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A Study on the Contour-Preserving Image Filtering for Noise Removal

(잡음 제거를 위한 윤곽선 보존 기법에 관한 연구)

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Abstract

In this paper, a simple contour-preserving filtering algorithm is proposed. The goal of the contour-preserving filtering method is to remove noise and granularity as the preprocessing for the image segmentation procedure. Our method finds edge map and separates the image into the edge region and the non-edge region using this edge map. For the non-edge region, typical smoothing filters could be used to remove the noise and the small areas during the segmentation procedure. The result of simulation shows that our method is slightly better than the typical methods such as the median filtering and gradient inverse weighted filtering in the point of view of analysis of variance (ANOVA).

Key words : contour-reserving filtering, smoothing filter, median filtering, gradient inverse weighted filtering, preprocessing, segmentation, noise and granularity

I. Introduction

The image from image acquisition system is very noisy and has granularity come from circuit itself and sensor noise. This granularity becomes often the source of small areas in the region growing process, and these small areas do not consist with real objects in the image, so these could be false contour. The goal of preprocessing is to reduce local granularity for improving performance of image segmentation preserving the effective contour. Typical granularity removing filter has a low-pass characteristic to remove the high frequency signal component as well as high frequency noise and blur object contour. So, the important objective of preprocessing is to solve this conflict problem, granularity removal and contour-preserving[1], [2].

Median filter and gradient inverse weighted filter have been used for these purpose, but they often blur the image significantly otherwise be computationally expensive. We suggest a simple contour-preserving filtering method with good performance. An image is divided into the edge region and non-edge region by the edge map. The edge map can be obtained using the typical edge operator like Sobel operator. For the non-edge

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region, the several robust filters could be applied without smearing the edge. For the edge region, nothing is done, so the edge or the contour is preserved.

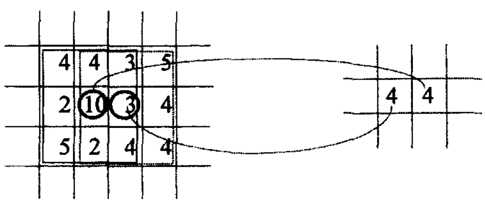
We perform quantitative analysis for the two conventional preprocessing filters and our suggested method. We use the fact that the image quality is better when the uniformity in the same region increase and the discrimination between the regions increase. To measure the uniformity in the same region and the discrimination between the regions, we use the analysis of the variance.

In chapter II, median filter and gradient inverse weighted filter are reviewed, and the suggested simple contour-preserving filtering method is introduced. In chapter III, the simulation is performed for a test image and the result of quantitative analysis is shown. Finally, in chapter IV, we summarize the results of our work.

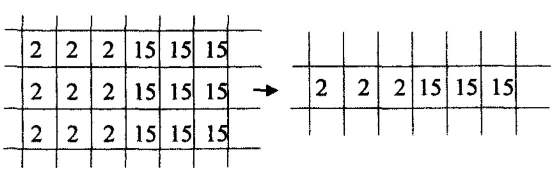
II. Contour-preserving Image Filtering Method

1. Median Filter

Median filtering is a nonlinear process useful in reducing impulsive or salt-and-pepper noise. Impulsive or salt-and-pepper noise can occur due to a random bit error in a communication channel. In a median filter, a window slide along the image, and the



(a) Principle of median filter



(b) Median filter's tendency to preserve edge

Fig. 1. Illustration of median filter.

median intensity value of the pixels within the window becomes the output intensity of the pixel being processed. For example, suppose the pixel values within a 3×3 window are as 4, 4, 3, 2, 10, 3, 5, 2, 4, and the pixel being processed has a value of 4.

Like low-pass filtering, median filter smoothes the image and thus is useful in reducing noise. Unlike low-pass filtering, median filtering can preserve discontinuities in a step function can smooth a few pixels whose values differ significantly from their surroundings without effecting the other pixels. Figure 1 shows illustration of median filter's tendency to preserve edge. Although the very sharp edges are not blurred, median filtering blurs the image significantly[3].

2. Gradient inverse weighted filter

Gradient inverse weighted filter is designed to have low-pass characteristic beyond the contour and high-pass characteristic around the contour by adaptation of filter weight coefficient according to local contrast of the image. A pixel at (x, y) near edges will have large weight coefficient value compared with ones beyond the edges. Thus large weight coefficient less contributes to smoothing and does not blur contour but Gradient inverse weighted filter must be applied repeatedly, thus computationally expensive[4].

Gradient inverse weighted filter has the 3×3 mask, and the mask is as follows.

$$W(r,c) = \begin{bmatrix} w(r-1,\ c-1) & w(r-1,\ c) & w(r-1,\ c+1) \\ w(r,\ c-1) & 1/2 & w(r,\ c+1) \\ w(r+1,\ c-1) & w(r+1,\ c) & w(r+1,\ c+1) \end{bmatrix} \quad (1)$$

The weight coefficient is defined as normalized gradient inverse.

$$w(r+k,\ c+l) = \frac{1}{2}\Big[\sum_{V(r,c)'} \delta(r,\ c;k,\ l)\Big]^{-1} \delta(r,\ c;k,\ l) \quad (2)$$

except $k,\ l = -1,\ 0,\ 1$

where $V(r, c)$ is 8 neighborhood of pixel (r, c) and the inverse of absolute gradientis $\delta(r, c:k, l)$ is

$$\delta(r, c:k, l) = \frac{1}{|p(r+k, c+1) - p(r, c)|} \quad (3)$$

The filtered image is represented as follows.

$$\hat{p}(r, c) = \sum_{k=-1}^{1} \sum_{l=-1}^{1} w(r+k, c+l)p(r+k, c+l) \quad (4)$$

3. Contour-preserving Filtering(CPF) Method using Edge Map

We suggest a simple contour-preserving filtering method with good performance. Our method finds edge map and separates the image into the edge region and the non-edge region using this edge map. For the non-edge region, typical smoothing filters could be used to remove the noise and the small areas in the segmentation procedure.

The algorithm is as follows:

1. Find the edge map.
2. Separate the image into the edge region and the non-edge region using the edge map.
3. Low-pass filter (or Median filter) for the non-edge region.
4. Combine the edge region and the low-pass filtered non-edge region.

We used a Sobel operator to find the edge map, and the Sobel mask is shown as follows.

L1	L2	L3
L4	F(i, j)	L5
L6	L7	L8

$$F(i, j) = |X| + |Y|$$
$$X = (L_1 + 2L_4 + L_6) - (L_3 + 2L_5 + L_8) \quad (5)$$
$$X = (L_1 + 2L_2 + L_)- (L_6 + 2L_7 + L_8)$$

Where, $F(i, j)$ is the output of the operator and considered as the edge point if it is larger than the threshold Ts. We use mean filtering method to smooth non-edge region and no operation is applied to edge region. By these methods, the sharp edge could be preserved but the noise in the edge region does not removed. In the point of view of the preprocessing for the image segmentation, the performance is better than other two methods[5].

Ⅲ. Experimental Results and Performance Analysis

Computer simulation has been conducted to evaluate the performance of the suggested method. The original test image is the 64×64 synthesized image with noise. Figure 2 shows the filtered image using 5×5 median filter. Figure 2 (c), (d) show one-dimensional profiles of the filtered images. Figure 3 shows the filtered image and it's 1-dimensional profile using gradient inverse weighted filter. Figure 4 shows the filtered image and it's 1-dimensional profile using the our suggested method. These figures show that our method is better than other two methods.

We perform quantitative analysis for above two pre-processing filters and our suggested method. We use the fact that the image quality is better when the uniformity in the same region increase and the discrimination between the regions increase. To measure the uniformity in the same region and the discrimination between the regions, we use analysis of variance (ANOVA).

Suppose an image I consists of N pixel and $\Omega_i\, i=1,2,\cdots,k$, and a region k consists of N_i pixel. For the measure of the uniformity in the regions and the discrimination between the region, the f-statistic is defined as follows.

$$f = \frac{SSB/(k-1)}{SSW/(N-k)} \quad (6)$$

$$SSW = \sum_{i=1}^{k} \sum_{(r,c)\in\Omega_i} |p(r, c) = \overline{p}_i|^2 \quad (7)$$

$$SSB = \sum_{i=1}^{k} N_i * (\overline{p_i} - \overline{p})^2 \quad (8)$$

where, $\overline{p_i}$ is the mean of the region Ω_i and $\overline{p}$ is the mean of the entire image I.

In the above equations, as the SSB meaning the discrimination between the region increase and SSW meaning the uniformity in the region decrease, f would be larger. Median filter, gradient inverse weighted filter and suggested method show higher value of f than the typical low pass filtering methods, maintaining SSB constant. In this chapter, we examine the value of f using the test image. Tablel 2 and 3 tabulate the mean, f, SSB and SSW. The tables show that the suggested method is slightly better than median filter or gradient inverse weighted filter[4].

Ⅳ. Conclusion

We have proposed a simple contour-preserving filtering method. Our method finds edge map using Sobel operator and separates the image into the edge region and the non-edge region using this edge map. For the non-edge region, we used mean filters to smooth the noise and the small areas resulting in the undesirable region for the segmentation procedure and no operation is applied to edge region. By these methods, the sharp edge could be preserved but the noise in the edge region does not removed. As the preprocessing for the image segmentation procedure, the performance is better than other two methods.

To evaluate the performance, we used the analysis of variance to measure of uniformity in the same region and the discrimination between the regions.

The result shows that noise in the edge region could not be removed because no operation is done around the edge. So our future work is to develop the method to remove noise in the edge region.

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Table 1. Performance Of Median Filtering.

image	filter size	mean	f	SSB	SSW
64×64 test image	original	59.7671	1.1751e+00	7.9089e+00	2.7555e+00
	3×3	61.0387	3.0850	7.3847e+00	9.8001e+00
	5×5	61.9986	5.0069e+00	7.0808e+00	5.7897e+00

Table 2. Performance Of Gradient Inverse Weighted Filtering.

image	interation	mean	f	SSB	SSW
64×64 test image	original	59.7671	1.1751e+00	7.9089e+00	2.7555e+00
	1	60.1538	1.7091e+00	7.3388e+00	1.8538e+00
	3	60.3045	2.0098e+00	7.6671e+00	1.5618e+00
	6	60.4160	2.2602e+00	7.6264e+00	1.3814e+00

Table 3. Performance Of Proposed Contour-Preserving Filtering.

image	filter size	mean	f	SSB	SSW
64×64 test image	original	59.7671	1.1751e+00	7.9089e+00	2.7555e+00
	CPF	61.4225	5.3698e+00	7.7182e+00	5.8844e+00

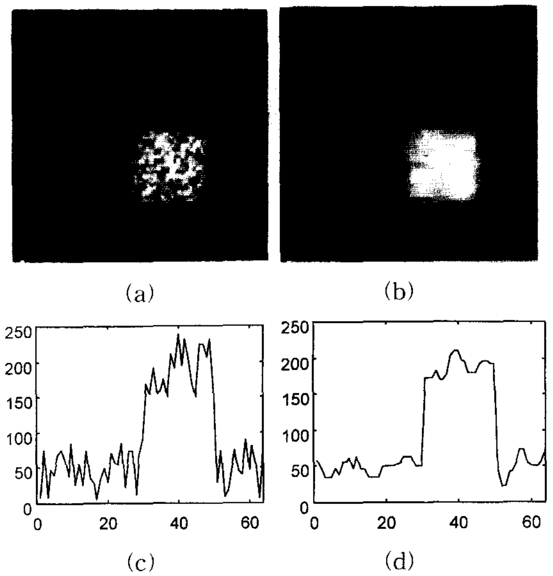

Fig. 2. The result of median filtering. (a) Test image(64×64). (b) 5×5 median filtering. (c) One-dimensional profile of (a). (d) One-dimensional profile of (b).

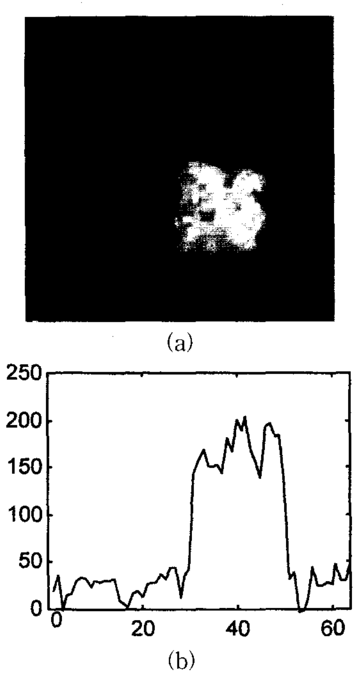

Fig. 3. The result of gradient inverse weighted filter. (a) The 6 iterations. (b) One-dimensional profile of (a).

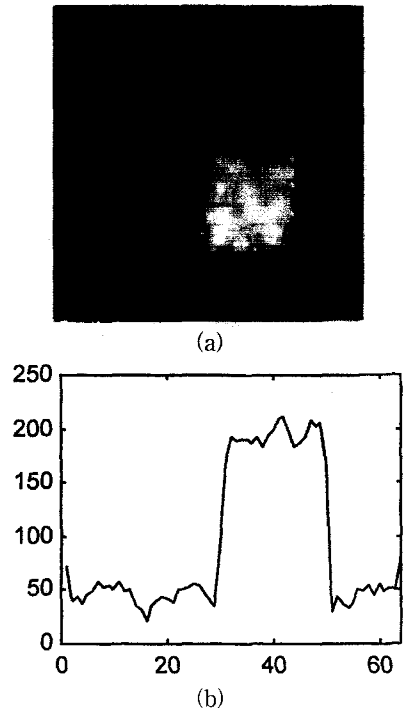

Fig. 4. The result of the suggested method. (a) Contour-preserving filtering using edge map. (b) One-dimensional profile of (a).

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