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Color texture description with novel local binary patterns for effective image retrieval

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ABSTRACT

We propose a novel local color texture descriptor called local binary pattern for color images (LBPC). The proposed descriptor uses a plane to threshold color pixels in the neighborhood of a local window into two categories. To boost the discriminative power of the proposed LBPC operator, local binary patterns of the hue component in the HSI color space, called the local binary pattern of the hue (LBPH) is derived. Further, LBPC, LBPH are fused to derive LBPC+LBPH which when combined with the color histogram (CH) of the hue component results in an effective image retrieval method LBPC+LBPH+CH. The uniform patterns of the two proposed descriptors ULBPC and ULBPH are combined to yield another low dimension local color descriptor ULBPC+ULBPH+CH which provides a good tradeoff between retrieval accuracy and speed. Detailed experiments conducted on *Wang, Holidays, Corel*-5K and *Corel*-10K datasets demonstrate that the proposed low dimension descriptors LBPC+LBPH+CH, and ULBPC+ULBPH+CH outperform the state-of-the-art color texture descriptors in terms of retrieval accuracy and speed.

1. Introduction

Content-based image retrieval (CBIR) is one of the active research areas in the field of pattern recognition and artificial intelligence. Even after more than three decades of extensive research, the quest for more-and-more effective CBIR systems has attracted many researchers to develop systems which provide high retrieval rates within low retrieval time. The early CBIR systems were focused on the grayscale images, but with the widespread use of color images over Internet and the advantage of a color attribute for discrimination purpose, color information is being incorporated to enhance the performance of retrieval systems. A retrieval system provides a user with a way to access, browse and fetch images efficiently from databases. These databases are used in a variety of fields including information security, biometric system (iris, fingerprint, and face matching), biodiversity, digital library, crime prevention, medical imaging, historical archives, video surveillance, human-computer interaction, etc.

The CBIR systems depend heavily on two steps: feature extraction and feature matching. Feature extraction is the most important step as it requires an image to be represented by highly discriminative features with small variations among the features of intra-class images and high variations among inter-class images. The features are desired to be robust to geometric and photometric changes such as translation, rotation, scale, occlusion, illumination, viewpoint, etc.

Broadly, there are two categories of feature representation: (1) global or holistic approach and (2) local approach. A global approach extracts features from the whole image ignoring the local characteristics and spatial relationship between pixels. They are computationally efficient and robust to image noise. The global methods suffer from their inadequacies to handle some of the issues related to occlusion, view points and illumination changes, and local characteristics of image shape. These issues are well addressed by the local feature extraction methods which extract features from local regions of an image. These local regions can be as simple as partitions of an image or are selected through key points.

The most common global feature extraction techniques based on color include the MPEG-7 feature sets such as color histograms, dominant color descriptor, scalable color descriptor, and color layout descriptor [1]. The color histogram features have been observed to yield very good performance; they are invariant to translation and rotation and can be made scale invariant after normalization by the image size. Texture based global feature extraction methods include gray level co-occurrence matrices [2], Tamura texture features [3], Markov random field model [4] and Gabor filtering [5]. A comparative performance analysis of these texture features on the retrieval of texture images establishes the superiority of Gabor filters over others [6]. Effect of different Gabor filter parameters on texture image retrieval has been studied in

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[7]. Rotation and scale invariant optimum Gabor filter parameters for texture image retrieval have been derived by Han and Ma [8]. They have observed that the optimum filter parameters provide much superior performance than the conventional filter parameters. Bianconi and Fernandez [9] have also improved Gabor filter parameters to provide better texture classification results. One of the problems associated with Gabor filtering is that its feature extraction process is very slow [7]. Shape features also provide powerful information for image retrieval. Shape matching is a well-researched area with many shape representation and matching techniques [10]. Shape features are generally used in two ways: boundary-based and region-based. In the boundary-based representation of an image, the boundary or contour of an object is required to be extracted, while in the region-based techniques all pixels of an image take part in the computation of the shape features [10,11].

The global feature-based methods have been the mainstay of many CBIR systems. However, their inability to deal with many complex issues related to geometric deformations and photometric changes have necessitated the extensive use of local feature extraction methods, which can resolve these issues effectively. Some of the effective local feature extraction methods are LBP [12], SIFT [13], PCA-SIFT [14], GLOH [15], SURF [16], HOG [17], DAISY [18], Rank-SIFT [19], BRIEF [20], ORB [21], WLD [22], and many more.

Color and texture provide important information for deriving effective features there by ensuring high performance of the retrieval systems. The classical texture features were derived for the grayscale images. Among the various local texture descriptors for grayscale images, SIFT has proven to be the most effective and successful descriptor in the state-of-the-art recognition and classification system [23]. To capture the texture of color images, it is extended to several variants e.g. color SIFT [24]. The color SIFT has further been evaluated against several color descriptors and found to outperform them. However, color SIFT is computation intensive especially when the size of the image or size of the database increases. The local binary pattern (LBP), developed by Ojala et al. [12] is also an effective texture descriptor which is found to be powerful and successful in many pattern recognition and computer vision applications. It captures local texture features, which are invariant to illumination changes. It is simple, fast and provides strong discriminative power as compared to many other local texture descriptors. The LBP operator has been used successfully in texture classification [25-28], face recognition [29-31], facial expression recognition [32-35], and image retrieval [36,37], etc. A survey paper [38] provides a comprehensive discussion on facial image analysis using the classical LBP operator and several of its variants and cites 159 papers in this area.

Most of the works on classical LBP operator and its variants have been developed for gray scale image processing. The increasing demand for color images over Internet and their ever increasing use for many practical applications have motivated the researchers to develop descriptors which can represent color texture pattern as effectively as the LBP operator does for gray scale images. A natural extension of the gray scale LBP operator is to process each channel of a color image as a gray scale image. This strategy was used by Mäenpää et al. [39] for color texture description. In their multispectral LBP (MSLBP), they use three channels of a color image and six sets of LBPs opponent color to capture spatial correlation between the two channels of the color spectra. The method is effective. However, it results in a very high dimensional feature vector. Later, Mäenpää and Pietikäinen [40] conducted experiments on color texture and observed that instead of taking six opponent color components only three pairs are sufficient for representing cross correlation features between the three color channels. Choi et al. [41] derived LBP histograms for each channel in YC_bC_r color space and applied PCA to reduce the dimensionality of the feature vector. They observed that their method performed better in face recognition application than the LBP operator on gray face images, which were derived from color images. Lee et al. [42] derived local color vector binary patterns (LCVBPs) for face recognition problem. The LCVBP operator consists of two parts: color norm patterns and color angular patterns. The color angular pattern captures discriminative features of two color spectra and derives spatial correlation of local color texture. The LCVBP operator is very effective as compared to the LBP of individual color channels. To reduce the dimension of LBP operator and apply it to color images, Zhu et al. [43] proposed an orthogonal combination of local binary patterns (RGB-OC-LBP). Their proposed RGB-OC-LBP operator performs better than the color SIFT operator in image matching, object recognition, and scene classification applications. Recently, Lan et al. [44] have introduced quaternion local ranking binary pattern (QLRBP), which combines the color information provided by multispectral channels in color images. The QLRBP operator is derived using quaternionic representation (QR) of color images. The QLRBP can handle all color channels directly in the quaternionic domain and represents color texture without treating the color channels separately. Li et al. [45] have developed local similarity pattern (CLSP) for representing the color image as the co-occurrence of its image pixel color quantization information and the local color image textural information. In an attempt to utilize the cross channel information, Dubey et al. [46] have developed two sets of patterns, multichannel adder and decoder-based LBPs (MDLBPs) and observed that the latter provides better retrieval performance than the former. The performance of their proposed approach is better than the other similar LBP-based descriptors, but the size of the feature vectors for both methods is large.

In this paper, we propose an operator called local binary pattern for color images (LBPC), which derives texture patterns for a color image similar to the way LBP operator derives texture for gray scale images. For this purpose, we treat a color pixel as a vector having m-components and form a hyperplane. The hyperplane is used as a boundary to threshold and partition color pixels into two classes. A color pixel in a 3×3 neighborhood of the current pixel is assigned a value 1 if it lies on or above the plane, and the value 0, if it is below the plane. Thus, the proposed operator provides spatial relationship among color pixels, which represents local texture features. We compute histograms of the binary patterns obtained from color images in a way akin to the histograms of LBP operator for gray scale images. If we use 8-neighborhood of a color pixel, then we have 256 histogram bins, which are used as features representing local texture patterns of color images. We refer this operator as the LBPC operator. The dimensionality of LBPC is reduced by deriving uniform patterns [12] with 59 bins. Since we are investigating effective descriptors for color images, a natural question arises as what is the retrieval performance when we use local binary patterns of the color component of color images. For the purpose of representing local binary patterns of the color components, the H component in the HSI color model [47] is an appropriate choice as compared to all other color models. Therefore, in our second proposed method, we derive the local binary patterns of H component of HSI color model. We refer this descriptor as local binary pattern of the hue (H) component (LBPH). The discriminative power of LBPC is enhanced by fusing the LBPC features with LBPH features. This approach is referred as LBPC+LBPH. The color histograms are among the best color image descriptors [48,49] and hence, in our proposed third approach, we derive color histogram (CH) of H channel in the HSI color model and fuse it with LBPC+LBPH. This approach is referred as LBPC+LBPH+CH. In order to reduce the dimension of LBPC+LBPH+CH, we derive the uniform patterns of LBPC and LBPH and fuse them to the CH features, which yields an effective low dimension local color texture