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인간시각 인식특성을 지닌 효율적 비선형 스케치 특징추출 필터

조 성 목*, 조 옥 래**

Effective Nonlinear Filters with Visual Perception Characteristics for Extracting Sketch Features

Sung-Mok Cho*, Ok-Lae Cho**

요 약

디지털 영상에서의 특징점 추출 기술은 로봇비전, 의료영상 진단시스템 및 비디오 전송과 같은 분야 등에서 많이 응용되고 있다. 디지털 영상에서 특징점을 추출하는 방법에는 비선형 그래디언트, 비선형 라프라시안, 엔트로피와 같은 필터들이 있다. 그런데 인간의 시각에서 영상의 특징이 형성되는 과정을 살펴보면, 밝은 영역보다는 어두운 영역에서의 특징에 더 민감한 특성을 가지고 있으므로 기존의 필터로써 특징점을 추출하는데 효과적이지 못하다. 본 논문에서는 국부영역의 밝기를 고려하는 특징점 추출 필터들을 제안한다. 이들 필터들은 연산이 간단하여 매우 신속하게 특징점을 추출할 수 있으며, 국부적인 밝기를 고려하지만 기존의 엔트로피 연산자가 지닌 단점을 극복하여 어두운 영역에서의 미세한 밝기 변화에는 강건한 특성을 가지는 특성을 지닌다. 실험결과 다양한 밝기변화와 국부영역에 걸쳐 매우 뛰어난 특징점 추출결과를 나타내었다.

Abstract

Feature extraction technique in digital images has many applications such as robot vision, medical diagnostic system, and motion video transmission, etc. There are several methods for extracting features in digital images for example nonlinear gradient, nonlinear laplacian, and entropy convolutional filter. However, conventional convolutional filters are usually not efficient to extract features in an image because image feature formation in eyes is more sensitive to dark regions than to bright regions. A few nonlinear filters using difference between arithmetic mean and harmonic mean in a window for extracting sketch features are described in this paper. They have some advantages, for example simple computation, dependence on local intensities and less sensitive to small intensity changes in very dark regions. Experimental results demonstrate more successful features extraction than other conventional filters over a wide variety of intensity variations.

▸ Keyword : Sketch Feature, Nonlinear Filter, Human Psychovisual Phenomena, Threshold

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* 동명대학교 정보보호학과 조교수 , ** 동명대학교 컴퓨터공학과 부교수

intensity change in very dark regions and exhibits a trend converging asymptotically from the De Vries-Rose region to the Weber region as intensity increases. Experimental results revealed good performance of the proposed filters as expected in the present study.

I. Introduction

Edge and valley are perceptually important features in digital images. In case of projection of object space with non-uniform reflection, the features called edges occur at points which have abrupt changes in luminance and in case of projection of object space with uniform reflectance, the features occur at points which have local luminance minima called valleys. Since the major portion of the visual information of an image is contained in the edges and valleys, these features extracting process from digital images is very important. Despite their fundamental importance in digital image processing and analysis, there is no precise and widely accepted mathematical definition of these features.[1-2]

In general, an observer's feeling associated with the features in an image is more sensitive to dark regions than to bright regions. Hence human visual system has visual increment thresholds and converges asymptotically from the De Vries_Rose region to the Weber region as intensity increases[1]. Therefore, to extract the significant features as perceived by human beings, a good sketch feature filter should match the above mentioned human psychovisual phenomena as closely as possible.

In this paper, we describe new nonlinear filters called "Max-Cen DBAH(Difference Between Arithmatic mean and Harmonic mean), Minx-Cen DBAH, Min-Max DBAH" for extracting sketch features which are defined by the difference between the arithmetic mean and the harmonic mean in a window. The proposed filters depend on the local intensities as well as the rates of intensity change. In addition, they have a proportional response for

II. Conventional Filters for Extracting Features

An approximation of the visual increment threshold was proposed by Kundu et al[3]. They pointed out that the perceived intensity of a surface depends on its local intensities and classified the visual increment threshold differently according to the De Vries-Rose region, the Weber region and the saturation region as a function of local intensity. The visual increment thresholds in each region were proposed as follows:

$$\Delta B_T = \begin{cases} K_1\sqrt{B}, & \textit{De Vries-Rose region,} \\ K_2 B, & \textit{Weber region,} \\ K_3 B^2, & \textit{saturation region,} \end{cases} \qquad (1)$$

where ΔB_T, B, K1, K2, and K3 denote the visual increment threshold, local intensity and constants of the corresponding regions respectively.

Several convolutional filters have been emerged to improve the performance of the sketch feature extraction in images. These include Van Vliet's nonlinear gradient and nonlinear Laplacian [4], and the entropy filter [5], etc.

The convolutional filters presented by Van Vliet et al. relate closely to the morphological gradient convolutional filters[6] and the implementation of these convolutional filter is very easy. The nonlinear gradient filter is relatively insensitive to noise and granularity but it extracts ramp edges often existing in real images as thick lines and does not depend on local intensities. The Laplacian filter produces a zero crossing at an edge location. It detects high frequency details accurately and its implementation is facilitated, but it is generally more sensitive to noise than other convolutional filters. This defect can be overcome to some extent by adopting its nonlinear versions. The shifting effect of the edge locations which occurs in the nonlinear gradient filter does not occur in the nonlinear Laplacian because of its second-order derivatives. However, the nonlinear Laplacian does not depend on local intensities and creates several false edges, especially in the areas where the image variance is small, because small intensity perturbations tend to produce false zero-crossings.

The entropy filter extracts the features of dark regions quite well because of its dependence on local intensities. However, the features are extracted as thick lines since it weights all pixels uniformly within the local region. It is noted that the entropy convolutional filter needs a large amount of computation due to the logarithmic operation.

III. DBAH Filters and their Characteristics Analysis

As reviewed in the preceeding section, the presently existing convolutional filters possess their shortcomings for extracting sketch features since they either do not consider local intensities or have some problems such as computational time and sensitivities in dark regions. In the present study, new convolutional filters, DBAH are described which are well appropriate for the effective extraction of sketch features similar to the human psychovisual phenomena. The DBAH convolutional filters calculate the difference between the arithmetic mean and the harmonic mean using the selected two pixel in window. The Maxima-Center DBAH filter uses the maximum intensity pixel value f_{max} and the center-pixel intensity value f_{cen} in a window, which is defined as follows:

$$DBAH_{max-cen} = \frac{f_{max} + f_{cen}}{2} - \frac{2 f_{max} f_{cen}}{f_{max} + f_{cen}} \qquad (2)$$

The Minima-Center DBAH filter uses the minimum intensity pixel value f_{min} and the center-pixel intensity value f_{cen} in a window, which is defined as follows:

$$DBAH_{min-cen} = \frac{f_{min} + f_{cen}}{2} - \frac{2 f_{min} f_{cen}}{f_{min} + f_{cen}} \qquad (3)$$

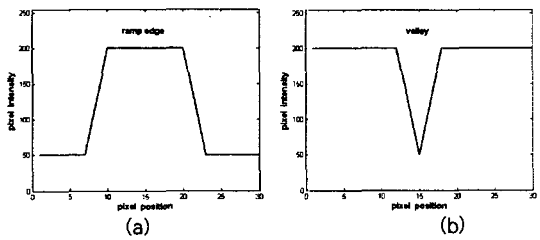
The Minima-Maxima DBAH filter uses the minimum intensity pixel value f_{min} and the maximum intensity pixel value f_{max} in a window, which is defined as follows:

$$DBAH_{min-max} = \frac{f_{min} + f_{max}}{2} - \frac{2 f_{min} f_{max}}{f_{min} + f_{max}} \qquad (4)$$

The above DBAH convolutional filters tend to become larger for the greater intensity change.

This tendency is the result that the arithmetic mean increases linearly but the harmonic mean approaches to the center pixel intensity with higher rate as the difference between the maximum and center pixel intensities increases. And the DBAH filters are apt to be larger in the dark region for the same intensity change rate. This tendency is the result that the arithmetic mean decreases linearly but the harmonic mean approaches more rapidly and closely to the center pixel intensity for the lower sum of the selected t 재 pixel intensity values. As a result, the DBAH filters tend to become larger for the greater difference between these two intensities and are apt to be higher in the dark region where the sum of these two intensity values is lower. Moreover, it is noted that the DBAH filters are extremely small in the very dark region because both of the intensities are quite small. The advantages of the DBAH filters discussed so far are that the DBAH filters can take into account the intensity change rates, the local intensities and the very dark regions as well in images, which make it possible to develope an efficient feature extraction technique akin to the human visual system.

(Figure 1) shows the output responses of each convolutional filters to an ideal ramp edge and an ideal valley. The nonlinear gradient and entropy filter exibit a possibility of a thick edge extraction and the entropy filter has a small response in the valley. On the other hand, Min-Cen DBAH and Min-Max DBAH do not occur the shifting effect of the edge locations and the Max-Cen DBAH extract edges at the bottom of the ramp but responds very well in the valley.



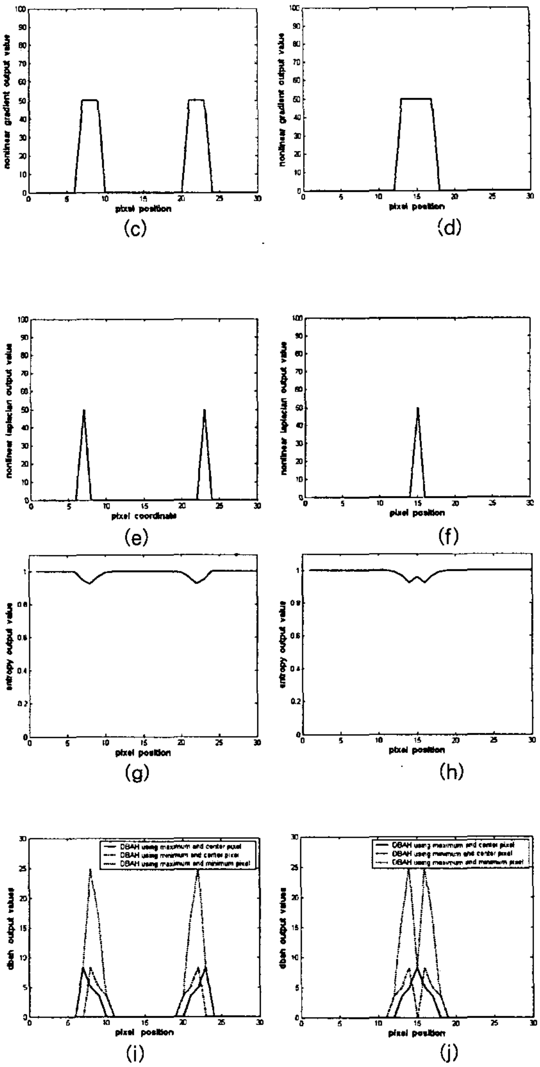


Figure 1. (a) an ideal edge; (b) an ideal valley; (c)-(j) filtered result applying nonlinear gradient, nonlinear laplacian, entropy and DBAH to (a) and (b), respectively.

(Figures 2) (b)-(d) show the transfer characteristic functions of convolutional filters employing to the input which has all possible combination of local intensities and intensity variations in an image (Figure 2(a)); independent of the local intensities (Figure 2(b)), dependent on the local intensities (Figure 2(c), for example entropy convolutional filter) and considered with DBAH (Figure 2(d)). As it is seen in (Figure 3), the outputs applying filters such as nonlinear gradient shows independence of local intensities and the outputs applying the entropy filter could not reveal the reality of images due to extremely high responding value for the small intensity change rates in the very low intensity regions. While the output of the proposed filters as shown in (Figure 2(d)) agrees quite closely with the perception of human being especially in very dark regions. Therefore, the proposed filters convolutional filter possesses unique advantages over the other convolutional filters for extracting sketch features.

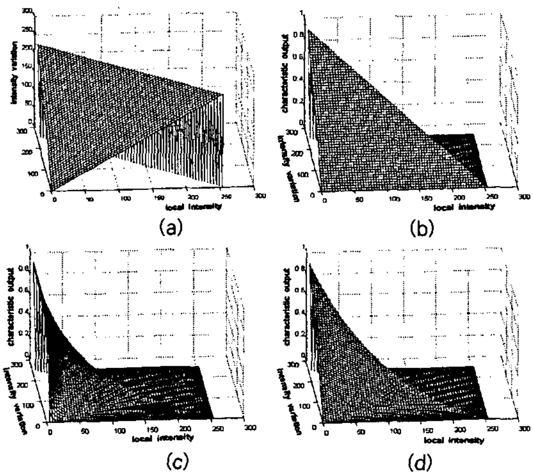
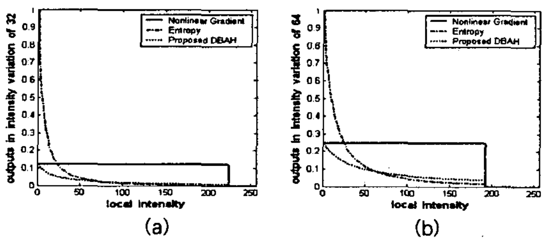


Figure 2. (a) all possibile combination of local intensities and intensity variations in an image; (b) local intensity independent transfer characteristic function(for example Nonlinear gradient, Nonlinear Laplace convolutional filter); (c) transfer characteristic function of the entropy convolutional filter; (d) transfer characteristic function of the proposed convolutional filters.



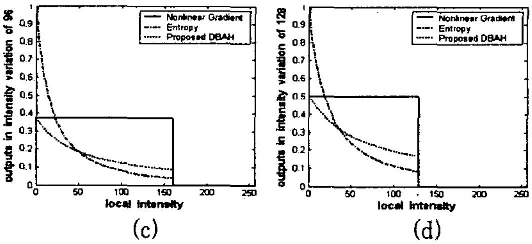
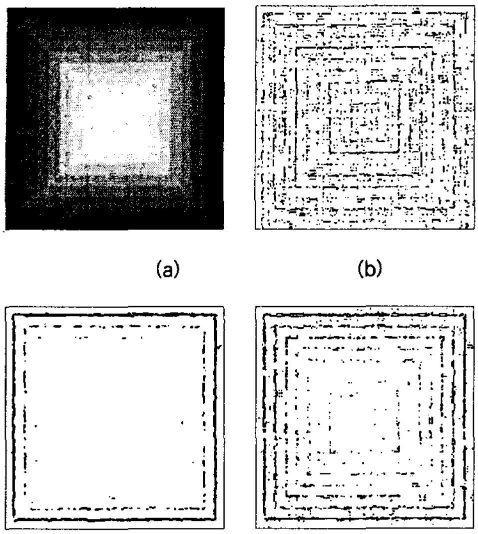


Figure 3. (a)-(d) responses of filters in case of intensity variation of 32, 64, 96, 128, respectively.

Ⅳ. Performance Results

In our experiments, the effectiveness of the convolutional filters dependent on local intensities was evaluated by applying the convolutional filters to a synthetic test image which had known structure, but which had been corrupted by Gaussian noise. The uncorrupted image having ramped square objects which are characterized by different grey level intensities with varying from 60 to 220 was created in (figure 4(a)). The image size is 256×256 pixel arrays with an intensity variation of 20 between neighbor intensity levels. (Figures 4(b), 4(c), and 4(d)) show the result of applying nonlinear laplacian convolutional filter, entropy convolutional filter and the proposed convolutional filter to a synthetic test image corrupted by additive zero-mean Gaussian noise with standard deviation equal to 5 respectively and the number of detected edge pixels is approximately 7% of the total number of pixels. As shown in (Figures 4(b)), the nonlinear laplacian convolutional filter is sensitive to noise. (Figure 4(c)) show that the entropy convolutional filter miss some valid edge elements in bright regions and is very sensitive in dark regions. On the contrary, (Figure 4(d)) shows that the proposed convolutional filter is able to detect a considerable amount of features while preserving a considerable amount of noise immunity.



(a) (b)

(c) (d)

Figure 4. (a) A synthetic original image, and the responses of applying (b) nonlinear laplacian convolutional filter, (c) entropy convolutional filter and (d) the proposed convolutional filter to (a) corrupted by additive zero-mean Gaussian noise with a standard deviation of 5

V. Conclusion

In this paper, new convolutional filters which are named as Max-Cen DBAH, Min-Cen DBAH and Min-Max DBAH for extracting sketch features are proposed. The Min-Max DBAH and the Min-Cen DBAH filters have good characteristics for extracting ramp edges and the Max-Cen DBAH filter shows excellent capability for valley feature extraction. Also, the transfer characteristic functions of the proposed filters agree quite closely with the perception of the human being especially in dark regions. In addition, the computation process applying the proposed filters are also very simple. Therefore, the proposed convolutional filters possess many advantages over the other convolutional filters for extracting sketch features. The excellence in performance and the simplicity in computation make the proposed convolutional filters attractive for wide range of applications such as robot vision, medical diagnostics and motion video transmission, etc.

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저자소개

조 성 목

1988. 2. Kyungbook Nat'l Univ. Dept. of Electronics (B.S.)
1990. 2. Kyungbook Nat'l Univ. Dept. of Electronics (M.S.)
1995년 Kyungbook Nat'l Univ. Dept. of Electronics (Ph.D..)
1992. 3. ~ 2006. 2. Tongmyong College Full time Lecturer -Associate Processor
2006. 3. ~ Tongmyong Univ. Dept. of Information Security Assistant Professor

조 옥 래

1980. 2. Kyungbook Nat'l Univ. Dept. of Statistics (B.S.)
1983. 2. Kyungbook Nat'l Univ. Dept. of Statistics (M.S.)
2006년 Kyungbook Nat'l Univ. Dept. of Statistics (Ph.D..)
1992. 3. ~ 2006. 2. Tongmyong College F.T. Lecturer - Processor
2006. 3. ~ Tongmyong Univ. Dept. of Computer Eng. Associate Professor