Object-Based Image Retrieval Using Dominant Color Pairs Between Adjacent Regions

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Abstract. Most existing methods for content-based image retrieval handle an image as a whole, instead of focusing on an object of interest. This paper proposes object-based image retrieval based on the dominant color pairs between adjacent regions. From a segmented image, the dominant color pairs between adjacent regions are extracted to produce color adjacency matrix, from which candidate regions of DB images are selected. The similarity measure between the query image and candidate regions in DB images is computed based on the color correlogram technique. Experimental results show the performance improvement of the proposed method over existing methods.

1 Introduction

Most of existing content-based image retrieval systems show some good results [1-6]. But in most cases, they use whole images instead of focusing on the regions of interest. Therefore, the systems may produce undesirable retrieval results because of the errors caused by backgrounds. In this paper, we propose an image retrieval method, where an object of interest is used as a query and the retrieval result is candidate regions in DB images where the object exists.

This paper is organized as follows. Section 2 introduces related works. Section 3 describes the proposed method. Experimental results are given in Section 4, and Section 5 concludes the paper.

2 Related Works

Color information in color images is a significant feature for content-based image retrieval. Because color features have very important low-level information, which is insensitive to noises or complexity of background, they have been used for robust retrieval against translation, rotation, and scaling.

One of significant works in color-based retrieval was done by Swain and Ballard who proposed color histogram intersection technique[7], where the similarity measure is the distance between a query image histogram and a DB image histogram. This method has been widely used since it is simple and the computational requirement is low. However, it may produce dome erroneous results since the histogram does not

M. Gavrilova et al. (Eds.): ICCSA 2006, LNCS 3984, pp. 404 – 411, 2006.

include any spatial information. To solve this problem, Huang proposed color correlogram method that includes spatial correlation in color information [6]. Even though the performance of this method has been improved, it is inappropriate for partial matching since it computes the similarity using whole images. Das proposed an image retrieval system (FOCUS) to find regions of interest in DB images, which contain the query object [8].

3 Proposed Method

The method proposed in this paper consists of the following steps.

For query image,

Step1. Segment the image and extract the object of interest
Step2. Determine dominant color from extracted object
Step3. Compute color correlogram and construct color adjacency matrix (CAM)

For DB image,

Step1. Segment the image and extract dominant colors
Step2. Extract color pairs
Step3. Determine candidate regions by CAM
Step4. Compute color correlogram
Step5. Compute the similarity between query image and candidate regions extracted from DB images using color correlogram

Fig. 1 shows the overall flowchart of the proposal scheme.

3.1 Image Segmentation and Object Extraction

From a given query image including the object of interest, the image is first segmented. Then by selecting the regions of interest, the object is identified. We use the image segmentation algorithm proposed by Demin Wang [9]. This algorithm is known to be an efficient algorithm in terms of computation time and performance. Fig. 2 shows the original image and the segmented image.

To generate the object of interest from the segmented image excluding background, the user selects the regions of interest. Then the selected regions are merged into one region. Fig. 3 shows the image containing the object of interest without background.

3.2 Dominant Color Extraction

The dominant color which is one of MPEG-7 color descriptors is useful when several colors or a specific color sufficiently represent either a whole image or a partial image [10]. In this paper, dominant color is used as a feature to represent each segmented region. The dominant color of a region is defined as the maximum bin of color histogram.

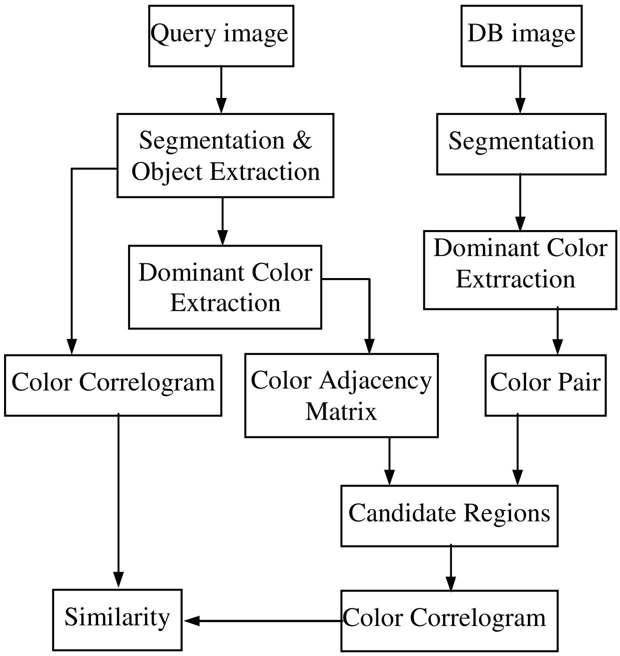

Fig. 1. Overall flowchart

(a) (b)

Fig. 2. Segmentation result. (a) Original image, (b) Segmented image.

3.3 Color Adjacency Matrix (CAM)

Objects in images usually have some colorful flat regions adjacent to each other, which produces some spatial information about the object of interest. Examples of those images include the ones in the FOCUS system [8]. We mainly focus on the characteristics of those adjacent regions. Along the boundaries of these adjacent regions, we extract color adjacency information and utilize color pairs which can be extracted from the color adjacency.

Fig. 3. Result of object extraction

In order to extract color pairs, we use 3x3 mask at each pixel. Among the pairs of the center pixel and its neighbors, the pair with the maximum color difference is defined as "color pair". When the color difference is over a threshold value, it is defined as an "edge". Color pairs can be identified by computing the color vector angular distance (CVAD) [11,12]. Many researchers have studied the measures based on the angle of a color vector, which produces perceptually admirable retrieval results in RGB domain. Regarding the color vector angular distance it is known that the angular measures are chromaticity-based, which means that they operate primarily on the orientation of the color vector in the RGB space and are robust against intensity changes [13]. Among these measures, we choose vector angle-based distance measure proposed by Androutsos. It is a distance measure based on the angular distance between two vectors. Also, it is a combinational distance measure, which is composed of an angle and magnitude [13]. CVAD measure is shown in equation (1),

$$\delta(\mathbf{x}_i,\mathbf{x}_j) = 1 - \underbrace{\left[1 - \frac{2}{\pi}\cos^{-1}\left(\frac{\mathbf{x}_i \cdot \mathbf{x}_j}{|\mathbf{x}_i||\mathbf{x}_j|}\right)\right]}_{angle} \cdot \underbrace{\left[1 - \frac{|\mathbf{x}_i - \mathbf{x}_j|}{\sqrt{3 \cdot 255^2}}\right]}_{magnitude} \quad (1)$$

where $\mathbf{x}_i$ and $\mathbf{x}_j$ is three-dimensional color vector of the center and its neighbor, respectively. The normalization factor of $2/\pi$ in angle portion is attributed to the fact that the maximum angle which can possibly be attained is $\pi/2$. Also, the $\sqrt{3 \cdot 255^2}$ normalization factor is due to the fact that the maximum difference vector which can exist is (255,255,255) and its magnitude is $\sqrt{3 \cdot 255^2}$. Extracting color pairs using equation (1), we can make the color adjacent matrix (CAM). We utilize not every color pair but some of them. Therefore, we have to choose color pairs to be used as a feature, prior to making CAM. We choose color pairs when the number of corresponding color pairs exceeds a threshold value. The threshold values are determined by experiments. In order to determine color pairs, we use equation (2). As shown in equation (2), the element of each color pair in CAM is assigned 1 or 0.

$$CAM(C_i, C_j) = \begin{cases} 1 & if \;\; N(C_i, C_j) \geq Th \\ 0 & others \end{cases} \quad (2)$$

Where $N(C_i, C_j)$ is the number of color pairs (C_i, C_j) and Th is a threshold value. Fig. 2 shows how color pairs are extracted and how CAM is constructed by equation (2).

3.4 Candidate Region Extraction

Given color adjacency matrix for the query image, we search for candidate regions in DB image, where the object of interest may exist. After segmenting a DB image, each segmented region is assigned a dominant color. Each pair of adjacent regions are selected as candidate regions if color adjacency matrix of query image with corresponding dominant color pair is equal to 1. Fig. 4 shows how the candidate regions are extracted from DB image.

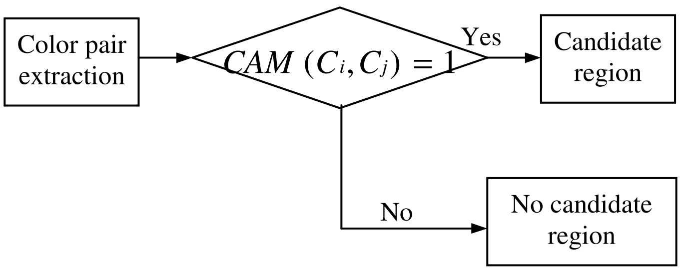

Fig. 4. Candidate region extraction

3.5 Color Correlogram

Among the candidate regions in DB image, the similarity between the query image and each candidate region is computed by using color correlogram [6]. Color correlogram expresses how the spatial correlation of pairs of colors changes with distance. Color correlogram is given by equation (3).

$$\begin{aligned} \gamma^{(k)}_{ci,cj}(I) &\equiv \Pr_{p_1 \in I_{ci},\, p_2 \in I} [p_2 \in I_{cj} \,|\, |p_1 - p_2| = k] \\ |p_1 - p_2| &\equiv \max\{|x_1 - x_2|, |y_1 - y_2|\} \end{aligned} \tag{3}$$

Here I is an n x n image. Colors are quantized into m colors $c_1, c_2, c_3, \ldots, c_m$. For a pixel $p = (x,y) \in I$, $I(p)$ denotes its color. $I_c \equiv \{p \mid I(p) = c\}$. Given any pixel of color c_i in the image, $\gamma^{(k)}_{ci,cj}$ gives the probability that a pixel at distance k away from the given pixel is of color c_j.

3.6 Similarity Measure

To determine the similarity between a query image and DB images, the metric given in equation (4) is computed.

$$|I - I'|_{\gamma, d} = \sum_{i,j \in [m], k \in [d]} \frac{|\gamma^{(k)}_{ci,cj}(I) - \gamma^{(k)}_{ci,cj}(I')|}{1 + \gamma^{(k)}_{ci,cj}(I) + \gamma^{(k)}_{ci,cj}(I')} \tag{4}$$

Where I is the query image, I' is a DB image, and d is the distance between pixels.

4 Experimental Results

For the experiment, FOCUS DB images which include 25 query images are used [2]. We evaluate the performance in terms of object extraction and image retrieval. Fig. 5 shows some query images used in the experiment.

Fig. 5. Some of the query Images

To evaluate the performance of the retrieval, we use the *ANMRR* metric that is the performance measure of MPEG-7 standards for color and texture, which is computed by equation (5) [14].

In equation (4), *NG(q)* implies the number of images in each category, *GTM* represents the largest number among *NG(q)*'s, and *Q* represents the number of query images.

$$ANMRR = \frac{1}{Q}\sum_{q=1}^{Q} NMRR(q) \tag{5}$$

$$NMRR(q) = \frac{MRR(q)}{K + 0.5 - 0.5 * NG(q)}$$

$$MRR(q) = AVR(q) - 0.5 - \frac{NG(q)}{2}$$

$$K = \min(4 * NG(q), 2 * GTM)$$

$$AVR(q) = \sum_{k=1}^{NG(q)} \frac{Rank(k)}{NG(q)}$$

ANMRR is a normalized measure for the average ranking and the value is always between 0 and 1. The smaller the ANMRR, the better the performance.

As shown in Table 1, the average performance of the proposed algorithm has been improved by 12% over DAS method.

Table 1. Performance comparison(ANMRR)

Method	ANMRR
FOCUS	0.313
Proposed Method	0.276

5 Conclusions

In this paper, we proposed an object-based image retrieval method using dominant color pairs. Query image is constructed by selecting regions of interest after the image is segmented. From the segmented query image, we extract dominant color pairs between adjacent regions at the boundary and we compose color adjacency matrix. From DB images, we extract candidate regions by using color adjacency matrix composed from the query image. To measure the similarity between the query image and candidate regions in DB images, the color correlogram technique is used. By Experimental results, it has been shown that errors caused by background colors have been reduced, resulting in the performance improvement over the existing methods.

Acknowledgement

This research was supported by the MIC (Ministry of Information and Communication), Korea, under the ITRC (Information Technology Research Center) support program supervised by the IITA (Institute of Information Technology Assessment).

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