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Enhancing color image retrieval performance with feature fusion and non-linear support vector machine classifier

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ABSTRACT

The purpose of this work is twofold: A fusion framework is proposed wherein the color histogram (CH), orthogonal combination of local binary patterns (OC-LBP), and color difference histogram (CDH) features are exploited to capture color, texture and shape information of an image, and a detailed comparative analysis of classical distance measures with non-linear support vector machine classifier (SVM) is presented. The proposed fusion is compared with individual and other fused features such as CH, OC-LBP, CDH, OC-LBP + CH, CH + CDH, OC-LBP + CDH in the $L^*a^*b^*$ color space. Detailed experiments reveal that the non-linear SVM classifier with pre-computed square-chord kernel, when used with any feature, outperforms other kernels and classical measures in terms of recognition rate on five datasets: *SIMPLIcity*/*Wang*, *OT-Scene*, *Corel-5K*, *Corel-10K*, and *UKbench*. Further, the proposed fused features i.e. CH + OC-LBP + CDH using non-linear SVM classifier with pre-computed square-chord kernel gives the best accuracy for all the aforementioned datasets.

1. Introduction

Color and texture features are important low level features extracted from color images for content-based image retrieval (CBIR). Among the most widely used color features, color histogram is very effective and is invariant to image size and orientation [1,2]. It is very simple to implement as well. In order to enhance the image retrieval performance, texture of the color image is also taken into consideration. However, most of the existing texture features of the color images are extension of their gray scale counterparts. Here, we discuss two major texture descriptors for the color images which have been developed recently and observed to be very effective in representing texture of color images. These two techniques are: color difference histogram (CDH) approach developed by Liu and Yang [3] and orthogonal combination of local binary patterns (OC-LBP) developed by Zhu et al. [4]. In the CDH approach, color and edge orientation features are combined and the spatial relationships of color differences in a local window are considered for the purpose of representing local features. Two histograms are formed in the $L^*a^*b^*$ color space: the histogram of perceptually uniform color difference between neighboring edge orientation using color index information as a constraint, and the histogram representing perceptually uniform color difference between neighboring color indexes with edge orientation information as a constraint. The method has been observed to outperform the state-of-art global features derived for color image retrieval. The purpose of OC-LBP technique is to enhance the computational efficiency of the local binary pattern LBP operator when applied to color images.

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The LBP operator has been developed originally for the gray scale images to represent texture features [5,6]. This has been extended to color images by considering each channel of a color image as a gray scale image. Thus, the number of histogram features for a color image is three times to that of a gray scale image. The OC-LBP operator reduces this dimensionality, thus enhancing the speed of color image retrieval. Recently, several attempts have been made to extract color features which can be considered to have been originated from the original LBP operator. The prominent operators belonging to this category are the local color vector binary pattern (LCVBP) [7] and quarternionic local ranking binary pattern (QLRBP) [8]. The LCVBP operator consists of two discriminative patterns: color norm pattern and color angular patterns. The color angular patterns represent the discriminative features among the different channels of a color image. The LCVBP operator has been found to be very effective in face recognition [7]. The QLRBP operator is different from classical operators that are extracted from each color channel separately or from vector representation of color pixels. It works on the quarternion representation (QR) of color images that encodes a color pixel using a quarternion. By applying a Clifford translation to QR of the color image, QLRBP uses a reference quaternion to rank QRs of two color pixels, and perform a local binary coding on the phase of transformed result to generate local descriptors of the color image. A reference QR generates 256 histogram features and for achieving high performance, three reference QRs have been proposed. Thus, the dimensionality of QLRBP operator is also high.

It is a well-known fact that a retrieval system designed on a single feature set does not provide very high retrieval performance, whatever may be its effectiveness. This is because an image contains many visual characteristics and objects may change their colors, textures, and shapes. Recently, image retrieval using a combination of visual features has evolved as an active research area. One of the major problems associated with combining features from different modalities is the problem of feature normalization. Normally, the fusion is performed by taking weighted average of the similarity metrics as performed in [9]. The similarity metrics have different ranges and, therefore, their weighted average sometimes yields less retrieval performance as compared to their individual counterparts.

We focus on three types of features which have been observed to be very effective in the CBIR systems. The three features are: (1) color histogram (CH) which represents color, (2) the OC-LBP features which represent color and texture, and (3) the CDH features which represent both color and shape. Deselaers et al. [10] have conducted extensive experimental analysis using color histograms and various features involving texture and shape. The color histogram is observed to be an effective image descriptor and it is suggested as a baseline descriptor for many applications. According to their observations, none of the shape or texture features was found to be as effective as the color features. The OC-LBP is a texture feature which is used for color images. It is similar to the LBP operator but has low dimensionality. The CDH approach is a novel visual attribute descriptor combining edge orientation, color and perceptually uniform color difference, as well as encoding the spatial layout. As individual descriptors, the three descriptors have been found very effective for color CBIR systems. The fusion of the features obtained from the three methods has not been studied. Moreover, these methods employ non-training based classifiers and the effect of training-based classifiers, such as the SVM classifier, is not yet reported.

In this paper, we analyze image retrieval performance of the color histogram, the OC-LBP and CDH approach using both the non-training and training-based classifiers. We propose to fuse the three modalities at the feature level and develop a framework which provides a normalized range of the similarity metrics in order to prevent the dominance of the one set of the features over the others. The normalization of the features is very important to provide optimum retrieval performance when the features are merged. Detailed experimental results demonstrate that the retrieval performance increases by 15%–26% between the best individual descriptor and the combination of the three methods using the SVM classifiers.

The rest of the paper is organized as follows. Section 2 presents some existing works based on combination of low level features. In Section 3, we provide overview of the existing state-of-the-art descriptors for color image i.e. CH, OC-LBP and CDH. The proposed fusion of features has been discussed in Section 4. In Section 5, we explain the various distance measures and SVM classifiers used in image retrieval application. Detailed experimental analysis on various datasets is presented in Section 6. Section 7 concludes the paper.

2. Related work

This section describes some of the existing works which have used combination of low level features for enhancing image retrieval performance. In one of the earliest attempts, Jain and Vailaya [22] introduced a method that is a combination of color and shape (edge) features. They used the color histogram and Canny edge operator to calculate features. It is efficient for processing large databases, but does not allow detail description of each object's shape and spatial information if there are multiple objects in the same images. This method gives approximately 90% accuracy on small databases consisting of logos and trademarks. Yue et al. [23] used a fusion of color and texture features based on color histogram and grey level co-occurrence matrix (GLCM) for image retrieval. They observed that the global color histogram provides the overall image color information without spatial information and it is rotation invariant. The block color histogram contains certain positional information. It gives better result than global color histogram with respect to human visual perception. Results of GLCM texture features are more focused on the same texture mode instead of same color. After the fusion of both block color histogram and GLCM, it yields better results than using them separately. Huang et al. [24] proposed an image retrieval approach based on color and texture. They used color moments as color features and Gabor filter to capture texture features whose similarity results are finally combined for color image retrieval. They applied color moments on HSV and RGB color spaces. When they evaluated average precision based on features of RGB and HSV color moments, it was found that precision based on HSV color moments gives approximately 24% better retrieval performance than that obtained by RGB color space.