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에지 검출을 이용한 잡음 예측

(Noise Estimation Using Edge Detection)

김 영 로*, 동 성 수**

(Young-Ro Kim and Sung-Soo Dong©)

요 약

본 논문에서는 에지 검출을 이용한 잡음 예측 방법을 제안하였다. 이 방법은 필터 기반으로 한 잡음 예측 방법이다. 에지 검출은 잡음 예측에 영향을 미치는 구조나 세밀한 정보들을 제거하기 위함이다. 에지 검출을 하기 위하여, 영상의 세밀함에 안정적인 수정한 래셔널 필터를 사용하였다. 제안한 잡음 예측 방법은 다양한 형태의 영상들의 잡음 예측에 더욱 효율적으로 적용되며 기존의 필터 기반으로 한 잡음 예측 방법들보다 좋은 결과를 얻는다.

Abstract

In this paper, we propose a noise estimation method using edge detection. It is a filter-based noise estimation method. Edge detection is to exclude structures and details which have an effect on the noise estimation. To detect edge, we use a modified rational filter which is robust to details of images. The proposed noise estimation method is more efficiently applied to noise estimation in various types of images and has better results than those of conventional filter-based noise estimation methods.

Keywords : Noise estimation, edge detection, filter

Ⅰ. Introduction

For image enhancement, noise reduction is very important. Thus, many methods are proposed to reduce noise[1~4]. However, these methods need a priori noise information such as kinds and amount of noise. Thus, noise estimation is required to apply these methods successfully. The noise estimation methods are proposed[5~8]. Generally, noise images are assumed to be contaminated by Gaussian noise as follows

$$y(i,j) = x(i,j) + n(i,j) \tag{1}$$

where $y(i,j)$ is noisy image pixel, $x(i,j)$ is original image pixel, and $n(i,j)$ is additive noise.

Noise estimation is classified into filter-based and block-based approaches. In filter-based methods, a noisy image is filtered on the pixel unit by a lowpass filter[5~6]. These methods have a high operation number and can overestimate the noise in many detailed images. In block-based methods, the standard deviation of the difference image between the filtered and noisy images within the selected blocks[7~8] are used to estimate the amount of noise. However, these methods have difficulties that their estimation is depending on noise level and selection of blocks. Wavelet transform based approaches are also proposed[9~12]. In these methods, the amount of noise is usually estimated through MAD(Median Absolute Deviation). Motion-compensated method is proposed[13]. However, estimation results of these

* 평생회원, 명지전문대학 컴퓨터정보과
(Myongji College)
** 평생회원, 용인송담대학
(Yong-In Songdam College)
© Corresponding Author(E-mail:ssdong@ysc.ac.kr)
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methods depend on the type of images. Also, these methods need operation time to decomposition for the wavelet transform.

Ⅱ. Existing filter-based noise estimation

In filter-based methods, they proposed a fast noise estimator using Laplacian operator and edge detection [5]. In the first stage, the edge map is obtained as follows

$$G_w = y(i,j) * \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$G_h = y(i,j) * \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{2}$$

$$G = |G_w| + |G_h| .$$

where G is used to detect edge. The threshold G_{th} is selected to be the G value when the accumulated histogram reaches $p\%$. Then, the edge map is obtained by the threshold value G_{th}. They set the p value as 10. In the second stage, they follow the same approach as “the Fast Estimation” [6], but exclude the edge pixels in the edge map. The standard deviation of the noise σ'_n is estimated as follows

$$\sigma'_n = \sqrt{\frac{\pi}{2}} \frac{1}{6(W-2)(H-2)} \sum |y(i,j) * L| \tag{3}$$

where W, H, and L are the width, height, and Laplacian operator, respectively. The Laplacian operator is given by

$$L = \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix} . \tag{4}$$

Ⅲ. Proposed noise estimation

The proposed fast noise estimation algorithm is based on filter-based approach. It has two stages. The proposed algorithm makes edge map with a modified rational filtering and estimates noise with averaging using a Laplacian operator.

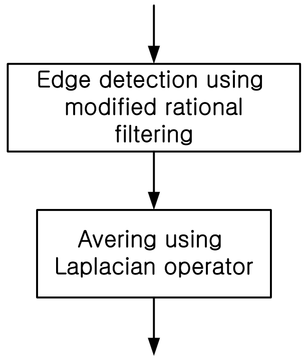

그림 1. 제안하는 알고리즘의 블록도
Fig. 1. Block diagram of the proposed algorithm.

Fig. 1 shows the flowchart of the proposed noise estimation method.

First, the proposed algorithm detects the edge with a modified rational filter. We modified a rational filter to make edge map which is used to exclude the edge pixels for estimation operations. A rational filter was devised to perform edge-preserving noise smoothing [14~15]. We modified the directions and coefficients to detect edge and isolate noisy pixels.

In the modified rational filter, the four directions of input pixels as shown in Fig. 2 are investigated with the absolute differences as follows

$$\begin{aligned} \Delta_{AI} &= |A - I|, \\ \Delta_{BH} &= |B - H|, \\ \Delta_{CG} &= |C - G|, \\ \Delta_{DF} &= |D - F|. \end{aligned} \tag{5}$$

These values are sorted as follows

$$\delta_0 < \delta_1 < \delta_2 < \delta_3. \tag{6}$$

A	B	C
D	E	F
G	H	I

그림 2. 수정한 래셔널 필터링에 사용하는 화소
Fig. 2. Pixel for a modified rational filtering.

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

case 1: $\delta_1 - \delta_0 > T_1$

case 2: $T_2 < \delta_1 - \delta_0 \leqq T_1$

case 3: $\delta_1 - \delta_0 \leqq T_2$이고 $\delta_2 - \delta_1 > T_2$

where T_1 and T_2 are threshold values to define edge. We have adopted values as $T_1 = 32$ and $T_2 = 16$, 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. Fig. 3 shows edge images of 'Lena' defined by case 1, 2, and 3.

Conventional methods[5~6] use the accumulated histogram of edge values. Thus, they struggled to find the best choice of the threshold value and have different performances according to different types of images. Fig. 4 shows performance comparison by edge map results. p means the threshold value for edge definition in histogram. Our edge map shows robust edge results without struggling to fine the best p value. As shown in Fig. 4, our method has better edge map results than those of existing method with various p values. The p value is used to separate the image pixels into the edge region and the flat regions. However, the best choice is difficult. Our method has no needs to find the best parameter values. Also, the method has good results of edge detection according to local gradient values.

We use 3x3 mask to expand the edge map as follows

$$m'(i,j) = \begin{cases} 1 & \text{if} \sum_{u=-1}^{1} \sum_{v=-1}^{1} m(i+u, j+v) > 3 \\ & \text{and } m(i,j) \equiv 0 \\ 0 & \end{cases} \tag{7}$$

where $m(i,j)$ is a pixel of the first edge map and $m'(i,j)$ is a pixel of the last expanded edge map.

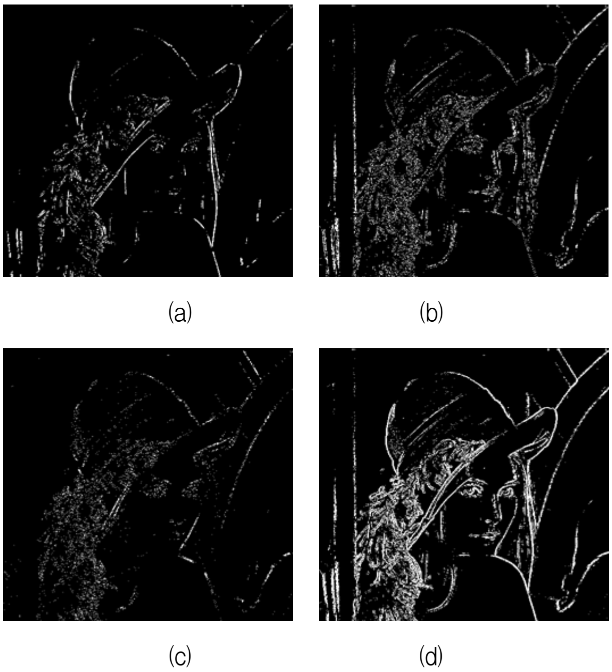

그림 3. 'Lena'의 에지 영상. (a) case 1, (b) case 2, (c) case 3, (d) case 1 + case 2 + case 3

Fig. 3. Edge images of 'Lena'. (a) case 1, (b) case 2, (c) case 3, (d) case 1 + case 2 + case 3.

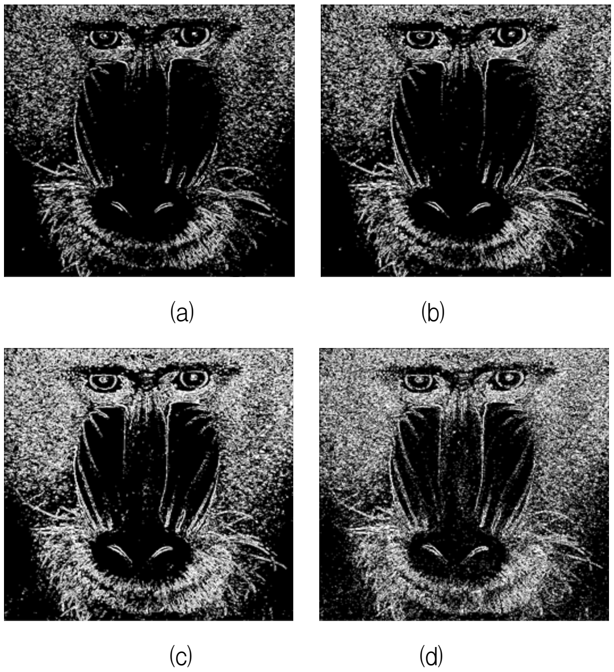

그림 4. 잡음의 표준편차 $\sigma_n = 5$일 때의 에지 영상. (a) 기존 방법 [5] $p = 10\%$, (b) $p = 20\%$, (c) $p = 30\%$, (d) 제안한 방법

Fig. 4. Edge images of 'Baboon' when the noise standard deviation $\sigma_n = 5$. (a) Existing method [5] with $p = 10\%$, (b) $p = 20\%$, (c) $p = 30\%$, (d) proposed method.

Finally, we simply follow the same averaging method using a Laplacian operator[5] which excludes edge pixels. We estimated the standard deviation of the noise σ_e as follows

$$\sigma_e = \sqrt{\frac{\pi}{2}} \frac{1}{6(W-2)(H-2)} \sum_{y(i,j) \in M} |y(i,j) * L| \quad (8)$$

where W, H, and L are the width, height, and Laplacian operator, respectively. M is a map image excluding detected edge pixels using the modified rational filter.

Ⅳ. Experimental results

In this section, the proposed algorithm and existing filter-based algorithm[5~6] are simulated on several images, and the results are compared. We set the p value in our method as 20, experimentally. Fig. 5 and Fig. 6 shows test original and noisy images which are corrupted by Gaussian noise $\sigma_n = 10$. Fig. 7 shows edge map images which are derived from our modified rational filter. Table 1, 2, and 3 show the absolute noise estimation error $e = |\sigma_e - \sigma_n|$ where σ_n, σ_e are amounts of original and estimated noises, respectively. Table 1, 2, and 3 show that the proposed algorithm has better performances than the existing method for noise level $\sigma_n = 5$, $\sigma_n = 10$, and $\sigma_n = 15$ cases. The proposed method is simple and fast by filter-based operations.

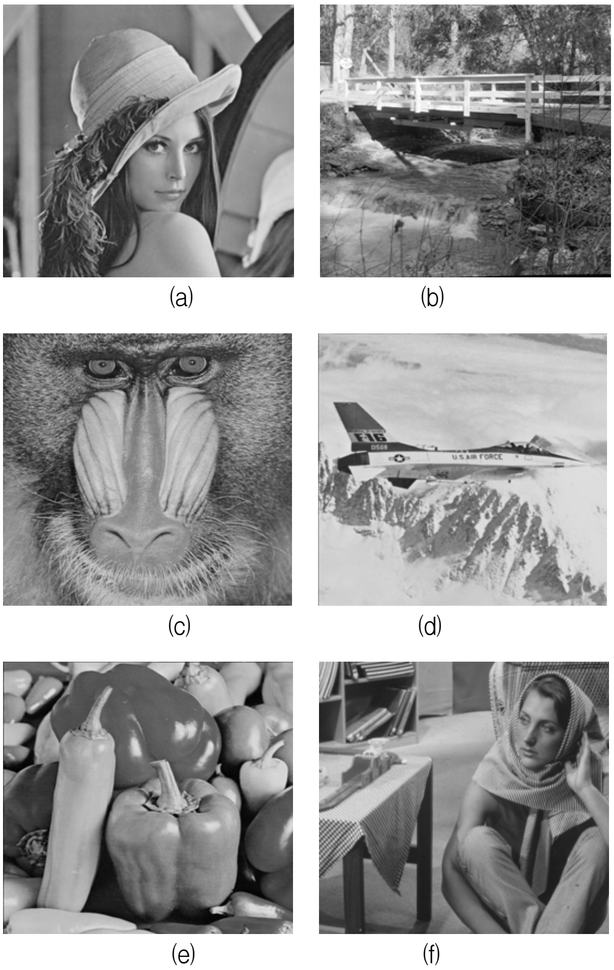

그림 5. 실험 원 영상들. (a) Lena, (b) Bridge, (c) Baboon, (d) Airplane, (e) Pepper, (f) Barbara
Fig. 5. Test original images. (a) Lena, (b) Bridge, (c) Baboon, (d) Airplane, (e) Pepper, (f) Barbara.

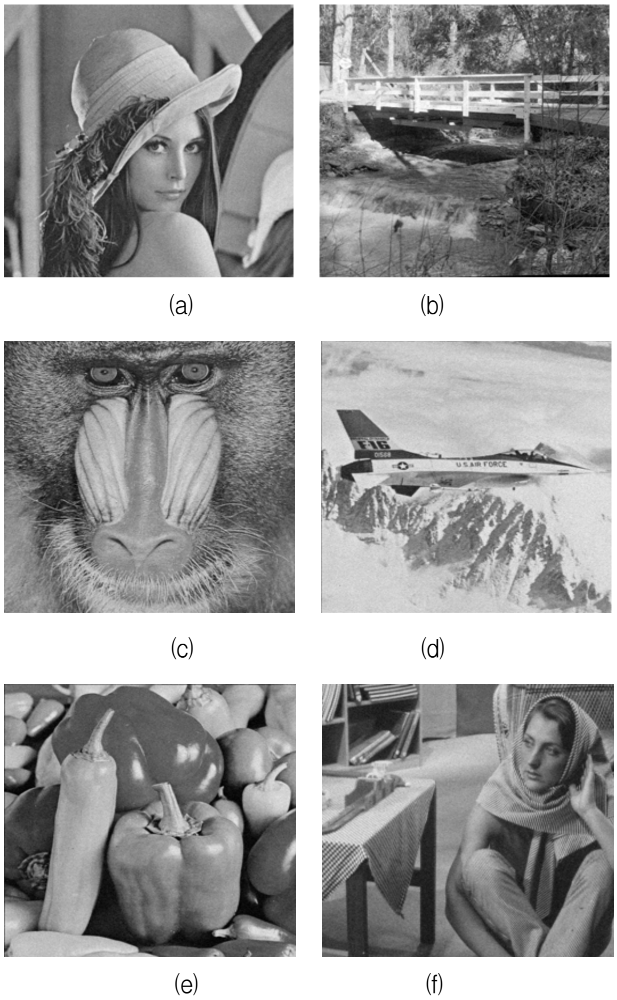

그림 6. 실험 잡음 영상들($\sigma_n = 10$). (a) Lena, (b) Bridge, (c) Baboon, (d) Airplane, (e) Pepper, (f) Barbara
Fig. 6. Test noisy images($\sigma_n = 10$). (a) Lena, (b) Bridge, (c) Baboon, (d) Airplane, (e) Pepper, (f) Barbara.

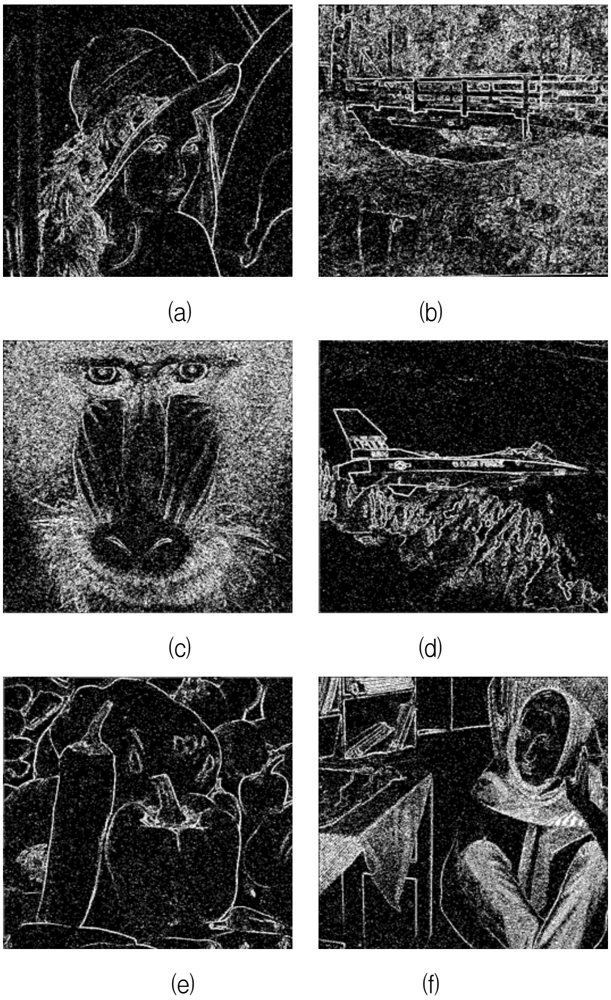

그림 7. 수정한 래셔널 필터를 이용한 에지 맵 영상 ($\sigma_n = 10$). (a) Lena, (b) Bridge, (c) Baboon, (d) Airplane, (e) Pepper, (f) Barbara

Fig. 7. Edge map images using our modified rational filter ($\sigma_n = 10$). (a) Lena, (b) Bridge, (c) Baboon, (d) Airplane, (e) Pepper, (f) Barbara.

표 1. 잡음 추정 에러의 절대값 ($\sigma_n = 5$)

Table 1. The absolute noise estimation error.($\sigma_n = 5$).

	Existing method [5]	Existing method [6]	Proposed method
Lena	0.28	0.42	0.27
Bridge	3.01	3.46	2.01
Baboon	4.22	4.86	2.54
Airplane	0.07	0.07	0.09
Pepper	1.72	1.87	1.73
Barbara	1.67	1.76	0.64
Average	1.83	2.07	1.21

표 2. 잡음 추정 에러의 절대값 ($\sigma_n = 10$)

Table 2. The absolute noise estimation error.($\sigma_n = 10$).

	Existing method [5]	Existing method [6]	Proposed method
Lena	0.06	0.02	0.10
Bridge	1.80	2.15	0.88
Baboon	2.66	3.18	1.20
Airplane	0.24	0.17	0.28
Pepper	0.71	0.82	0.68
Barbara	0.93	0.99	0.13
Average	1.07	1.22	0.55

표 3. 잡음 추정 에러의 절대값 ($\sigma_n = 15$)

Table 3. The absolute noise estimation error.($\sigma_n = 15$).

	Existing method [5]	Existing method [6]	Proposed method
Lena	0.19	0.14	0.52
Bridge	1.11	1.39	0.10
Baboon	1.81	2.25	0.18
Airplane	0.31	0.27	0.65
Pepper	0.22	0.30	0.12
Barbara	0.52	0.57	0.40
Average	0.69	0.82	0.33

V. Conclusions

We proposed an efficient noise estimation method based on filter-based filtering. It detects the edge map using the modified rational filtering and noise estimation is performed on the region without edge pixels. Thus, the proposed algorithm performs well for different type images.

Experimental results show the proposed method has better noise estimation than those of the conventional filter-based methods.

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저 자 소 개

김 영 로(평생회원)
1993년 고려대학교 전자공학과 학사
1996년 고려대학교 전자공학과 컴퓨터공학 석사
2001년 고려대학교 전자공학과 컴퓨터공학 박사
2001년～2003년 삼성전자 시스템LSI 책임연구원
2003년～현재 명지전문대학 컴퓨터정보과 교수
<주관심분야 : 신호 및 영상처리, 멀티미디어 통신>

동 성 수(평생회원)
1990년 인하대학교 전기공학과 학사
1992년 인하대학교 전기공학과 공학 석사
2009년 인하대학교 전기공학과 공학 박사
1992년～1995년 나우정밀 중앙연구소 전임연구원
1996년～2000년 삼성전자 정보통신 선임연구원
2001년～현재 용인송담대학교 디지털전자과 부교수
<주관심분야 : ASIC/SOC/FPGA 설계, 마이컴/로봇 제어, 멀티미디어 통신>