

LETTER

Image Retrieval Based on Structured Local Binary Kirsch Pattern

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SUMMARY This Letter presents a new feature named structured local binary Kirsch pattern (SLBKP) for image retrieval. Each input color image is decomposed into Y, Cb and Cr components. For each component image, eight 3×3 Kirsch direction templates are first performed pixel by pixel, and thus each pixel is characterized by an 8-dimensional edge-strength vector. Then a binary operation is performed on each edge-strength vector to obtain its integer-valued SLBKP. Finally, three SLBKP histograms are concatenated together as the final feature of each input colour image. Experimental results show that, compared with the existing structured local binary Haar pattern (SLBHP)-based feature, the proposed feature can greatly improve retrieval performance.

key words: image retrieval, structured local binary Haar pattern, structured local binary Kirsch pattern

1. Introduction

Content-based image retrieval (CBIR) is the process of retrieving desired images that are similar to a query image from a large collection on the basis of syntactical image features. Most existing CBIR systems adopt four kinds of visual cues: color, texture, shape, and object layout. Recently, local feature based CBIR [1] and invariant feature based CBIR [2] have become two important research topics, since they were successfully used in object detection and recognition [3]. A variety of research efforts have been made in this area: Shin et al. [4] proposed a vector quantization-based local texture feature that is extracted by a Gabor filter bank at interest points. Rahman et al. [5] presented an invariant texture feature based on Gabor filters with circular shifting in both the scale and rotation dimensions. An et al. [6] suggested a modified angular radial partitioning for edge image description that is rotation-invariant. Su et al. [7] proposed a new feature named structured local binary Haar pattern (SLBHP) that combines the merits of Haar wavelet and local binary pattern (LBP). Inspired by the SLBHP feature, this Letter proposes a new local feature based on the Kirsch edge detector that is more effective for color image retrieval.

2. Proposed Structured Local Binary Kirsch Pattern for Image Retrieval

Our idea originates from the SLBHP feature proposed in [7] that adopts four 3×3 Haar basis templates as follows

$$\mathbf{H}_1 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{bmatrix}, \mathbf{H}_2 = \begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{bmatrix}, \quad (1)$$

$$\mathbf{H}_3 = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}, \mathbf{H}_4 = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Its purpose is to capture the changes of grey values along four directions, i.e., the horizontal, the vertical and the two diagonal directions. In order to capture the edge information along more directions, we think of the Kirsch edge detector with eight-direction templates as follows

$$\mathbf{K}_1 = \begin{bmatrix} -5 & 3 & 3 \\ -5 & 0 & 3 \\ -5 & 3 & 3 \end{bmatrix}, \mathbf{K}_2 = \begin{bmatrix} 3 & 3 & 3 \\ -5 & 0 & 3 \\ -5 & -5 & 3 \end{bmatrix}, \mathbf{K}_3 = \begin{bmatrix} 3 & 3 & 3 \\ 3 & 0 & 3 \\ -5 & -5 & -5 \end{bmatrix}, \quad (2)$$

$$\mathbf{K}_4 = \begin{bmatrix} 3 & 3 & 3 \\ 3 & 0 & -5 \\ 3 & -5 & -5 \end{bmatrix}, \mathbf{K}_5 = \begin{bmatrix} 3 & 3 & -5 \\ 3 & 0 & -5 \\ 3 & 3 & -5 \end{bmatrix}, \mathbf{K}_6 = \begin{bmatrix} 3 & -5 & -5 \\ 3 & 0 & -5 \\ 3 & 3 & 3 \end{bmatrix},$$

$$\mathbf{K}_7 = \begin{bmatrix} -5 & -5 & -5 \\ 3 & 0 & 3 \\ 3 & 3 & 3 \end{bmatrix}, \mathbf{K}_8 = \begin{bmatrix} -5 & -5 & 3 \\ -5 & 0 & 3 \\ 3 & 3 & 3 \end{bmatrix}$$

The original Kirsch operator is a non-linear edge detector that finds the maximum edge-strength in 8 directions with 45° differences. However, in image retrieval, we should record all the 8 edge-strength values to compose an edge-strength vector for each pixel. The extraction process of the proposed SLBKP feature from an input image $\mathbf{X} = \{x(m, n), 1 \leq m \leq M, 1 \leq n \leq N\}$ can be illustrated as follows: First, perform eight 3×3 Kirsch templates on each pixel $x(m, n)$, $2 \leq m \leq M - 1, 2 \leq n \leq N - 1$ to get the edge-strength vector $\mathbf{V}(m, n) = (v_1(m, n), v_2(m, n), \dots, v_8(m, n))$ as

$$v_i(m, n) = \left| \sum_{p=0}^2 \sum_{q=0}^2 [x(m+p-1, n+q-1) \times k_{i,pq}] \right|, \quad 1 \leq i \leq 8 \quad (3)$$

where $k_{i,pq}$ stands for the element at the position (p, q) of

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Template \mathbf{K}_i . Then, obtain two integer values $P_1(m, n)$ and $P_2(m, n)$ as the structured local binary Kirsch pattern (SLBKP) for $x(m, n)$ by

$$SLBKP(m, n) = \{P_1(m, n), P_2(m, n)\} \quad (4)$$

$$P_j(m, n) = \sum_{i=1}^4 B(v_{i+(j-1) \times 4}(m, n)) \times 2^{i-1} \quad j = 1, 2$$

$$\text{where } B(u) = \begin{cases} 1 & \text{if } |u| > T \\ 0 & \text{otherwise} \end{cases}$$

is the binary operation with T as a predefined threshold. Here, we should note that, for each pixel $x(m, n)$, SLBHP [7] only produces one integer value, while our SLBKP generates two integer values. Finally, based on the obtained SLBKPs, calculate the corresponding histogram as the final 32-dimensional feature vector \mathbf{F} as follows

$$\mathbf{F} = (\mathbf{F}_1, \mathbf{F}_2) = (f_{1,0}, \dots, f_{1,15}, f_{2,0}, \dots, f_{2,15}) \quad (5)$$

$$f_{j,i} = \sum_{m,n} I(P_j(m, n) = i) \quad j = 1, 2; 0 \leq i \leq 15$$

$$\text{where } I(P) = \begin{cases} 1 & \text{if } P \text{ is true} \\ 0 & \text{otherwise} \end{cases}$$

3. Experimental Results

To evaluate the effectiveness of the proposed SLBKP feature, we compare it with the existing SLBHP feature [7] in color image retrieval. We use a standard database named photography image database [8] in the experiment that is carried out on an ACPI x64-based PC with 3.60 GHz CPU and 8 G RAM. The database includes 1000 images of size 384×256 or 256×384 , which are categorized into ten classes, each class including 100 images. For the existing SLBHP feature, we adopt $T = 15$ and extract three 16-bin histograms from each image based on the YCbCr color space. For the proposed SLBKP feature, we adopt $T = 45$ and generate three 32-bin histograms based on the YCbCr color space. Figure 1 and Fig. 2 show concrete retrieval examples based on the existing SLBHP and the proposed SLBKP respectively. Here, the same query image from the class “people” is adopted in both figures as shown in the top left corner, and the first 16 most similar images retrieved from the database are provided in each figure (obviously, the most similar image is the query image). We can see that the SLBHP scheme returns 4 irrelevant images (i.e., the fifth image and the eighth image from the class “food”, the eleventh image from the class “horse” and the fourteenth image from the class “food”), while the proposed SLBKP scheme only returns one irrelevant image (i.e., the thirteenth image from the class “food”).

To compare the performance more reasonably, we randomly select 20 images from each class, and thus in total 200 images, as the test query images. For each test query image, we perform the retrieval process based on each kind of features. For each number of returned images (from 1 to 1000), we average the recall and precision value over 200 test query images. Here, the precision and recall are defined



Fig. 1 A retrieval example based on the existing SLBHP feature. Here, the first 16 most similar images to the query image (on the top left corner) are shown.



Fig. 2 A retrieval example based on the proposed SLBKP feature. Here, the same query image as in Fig. 1 is adopted.

as follows:

$$\text{precision} = \frac{\text{No. relevant images}}{\text{No. images returned}} \quad (6)$$

$$\text{recall} = \frac{\text{No. relevant images}}{100}$$

Based on above test conditions, Fig. 3 compares the average P-R curves among the SLBHP feature [7], the MARP feature [6] and the proposed feature. From Fig. 3, we can see that each curve has the same start point and the same end point, because the first point corresponds to the case of returning one image (the query image), while the end point corresponds to the case of returning 1000 images (all the 100 images from the same class of the query image must be returned). Statistically, we can easily find that the proposed feature and the MARP feature have nearly the same performance, and they can get a much better performance than the SLBHP feature in precision and recall. When the recall is around 0.5, the improvement in precision is the largest. As far as SLBKP and SLBHP are concerned, the main reason is that the Kirsch operator utilizes eight edge directions while the Haar descriptor only considers four directions. The second reason is that the Kirsch operator takes 8 pixels around the center pixel into account, while the Harr

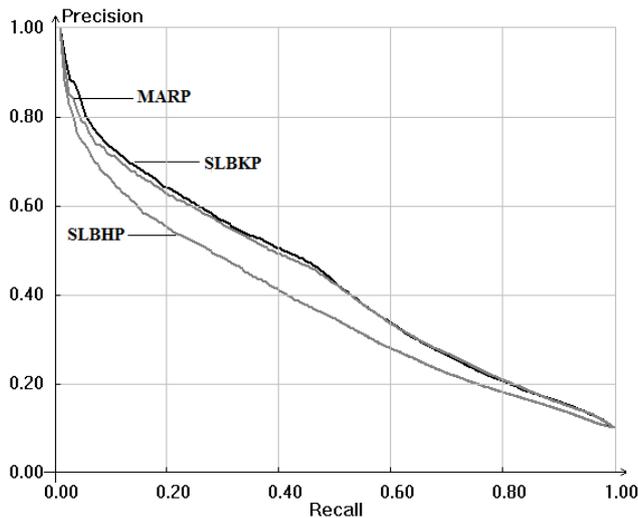


Fig. 3 Comparison of the P-R curves between the existing SLBHP feature and the proposed SLBKP feature.

descriptor only considers 6 pixels, thus our feature can capture more detailed information from the image. In addition, SLBKP generates two integer values for characterizing each pixel, which makes our feature more effective to distinguish different images while making similar images more close to each other. Therefore, the proposed SLBKP feature can more effectively characterize the input image than the existing SLBHP feature.

4. Conclusions

A simple local feature named SLBKP, which makes use of eight 3×3 Kirsch edge templates, is presented in this Letter. Compared with SLBHP, our feature can capture more edge information, since two more pixels around the center pixel and four more edge directions are taken into account, and one more integer value is generated to characterize

each pixel. The experimental results based on a standard image database show that our SLBKP feature outperforms the existing SLBHP feature in color image retrieval. Future work will concentrate on how to extract scale and rotation-invariant local binary patterns from the image.

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