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EDGE LINKING BY RIDGE TRACING+

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ABSTRACT

A multi-phase ridge tracing algorithm for edge linking is proposed in this study. The main ideal behind our method is that edge gradient maps are regarded as continuous mountain ranges in three-dimensional view. For each tracing phase, we start out with somewhat candidate edge points confined by the first threshold T_1 and local maximum. Then the second threshold T_2 is acquired to terminate linking. Moreover, to distinguish low gradient magnitude edge and noise or background, multiple processes are applied and the experimental results exhibit that our effort successfully traces edge points in edge gradient maps.

1. Introduction

Edge detection detects the changes or discontinuities of luminance and tri-stimulus values to present primitive characteristics or features in an image. Traditionally, it is mainly a two-stage process [8]: edge enhancement followed by edge linking. Most recipes for edge enhancement include the first order derivative detectors such as Sobel [16], Roberts [17], and ∇G [2, 18] operator and the second order derivative detectors such as Laplacian of the Gaussian and $\nabla^2 G$ operator [1]. However, the first stage process seldom characterizes boundaries completely because of noise, breaks in the boundary from non-uniform illuminations, and other effects that introduce spurious intensity discontinuities. Thus edge detection algorithms typically are followed by linking procedures designed to assemble edge pixels into meaningful boundaries for object extraction or pattern recognition in computer vision and image processing.

In this article, we are mainly focus on linking phase and develop a new linking algorithm. Many pioneer's endeavors Martelli [3-4], Ashkar and Modestino [5], Cooper [6], and Eichel and Delp [7-8] based on search algorithm and Payne and Riordan [12] by directional potential function (DPF) have been shown to provide better object boundary. Among them, the algorithm (SEL) [7] provides good result in various medical and industrial images. Recently, edge linking has also been equipped into color edge detection [13]. Throughout this paper, we developed a new edge linking method according to ridge tracing by two threshold values.

Given a gradient edge map, it is difficult to distinguish low and non-significant edge gradient points from noise and background by a single perceptive value. For the purpose of obtaining actual edge points with low gradient magnitude to contribute connection property, some noisy points will appear, usually. And, for the purpose of suppressing

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noise, the edge connection property will be destroyed. To tackle this problem, we propose a multi-phase edge linking method. Each phase is associated with two thresholds for tracing. The first threshold is a parameter for choosing initial candidate edge points and the second threshold is a parameter to terminate linking process.

The main ideal behind our method is that gradient edge maps are regarded as continuous mountain ranges in three-dimensional view. Thus, we start out of allocating the mountaintop to be candidate edge points. Then the linking direction, will be called hill-ridge, are observed simply by the first and secondary maximal gradients of vicinity around the center pixel in a 3×3 mask. And then we trace the edge according to the linking direction step by step.

To be convenient in the linking process, two operations are concerned. A hill-ridge enhancement is applied by high-pass filter and a local maximum preserving should be operated to capture the candidate edge point. Moreover, gap repairing and redundancy removing should be included because of noise, breaks in the boundary from non-uniform illuminations. Finally, if the linking length is too short it is regarded as noise and should be removed.

Under noise condition, a pure gradient map is acquired as many as possible. Many filters do well for little noise removing such as median filters. In this study, we will not investigate this subject explicitly. The organization of the rest of this report is as follows. We will outline the tracing algorithm in Section2 in detail. In Section3, some experimental results are explored. And discussion is given in Section 4.

2. Proposed method

A gradient edge map can be regarded as continuous mountain ranges in three-dimensional view. If a pixel with high gradient, the probability of it to stand on the ridge of a mountain is increasing except for noise. It is clear that most edge points belong to ridge of the mountain ranges by perception. For example, Figure 1 shows a gradient map and its 3-D view of Lena's face. Here, we firstly define the edge hilltop, the hilltop of the mountains, as candidate points of edge by following:

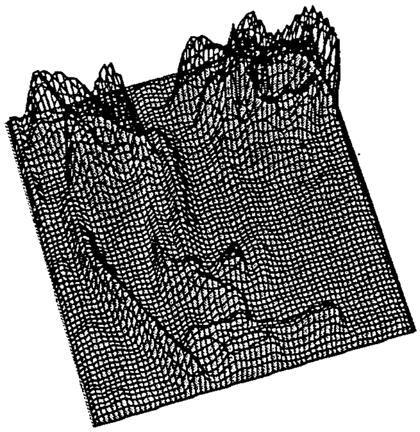

Figure 1. The 3-D face edge gradient map of Lena image.

***Definition**: Edge Hilltop*

A point p belonging to a gradient edge map is regarded as an *edge hilltop* if it has local maximal value with his 8 neighborhood and its gradient value is larger than the threshold T_1.

Intuitively, we trace edge points from each *edge hilltop*, initial candidate edge points suppressed by a larger threshold T_1 and the local maximum, to another *edge hilltop* in term of the second threshold T_2 and the directions of hill-ridge to forward those with larger gradient magnitude neighbors. The threshold value T_1 plays a pivotal role on indicating the accurate edge points. Since the threshold T_1 is fully dependent on different gradient magnitudes of edge maps, it should be determined automatically. The mean of the edge gradient map is the simplest method but not the most effective (Venetsanopoulos [13]). Thus, the mean value is displaced by a delicate approach. We assume that an edge map is commonly constituted with object edges and background. Tsai [15] proposed an automatic threshold algorithm which calculated a threshold T for bilevel thresholding or segmentation by moment preserving. Thus, object edges and background can be distinguished by choosing $T_1 \geq T$ with edge gradient map. Simultaneously, to indicate the edge hilltop, a local maximum preserving is limited. In generally, edge maps contain non-roof gradient edges. In this case, a high-pass filter can be applied first to enhance hill-ridges.

Our approach firstly starts out from the detected points mentioned above. For an edge hilltop centered in a 3×3 window, the directions of the hill-ridge in this window is determined by the second threshold T_2 and located on the largest and the second largest gradients points. From the directions of the hill-ridge in this window, tracing step forwards repeatedly. If the direction of the hill-ridge has been traced, the tracing step stops. Finally, some templates of gaps each centered in a 3×3 window are selected to link edge points if there exists a pair of (✓, ●), as shown in figure 2 (a). And, some redundant edge points centered in templates of figure 2(b) should be removed. The linking algorithm is given as follows:

Algorithm:

Input: X: edge gradient map.
Output: Y: edge linking result.
Step1: Convolute high-pass filter to X as X'.
Step2: Find each edge hilltop $h_i = (x_i, y_i),\ i = 1,2,\ldots,N$ of the edge gradient map X' and classify them as edge points.
Step3: For each edge hilltop h_i do
Find the largest m_{i1} and the second largest m_{i2} around the 8 neighborhoods of h_i;
If the edge magnitude of m_{ik}, $k = 1, 2,$ is larger than T_2 and m_{ik} is not an edge point do
Mark m_{ik} as an edge point and ignore other neighborhoods m_{ij}, $j = 3,\cdots,8$;
Trace the hill-ridge of a 3×3 window centered in m_{ik} as edge points along the maximum neighbor M of m_{ik}, except the fronter edge point of m_{ik};
Until edge magnitude value of M is smaller than T_2 or it is another edge hilltop.
Else, remove h_i.
/* Remove impluse noise */
Step4: Gap linking and redundance removing.

To distinguish low magnitued edge from noise or background, the multiple processing is acquired and the linking result obtained in previous phase should be excluded in the next phase and each moment preserving process is applied on resuide gradient image map. The main contribution of this article is the development of a simple, non-thinning process and automatic linking algorithm based on two thresholds.

3. Experimental Results

For illustrating the effectiveness of our algorithm, two testing edge gradient maps in Figure 3 (c) and (d) are explored. The original images, Figure 3(a) and (b) are with size of 256×256 and with 256 gray-level. Figure 4 (a) and (b) show the corresponding linking results. The experimental results show that our method traces edge points and obtains pure edge map in gradient edge maps successfully. A larger threshold T_2 is chosen for tracing the configuration of images and a small number threshold T_2 is selected for tracing the minutiae of images.

Moreover, for the purpose of reducing computation at determinting T_1, we reduce the size of images for testing. Table 1 shows that as the image size reduces to a quarter or one eight of the original image size threshold T_1 changes scarely. In our experimental, the threshold T_1 is all determined with a quarter of original testing images.

4. Conclusions

In this article, a new algorithm for edge gradient map linking with two threshold values is introduced. The method is exempt from the isolated noise peaks and distinguished effectively low gradient edge points from noise peaks. And the experimental results show that our method is better than classical thresholding methods.

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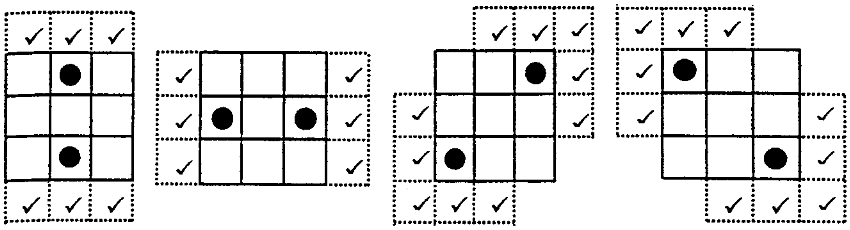


Figure 2. (a) Templates of the gaps.

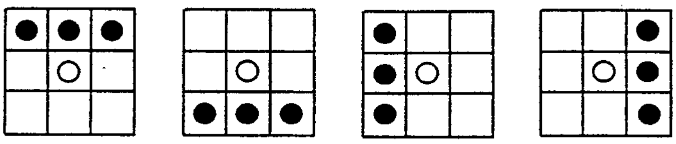


Figure 2. (b) Templates of the redundant edge points.

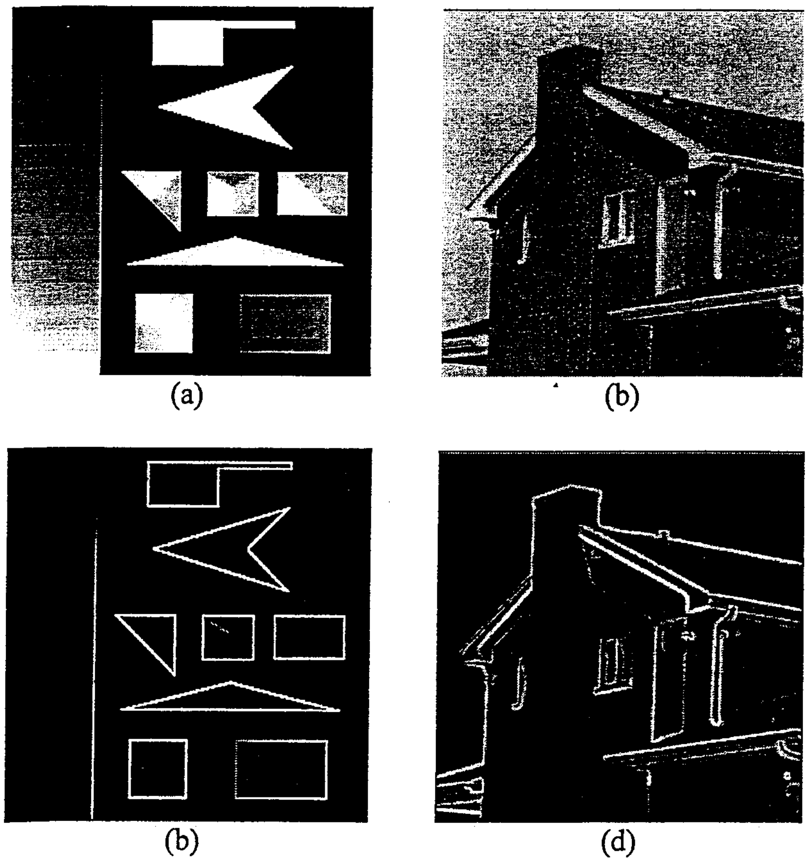
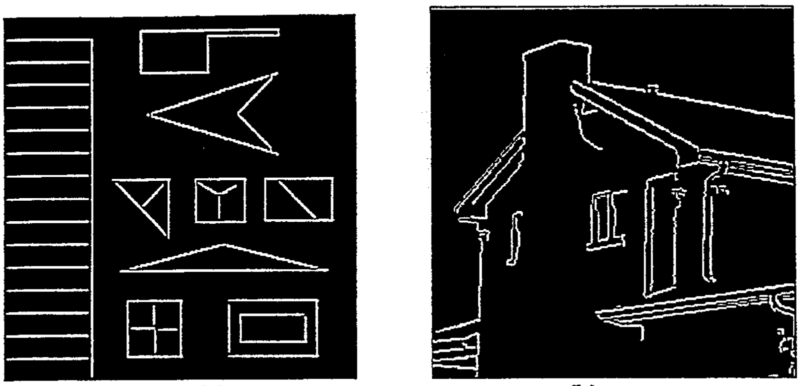


Figure 3. Testing images and its edge gradient map, respectively.



(a) (b)

Figure 4. The corresponding edge linking maps of Figure 3.
(a) T2=5 by four phases; (b) T2=10 by one phase.

Image sizes	Lena image	Building image
$\frac{1}{1}$	T_1=29	T_1=24
$\frac{1}{2}$	T_1=29	T_1=25
$\frac{1}{4}$	T_1=29	T_1=24
$\frac{1}{8}$	T_1=24	T_1=21
$\frac{1}{16}$	T_1=19	T_1=16

Table 1. The first threshold T_1 determined with different image sizes.