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A varied local edge pattern descriptor and its application to texture classification ☆

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ABSTRACT

Similar images can be classified by the aid of texture cues among which edge is widely considered as one of the most valuable features. In this paper, we firstly proposed a flexible edge descriptor, called varied local edge pattern (VLEP). Then we apply VLEP to similar texture classification. The proposed VLEP descriptor has multi-scale, multi-direction (or multi-resolution) properties. Because VLEP uses histogram spectrum to describe image information, it is very easy to fuse local binary pattern (LBP) and Zernike moments histogram spectrum features due to their excellent properties and supplementary roles. The fused histogram spectrum features representing the images are classified via the nearest neighbor classifier. Experimental results show that the VLEP-based method can be remarkably superior to other state-of-the-art texture classification methods on the large and comprehensive CUReT and Outex texture database.

1. Introduction

Similar texture classification plays a vital role in many important applications such as object tracking or recognition, remote sensing, and image retrieval based on similarity [1–4]. However, it is still very difficult to analyze existing texture in the real world mainly because of some uncertain factors such as inhomogeneity, illumination changes and variability of texture appearance. In the early stage, researchers focus on using statistical features to classify texture images. Haralick et al. [5] firstly proposed a cooccurrence statistics based method to describe texture features. In the nineties, the Gabor filtering method of Manjunath and Ma [6] is credited as the current excellent technique in texture analysis. Local binary pattern (LBP) has been a reputable texture classification method due to its effectiveness, speediness and rotation invariant property since it was mentioned by Harwood et al. [7]. Later it was introduced to the public by Ojala et al. [1]. Many researchers developed LBP methods based on Ojala's idea. For example, Zhao et al. [8], Maani et al. [9], and Ahonen et al. [10] respectively improved LBP method using frequency domain analysis methods. Principal component two dimensional long short-term memory proposed by Tao et al. [11] is also a good method to extract texture feature which considers a principal component layer convolution operation to remove the noise and to get reasonable texture information. For improving the result of classification, some researchers proposed to develop better classifier. For example, Tao et al. [12] present a new variant of SVM, Hessian regularized SVM, which uses a large number of unlabeled samples to construct the Hessian regularization to boost the classification performance of SVM, when the number of labeled samples is small.

Edge is one of important texture attributes in the multichannel model based on human vision [13], and can be considered as an effective feature to classify similar texture. It is usually accompanied by a discontinuity in either the image intensity or the first derivative of the image intensity. Senthilkumaran [14] classified the edges into four classes including step edge, ramp edge, line edge and roof edge. The changes of image intensity in step edges and line edges are abrupt and sharp by definition. However, step and line edges are rare in the real world because low frequency components and the smoothing effect are often introduced by most sensing devices. Therefore, step edges are often evolved to ramp edges, and line edges are usually developed to roof edges, where discontinuity in the image does not happen instantaneously but occurs over a period of time [15].

If edge features are extracted and classified, they should be easily calculated, robust, and insensitive to not only distortions of the images but also disturbance resulting from the outside world such as noise. Many classic methods on edge extraction are pro-

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posed, and they generally be classified into three categories including gradient, Laplacian and image approximation algorithms [16]. Roberts [17], Prewitt [18] and Sobel [19] belong to gradient-based methods. Canny edge detector [20] is also based on computing squared gradient magnitude, in which the edges are detected by convolving the image with a mask and the local maxima of the gradient magnitude is marked as edge. Laplacian method uses zero crossing detectors, the second derivative, to determine the actual location of the edge [21]. In addition, Grompone et al. [22] proposed a linear-time line segment detector, which is obtained using a contrario validation approach, to extract edge information. Excellent surveys on edge detection and extraction are given in the articles [14,23].

Edge information is very useful for image retrieval. Chee et al. [24] proposed an edge histogram descriptor to retrieve semantically similar images. This method fuses global, semi-global, and local histograms of images to measure the image similarity. Fan et al. [25] proposed a color edge extraction method to segment images which contains four 3×3 square operators respectively representing horizontal, vertical, northeast diagonal and northwest diagonal edge patterns. Yao et al. [26] proposed a 3×3 local edge pattern to retrieve images which is based on local binary pattern (LBP) method [1]. The original image is firstly changed into binary image using Sobel edge detector. Then the LBP method is applied to the binary image.

Although the above mentioned edge extraction methods obtain excellent performance in different practical applications such as image retrieval and image segmentation, the following shortcomings exist due to the inherent nature of the algorithms. On one hand, all the operators are designed based on the smallest image unit like 2×2 pixels, or the smallest image unit containing a central pixel such as 3×3 pixels as shown in Fig. 1. They are not possessed of multi-scale properties and only contain local intensity changes within a very small range of the image. As we know, different scale space supports different discontinuities of the image. Therefore, it is easy and possible to consider the false edges as real ones by these methods. On the other hand, the categories of edge operators are rare, which usually include two or four directions such as 0° and 90°, or 0°, 45°, 90° and 135°. All of these disadvantages result from square form and the size of these operators which are not enough flexible and limit the number of edge direction. If the edge operator can be designed as a circle form, it can be easily derived multi-scale and multi-direction (or multi-resolution) versions. Furthermore, fusion idea based on multi-scale and multi-direction can also be fully considered to further improve the completeness of edge features.

Illuminated by the above ideas, a flexible circular VLEP edge detector is proposed in this paper which can be arbitrary radius R and neighbors P. Furthermore, multi-scale and multi-direction (or multi-resolution) properties lacked by conventional methods are contained by the VLEP-based method, which paves the way for the fusion idea. That is to say, different scale and direction features based on circular VLEP can be extracted. In addition, two sorts of non-edge VLEPs are also designed for adding the variety of the extracted features. Finally, many practical applications can be realized using VLEP operators such as pattern recognition, image retrieval, and object tracking, and here we take similar texture classification for example. A brief explanatory graph about similar texture classification is given which is beneficial to the further understanding of the proposed method as shown in Fig. 2.

The rest of the paper is organized as follows. Section 2 presents different kinds of VLEP descriptors including basic and extended VLEPs. Section 3 describes a complete texture classification method based on the above VLEPs in which subdivision and fusion ideas are used to further improve the accuracy of texture classification. The experimental results using the VLEP-based method and the other comparative methods are shown in Section 4. Finally, a conclusion is drawn.

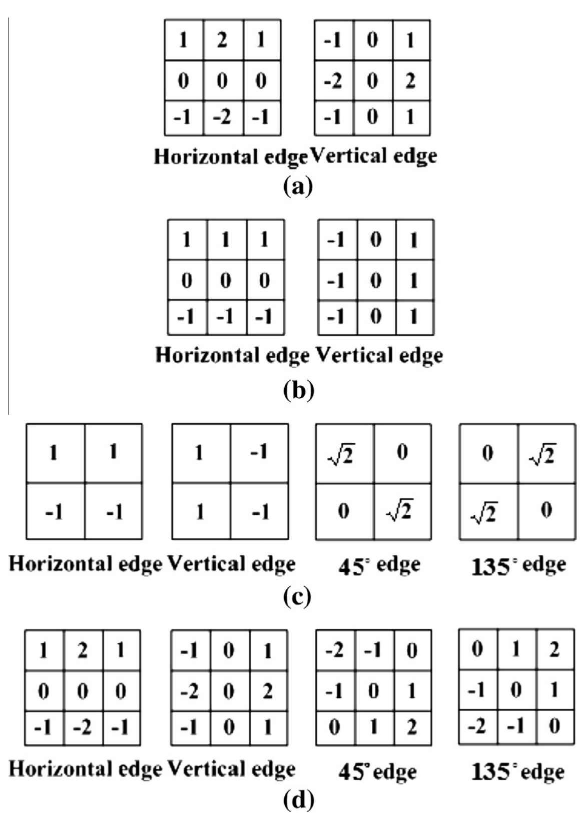

Fig. 1. Some edge descriptors proposed in (a) Sobel method, (b) Prewitt method, (c) Chee et al.'s method, and (d) Fan et al.'s method.

2. The proposed VLEP descriptor

A novel circular VLEP descriptor is proposed in this paper, and the detailed information about it will be described in the following subsection.

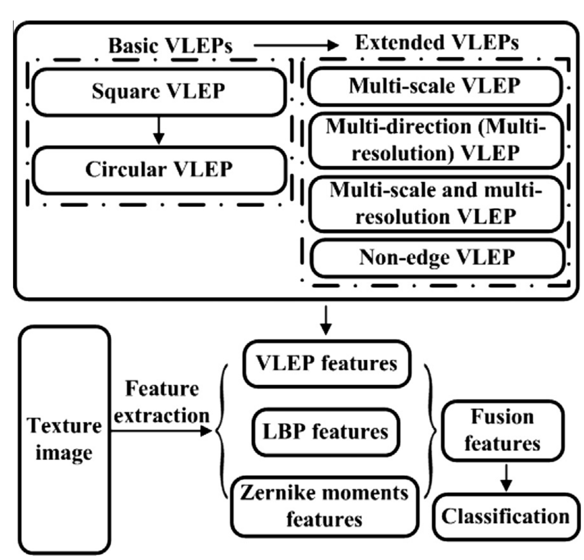

Fig. 2. A brief explanatory graph about the proposed similar texture classification system.