Image edge detection based on adaptive weighted morphology

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Received August 11, 2006

A novel morphological edge detector based on adaptive weighted morphological operators is presented. It judges image edge and direction by adaptive weighted morphological structuring elements (SEs). If the edge direction exists, a big weight factor in SE is put; if it does not exist, a small weight factor in SE is put. Thus we can achieve an intensified edge detector. Experimental results prove that the new operator's performance dominates those of classical operators for images in edge detection, and obtains superbly detail edges.

OCIS codes: 100.0100, 070.4690, 120.2650, 110.2970.

Edges can be defined as where gradient of image intensity function reaches its local maximum. In other words, edge points are points in the image where pixel brightness changes drastically. Typically, edge points are associated with the boundaries of objects in the image and edge detection can also be used for region segmentation and feature extraction. Edge detection methods can be classified into directional and non-directional or gradient-based operators[1−3]. Directional operators use two masks and two convolutions. While non-directional ones use single mask and convolution but they are sensitive to noise due to gradient nature of the operators. In recent year, classical popular gradient-based edge detection algorithms were experimented on images including Roberts, Sobel, Laplacian of Gaussian (LoG) and so on[4]. Mathematical morphology (MM) has achieved the status of a powerful tool in the design of edge detection and nonlinear filters for signal/image processing[3,5,6].

In this paper, a new edge detection algorithm based on adaptive weighted morphological operations is presented. The primary objective of the adaptive weighted morphological grads operations in the proposed algorithm is to generate the high connective edge features of the image. Then applying morphological gradient operators to detect edge of images, according to edge conditions, weighted factors in structuring element (SE) are selected. If the points belonging to the edge should be given by big weighted factors, the small weighted factors is put. Thus we can achieve an intensified edge detector.

Weighted erosion (WER) and weighted dilation (WDI) are defined as

$$\mathrm{WER}(k,l) = \min_{u,v}\{X(k+u,l+v)/B(u,v)\}, \tag{1}$$

$$\mathrm{WDI}(k,l) = \max_{u,v}\{X(k-u,l-v)\times B(u,v)\}. \tag{2}$$

The other operators, such as weighted opening (WOP) and weighted closing (WCL), are simple cascades of WER and WDI which can be described as $\mathrm{WOP}(X) = \mathrm{WDI}(\mathrm{WER}(X))$ and $\mathrm{WCL}(X) = \mathrm{WER}(\mathrm{WDI}(X))$, respectively. Weighted open-closing (WOPCL) and weighted close-opening (WCLOP) are denoted as $\mathrm{WOPCL}(X) = \mathrm{WCL}(\mathrm{WOP}(X))$ and $\mathrm{WCLOP}(X) = \mathrm{WOP}(\mathrm{WCL}(X))$, respectively. The SE B has a normalized weight factor and its elements are calculated such that the edge directional points' weights are 1 and the farthest points' weights are assigned with a weight factor $\omega > 1$, leading to an emphasis on the effect of the edge directional points and a reduction of the effect of the neighborhood points. The rest of the weights are calculated based on an increment:

$$\Delta\omega = (\omega-1)/d, \tag{3}$$

where d denotes the distance between the edge directional points and the farthest points from the edge directional points. In the vertical and horizontal directions, the weight decreases by $\Delta\omega$, each step starting from the edge directional points. For example, for SE of size 3×3 with its edge direction at the horizontal direction, if $\omega_1 = 3$, the SE will look like B_1, where $\Delta\omega = 2$, and for $\omega_2 = 3$, for the same edge direction points (underlined) at the oblique 45°, it will change to B_2, where $\Delta\omega = 1$

$$B_1 = \begin{bmatrix} -1 & -1 & -1 \\ \underline{1} & \underline{1} & \underline{1} \\ -1 & -1 & -1 \end{bmatrix}, \quad B_2 = \begin{bmatrix} \underline{1} & 0 & -1 \\ 0 & \underline{1} & 0 \\ -1 & 0 & \underline{1} \end{bmatrix}.$$

In mathematical morphological operations, there are always two sets involved: dilation and erosion. The shape of an image is determined by the values that the signal takes on. The shape information of the image is extracted by using a SE to operate on the image. So morphological image processing lies on morphological operations combination and SEs. In case operations' mode is selected, relevant result is ascertained by SEs. Yet designing effective SEs is a difficult task. In this paper, a new algorithm based adaptive weighted morphological operations is proposed, using adaptive select weight SE to extract edge. Morphological gradient operator is defined as

$$\text{Edge operator} = (X \oplus B) - (X \odot B). \tag{4}$$

It can reinforce comparatively speculated grey transition region in images. So the operator is applied to detect edge and simultaneously adaptively select SEs to extract edge.

The weighted morphological operators emphasize the edge direction points of window effect. Therefore an adaptive weighted morphological transformation algorithm is proposed. If pixels in the edge of window are edge, a big weight factor in SE is put; if it does not exist, a small weight factor in SE is put. Thus the probability of the edge detection is improved by morphological operations. So the first step is looking for edge in this paper. Circumrotate cover edge search method is adopted, more details about circumrotate cover edge is found in Ref. [4].

The SE is confirmed, then adopt adaptive weighted matrix to detect image edge. The SE B has a normalized weight factor and its elements are calculated such that the edge directional points' weights are 1 and the farthest points' weights are assigned with a weight factor $\omega > 1$, leading to an emphasis on the effect of the edge directional points and a reduction of the effect of the neighborhood points. The rest of the weights are calculated based on an increment $\Delta\omega$ (refer Eq. (3)), each step starting from the edge directional points.

Finally, whether or not edge pixels exist is judged by selecting weight SE that can let non-edge pixels and give small weight factor, so let edge pixels give big weight factor. When the SEs is toned or restrained, edge is given prominence by morphological swell operation; edge is given weaken by morphological erode operation. So edge is much more extruded. At the same time some of the small details edges are more distinct.

In this paper, the Lena image is used in this experiment to process edge detection. Several popular gradient-based edge detection algorithms were experimented on the images, including Sobel, LoG and so on. The original image is shown in Fig. 1(a), LoG edge detector image, common morphological edge detect image, Sobel edge detector image, and the proposed method image are shown in Figs. 1(b), (c), (d), and (e), respectively.

As can be seen from the images, Sobel edge detector is highly subjected to detection of false edges. This is probably due to the high threshold value used to detect weak edges in the Sobel detector. The most common error that occurred in four detectors (Sobel and LoG) tested is missing true edges. This is especially obvious in LoG detector probably due to the smoothing operation prior to edge detection. LoG detector also produces a small degree of disconnected edges especially in complex shapes such as map in Lena. The proposed method cannot only primely extract detail edge, but also superbly preserve integer effect.

An image segmentation algorithm based on adaptive weighted morphology edge detectors is presented. The performance of the proposed algorithm has been demonstrated on the Lena image. The image was first processed by the mathematical morphological closing and dilation residue edge detector to enhance the edge features and sketch out the contour of the image, respectively. Then the adaptive weight SE operation was applied to the edge-extracted image to fuse edge gaps and hill up holds. Experimental results show that it can not only primely extract detail edge, but also superbly preserve integer effect compared with classical edge detection algorithm.

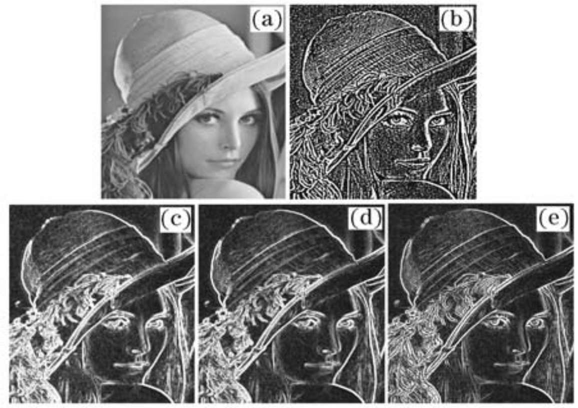

Fig. 1. Experimental results. (a) Original image; (b) LoG edge image; (c) common morphological edge image; (d) Sobel edge detection image; (e) the proposed method edge image.

This work was supported by the National Natural Science Foundation of China under Grants No. 60372034 and 60672168. L. Jiang's e-mail address is jlhhit@163.com.

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