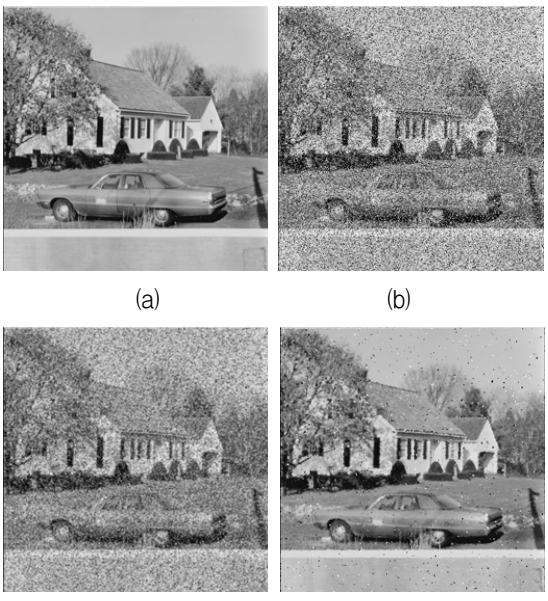
그림 7. Baboon 테스트 결과.
(a) 원 영상, (b) 잡음 영상, $p = 30\%$,
(c) AF, (d) MF, (e) MMF, (f) 제안하는 방법

Fig. 7. Test results of Baboon.
(a) Original image, (b) Noisy image, $p = 30\%$,
(c) AF, (d) MF, (e) MMF, (f) Proposed method



(a) (b)

(c) (d)



(a) (b)

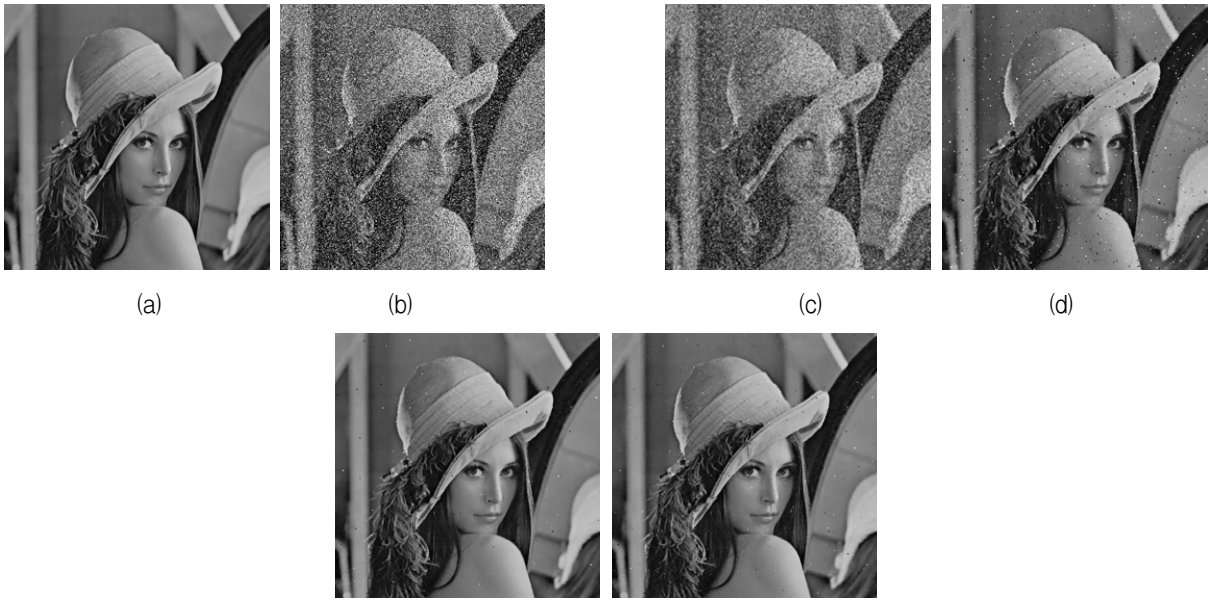
(c) (d)

(e) (f)

그림 8. Boat 테스트 결과.
(a) 원 영상, (b) 잡음 영상, $p = 30\%$,
(c) AF, (d) MF, (e) MMF, (f) 제안하는 방법
Fig. 8. Test results of Boat. (a) Original image,
(b) Noisy image, $p = 30\%$, (c) AF, (d) MF,
(e) MMF, (f) Proposed method

(e) (f)

그림 9. House 테스트 결과.
(a) 원 영상, (b) 잡음 영상, $p = 30\%$,
(c) AF, (d) MF, (e) MMF, (f) 제안하는 방법
Fig. 9. Test results of House. (a) Original image,
(b) Noisy image, $p = 30\%$, (c) AF, (d) MF,
(e) MMF, (f) Proposed method.



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

(e) (f)

그림 10. Lena 테스트 결과. (a) 원 영상, (b) 잡음 영상, $p = 30\%$, (c) AF, (d) MF, (e) MMF, (f) 제안하는 방법
Fig. 10. Test results of Lena.
(a) Original image, (b) Noisy image, $p = 30\%$, (c) AF, (d) MF, (e) MMF, (f) Proposed method

The PSNR(Peak Signal-to-Noise Ratio) is used to evaluate the performance.

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \tag{6}$$

where MSE means the value of Mean Squared Error. In Table 1~Table 5, we show restoration results of our proposed method and existing methods: AF(Average Filter)[1], MF(Median Filter)[4], and MMF(Modified Median Filter)[7].

As shown in Table 1~Table 5, our proposed method has higher PSNR performance that those of conventional methods. Especially, in spite of severe

표 1. Airplane 테스트 영상 비교 결과, PSNR(dB)
Table 1. Comparison results of Airplane in PSNR(dB).

Noise prob.	AF[1]	MF[4]	MMF[7]	Proposed method
10%	23.21	31.88	38.28	39.88
20%	20.03	28.30	34.41	35.50
30%	17.97	23.20	30.65	31.64
40%	16.38	18.73	25.75	26.61
50%	15.07	14.99	20.48	21.70

표 2. Baboon 테스트 영상 비교 결과, PSNR(dB)
Table 2. Comparison results of Baboon in PSNR(dB).

Noise prob.	AF[1]	MF[4]	MMF[7]	Proposed method
10%	21.03	23.23	31.46	31.85
20%	19.33	22.22	27.99	28.31
30%	18.03	20.20	25.46	25.81
40%	16.93	17.46	22.71	23.19
50%	16.00	14.62	19.21	19.98

표 3. Boat 테스트 영상 비교 결과, PSNR(dB)
Table 3. Comparison results of Boat in PSNR(dB).

Noise prob.	AF[1]	MF[4]	MMF[7]	Proposed method
10%	22.55	30.36	37.40	38.57
20%	19.36	27.25	33.26	33.84
30%	17.26	22.73	29.71	30.05
40%	15.59	18.35	25.26	25.59
50%	14.22	14.69	20.18	21.05

표 4. House 테스트 영상 비교 결과, PSNR(dB)
Table 4. Comparison results of House in PSNR(dB).

Noise prob.	AF[1]	MF[4]	MMF[7]	Proposed method
10%	23.08	29.76	36.85	37.94
20%	20.26	27.06	32.69	33.72
30%	18.37	22.83	29.35	30.13
40%	16.91	18.69	25.20	26.01
50%	15.70	15.13	20.45	21.55

표 5. Lena 테스트 영상 비교 결과, PSNR(dB)
Table 5. Comparison results of Lena in PSNR(dB).

Noise prob.	AF[1]	MF[4]	MMF[7]	Proposed method
10%	23.79	33.69	40.91	41.90
20%	20.58	29.61	36.82	36.98
30%	18.52	23.87	32.33	32.27
40%	16.95	19.10	26.79	27.33
50%	15.64	15.24	20.86	21.89

noisy environment, our proposed method has better performance because of filtering according to edge direction.

V. Conclusions

We proposed an efficient modified median filtering method based on multi-step. In our proposed method, rational linear filtering is used to replace vicinity pixels. Proposed algorithm considers local features and patterns. Thus, we not only remove noise, also preserve edge and details correctly.

Experimental results show the proposed method has better performance of impulse noise reduction than those of the conventional methods.

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