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Edge-Enhanced Shape Feature Extraction for Image Retrieval

Rongguo Zhang, Zongjian Zhang, Li Li and LiyangPeng +

VANCL Research Institute, 41 Guangqumen Main Street, 100062, Dongcheng District, Beijing, China

Abstract. This paper demonstrates how to extract shape feature based on enhanced edge for image retrieval. In our framework, the modified pyramid histogram of gradient orientation is used as the basic shape feature. The shape is always closely related with the edge. However, some images have weak edges due to the similarity of background and foreground. For the accurate and complete image retrieval based on shape feature, we enhance the edges of these images. In measuring the similarity of feature vectors, we compare the standardized Euclidean distance with histogram intersection method. Experimental results show that our retrieval framework is very effective.

Keywords: edge enhancement, shape feature, pyramid histogram of gradient orientation, content-based image retrieval.

1. Introduction

Content based image retrieval (CBIR) is one of the important topics in multimedia information area. Shape feature is frequently used as visual content in CBIR. Color and texture based similarity measures without shape information failed to produce desired retrieval results [1]. Our proposed work is built on the shape feature expressed with the pyramid histogram of gradient orientation (PHOG) [2]. PHOG contains the global and local shape feature. The global shape is captured by the distribution over edge orientations in the whole image, while the local shape is captured by the distribution over edge orientations within the sub-sections at multiple resolutions. Therefore, the edges are very important in the process of extracting the shape feature.

Zhou et al. [3] proposed structural features for CBIR to efficiently extract information embedded in the edges. They showed that the feature can catch salient edge information and improve the retrieval performance. Edge is a strong feature for characterizing an image. Banerjee et al. [1] presented a robust technique for extracting edge map of an image which is followed by computation of global feature using gray level as well as shape information of the edge map. Janney et al. [4] showed a method for enhancing the capabilities of texture based feature extraction to improve the result of CBIR. Histogram of oriented gradients is feature descriptor widely used in computer vision and image processing for the purpose of object detection. It was firstly described by NavneetDalal and Bill Triggs [5] which is similar to edge orientation histograms and SIFT descriptors [6].

In this paper, we first modify PHOG as the basic shape feature in image retrieval. Then, aiming at the situation that weak edge cannot express the shape feature well; we bring in the edge-enhanced method mentioned in paper [7]. They characterize edges with a simple threshold on pixel values that allows differentiating large-scale edges from small-scale details. Using this method, the PHOG feature can be extracted exactly and the contour of the image can be easily obtained. In the following sections, we will introduce the edge-enhanced shape feature extraction method for image retrieval in detail.

2. The Method

+Corresponding author. Tel.: +010-59356559; fax: +010-59356559.
E-mail address:zhangrongguo@vancl.cn.

2.1. Feature Extraction

The author [2] divided the image into some regions, and each region was represented as a histogram of oriented gradients [5]. In forming the pyramid, the grid at level l has 2^l cells along each dimension. Instead, we modified the PHOG feature extraction by dividing the image region as shown in Fig.1.

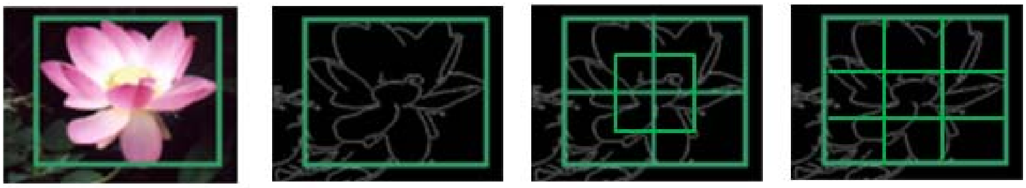

Fig. 1: The way of dividing image into regions for feature extraction in this paper.

As shown in Fig.1, this dividing way can help catching the main part of the feature and the dimension of the pyramid feature descriptor is not too large. Each bin in the histogram represents thenumbers of edges that have orientations within a certain angular range. This representation can be thought of as a traditional "bag of visual words", where here each visual word is a quantization on edge orientations [2]. Here, we divide the orientations in the range [0,180] into 9 bins. Therefore, the dimension of the descriptor is (1+5+9)*9=135.

In our experiments, the PHOG features are extracted from both original images and their corresponding contour images. To extract the edge contours, the*Canny*edge detector is firstly used on gray images, then some post-processing operations are applied. If the background and foreground have strong contrast, the contour of the object contained in the image can be unbrokenly obtained. However, due to the variability of images, some contours cannot be easily got.

2.2. The Enhanced Edges

For example, to get the contour of an image, we should convert the image to gray scale, and then the edges are got by using the Canny edge detector. The parameters of the edge detector are also selected through experiment method. To get more continuous edges, some morphologic operations are applied. Finally, the Flood-Fill operation is used. The whole process is illustrated in Fig.2.

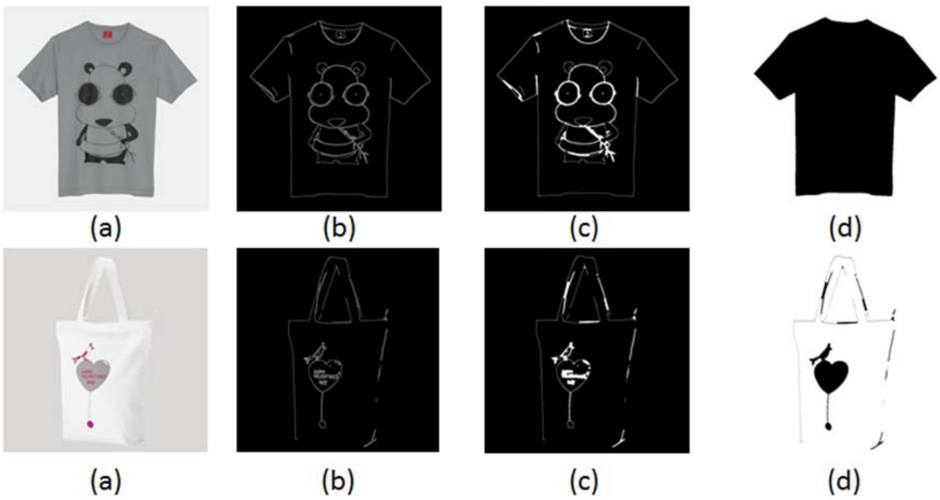

Fig. 2: The traditional way of extracting contour based on edges. (a) The original images. (b) The Canny edge images. (c) The edge images after the morphologic close operation. (d) The images after the Flood-Fill operation.

In Fig.2, we see that the contour of the upper image can be got unbrokenly, while the lower not. The bag in the lower image has no clear border, so the edges are too weak to form a complete contour. And then, the PHOG feature based on the edges is not very precise to express the shape of the bag. Therefore, the edge of the image should be enhanced.

The author of paper [7] proposed an algorithm that has a $O(N\log N)$ complexity for an image with N pixels. Their approach builds upon a new understanding of how image edges are represented in Laplacian pyramids and how to manipulate them in a local style. Based on this, they design a set of edge-aware filters that produce high-quality results. Given an image I, its Gaussian pyramid is a set ofimages $\{G_l\}$ called levels, representing progressively lower resolution versions of the image, in which high-frequency details gradually disappear. In the Gaussian pyramid, the bottom-most level is the original image, $G_0 = I$ and $G_{l+1} = \mathrm{downsample}(G_l)$ is a low-pass version of G_l with half the width and height. The filtering and downsample process is iterated n times, typically until the level G_n has only a few pixels. The Laplacian pyramid is a closely related construct, whose levels $\{L_l\}$ represent details at different spatial scales, decomposing the image into roughly separate frequency bands. Levels of the Laplacian pyramid are defined by the details that distinguish successive levels of the Gaussian pyramid, $L_l = G_l - \mathrm{upsample}(G_{l+1})$ where $\mathrm{upsample}(\cdot)$ is an operator that doubles the image size in each dimension using a smooth kernel. The top-most level of the Laplacian pyramid, also called the residual, is defined as $L_n = G_n$ and corresponds to a tiny version of the image. A Laplacian pyramid can be collapsed to reconstruct the original image by recursively applying $G_l = L_l + \mathrm{upsample}(G_{l+1})$ until $G_0 = I$ is recovered.

Using the method mentioned above, we take the lower image with an 800x800 resolution in Fig.2 as the example. After some tests, we find that the top-five levels of {G_l} and {L_l} are enough to enhance the edges of image. What's more, the algorithm of [7] is kind of slow using the single thread with MATLAB code. The result of using the top-five pyramid levels is illustrated in Fig.3.

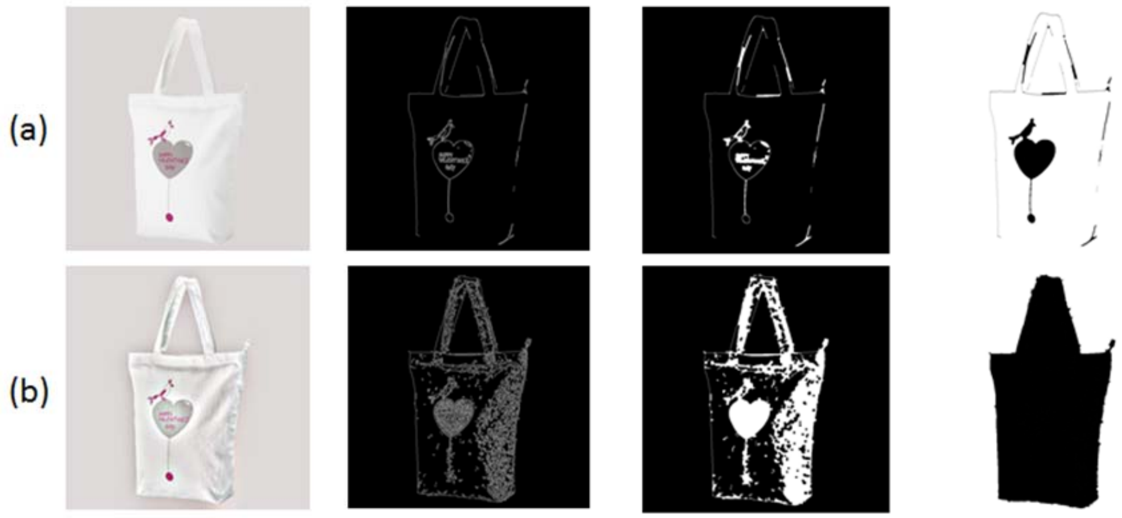

Fig. 3: The contrast of the same image before and after the edge-enhanced application. (a) The process of extracting contour using the original image. (b) The process of extracting contour using the edge-enhanced image.

As shown in Fig.3, we can see that the same image with edge enhanced can be extracted a complete contour. The whole contour is very important for shape feature extraction in image retrieval. To demonstrate the influence of the edge-enhanced operation visually, we show the histogram distributions of the image in Fig.3 with and without edge-enhanced operation. We can see that the weak shape features in some bins are boosted as some weak edges are enhanced after the operation.

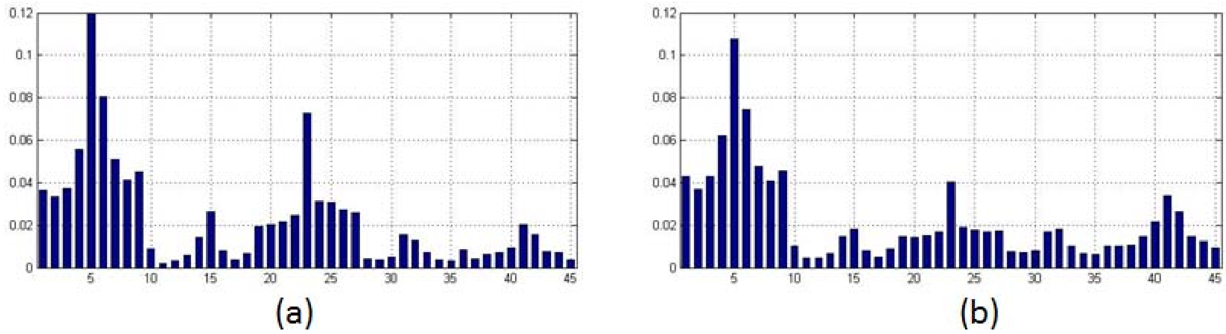

Fig. 4: The comparison of feature histograms with and without edge-enhanced operation. (a) The top-45 dimensional histogram distribution of the original image in Fig.3. (b) The top-45 dimensional histogram distribution of the image after the edge-enhanced operation in Fig.3.

3. Experiments

To test our image retrieval framework by shape feature, two datasets are prepared from VANCL commodity images. The small dataset contains 200 images while the larger set contains 1507 images.We choose the commodity images with bags, because the bags in these images have various appearances in size, shape and other styles. Some examples of these images are shown in Fig.5.

Fig. 5: Several samples of bags' images in VANCL datasets.

In the datasets, there are 24 images containing bags with the same shape as shown in the first row of the fourth and the fifth column. Some of the 24 images have weak edges. We do the image retrieval experiments with the original images and the edge-enhanced images.

We take each image from the 24 images as the query image in order to compare the results of experiments. For each query image, we count the correct retrieval number of Top5, Top 10, Top 15 and Top 20. Then, the average values of accuracy are calculated. For comparison, the experimental results of the small dataset are illustrated in Fig.6. The horizontal ordinate represents the different numbers for retrieval statistics, while the vertical ordinate represents the accuracy rate for each statistic. We can see that the accuracy rate of the retrieval based on shape feature is drastically improved with the edge-enhanced images.

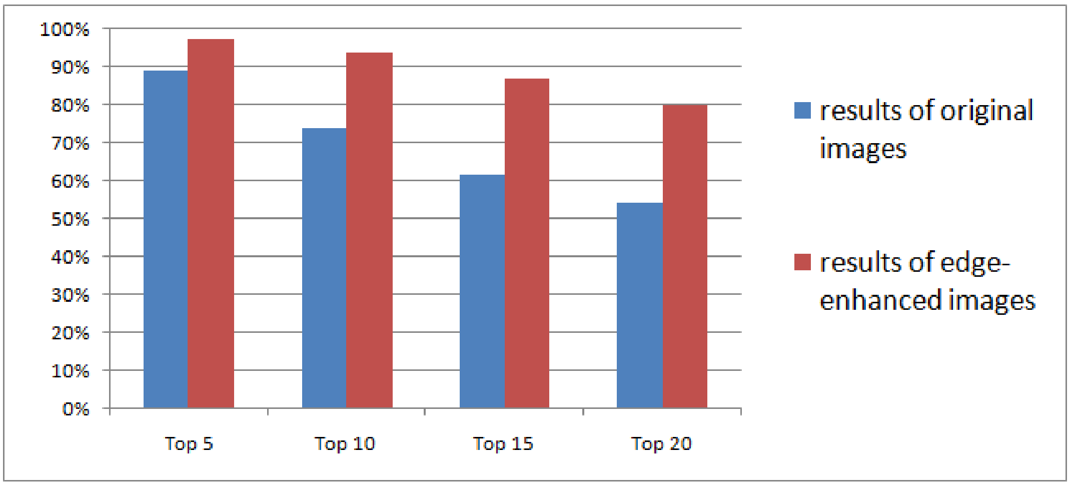

Fig. 6: The comparison of retrieval accuracy for the original images and the edge-enhanced images.

Table. 1: The retrieval results of using three distance measures between the histogram features.

	Top 5	Top 10	Top 15	Top 20
Euclidean distance	4.250	7.833	10.625	12.875
Histogram Intersection	4.636	8.864	12.682	**16.000**
Standardized Euclidean distance	**4.875**	**9.375**	**13.042**	15.958

We also compare the experimental results using three different distance measure as shown in Table 1. The numbers are the average values of accurate retrieval. Histogram intersection [8] is a similarity measure well known in the computer vision literature as an effective indexing technique for color-based recognition. It should be pointed out that StandardizedEuclidean distancemakes each dimension in the feature standardization among the whole dataset. It's a kind of Weighted Euclidean distance. Its performance is better than the other two measures.

Table. 2: The accuracy rate of retrieval results with the larger dataset.

	Top 5	Top 10	Top 15	Top 20
Original images	**93.33%**	82.92%	74.44%	66.46%
Edge-enhanced images	**93.33%**	**89.58%**	**86.39%**	**81.46%**

We also use the method in the larger dataset. For the same query images, the retrieval scope is expanded to 1507 images. The final results are listed in Table 2. It proves again that the edge-enhance operation can help to improve the retrieval performance based on shape feature. Some images' retrieval examples are illustrated in Fig.7.

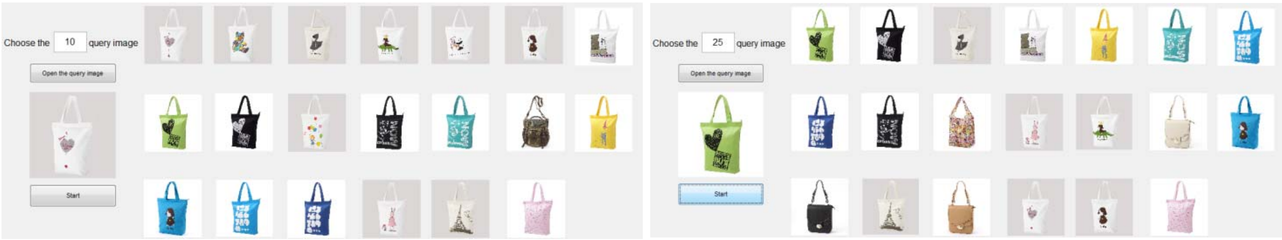

Fig. 7: Some examples of the image retrieval based on shape feature.

4. Summary

The paper proposed an image retrieval method based on shape feature. To extract more effective shape feature, the modified PHOG and edge-enhanced operations are used. Especially, some image without clear edges can be extracted more complete contour after edge enhancement, which is important for shape representation. Detailed experimental results proved that the edge-enhanced shape feature extraction method can improve the performance of image retrieval.

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6. References

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