HIERACHICAL REGION OF INTEREST QUERY AND INDEXING FOR CONTENT-BASED IMAGE RETRIEVAL

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Abstract. In this paper, we present a Content-based Image Retrieval (CBIR) system using hierarchical Region of Interest (ROI) query and indexing. During indexing process, all the images in the database are segmented using Vector Quantization (VQ) technique. Color features of color histogram and color correlogram analysis are then extracted from each segmented region and stored in the database as the key to retrieve the relevant images. In the proposed retrieval system, users are allowed to select ROI directly over the sample or user's submission image and the query process then focuses on the content of the selected ROI in order to find those images containing similar regions from the database. The hierarchical region-of-interest query is performed to retrieve the similar images. Two-level search is exploited in this paper. In the first level, the most important regions, usually the large regions at the center of user's query, are used to retrieve images having similar regions using static search. This ensures that we can retrieve all the images having the most important regions. In the second level, all the remaining regions in user's query are used to search from all the retrieved images obtained from the first level. By using the proposed hierarchical ROI query, the searching time is reduced and the experimental results show good retrieval performance even in the case where the query ROI is in different scales, points of view, and background or partially appears in the indexing images.

1. Introduction

More and more digital images are captured and stored in the databases. One of the significant issues is how this information can be organized such that fast and efficient browsing, indexing and retrieval of the image content can be achieved [1]. A number of indexing and retrieval systems have been proposed to query the images in the database [1-3]. One approach is the content-based indexing and retrieval, which is widely adopted since all the meaningful attributes can be derived directly from the content containing in that image itself. The generated attributes are usually the visual features such as color, texture, or shape. These features are used as the key to retrieve the relevant images from the database according to user's query. Color histograms [3] are generally used as color features to describe the global color distribution in an image. Even though the histogram can be computed easily and is invariant to small changes in viewing position, it does not give any spatial or structure of colors in the image. This may cause false positives especially in large databases since different images may have similar global color distribution. To solve this problem, color correlogram [4, 8] was proposed in order to incorporate spatial correlation of colors with the global distribution of local spatial correlation of colors. This feature is easy to compute while the size of the feature is relatively small.

Retrieval systems are also important. Several retrieval systems [3,4] perform searches for relevant images from the database using features extracted from all regions of the user's query image. This type of query is good when user wants to find similar image to the example, which unlikely happens. Users usually try to search for such a specific object, such as "find a golden car", and sometimes do not pay attention on background or other objects in the sample image. Therefore, the retrieval system should allow human assistance to specify region-of-interest and then identify images that best describe the user's ROI query using the pre-calculated features.

2. The proposed indexing algorithm

In the proposed algorithm, each image is segmented into N homogeneous regions using vector quantization of color information. Before segmentation process, peer group filtering and perceptual color quantization [6] is applied to provide smoothness and noise reduction in the image. This technique was shown to be effectively removed noise without blurring the edges and detains in the image. Then, the smoothed image is segmented using a modified general Lloyd (GLA) vector quantization technique. VQ algorithm requires a set of initial classification. One approach uses random initialization to generate the initial classification set [7]. However, using random initialization, the segmentation results may be different in the case that the same object or ROI is in different background images or the images contain the chosen ROI but in different sizes or points of view due to the randomness of pixel values. This leads to the difficulty in matching user's query ROI with the similar regions of the images in the database. Therefore, in this paper, color quantization is used to first generate the initial color sets. By using the proposed initialization technique, the segmentation process results in the similar segmented regions even in the problem cases discussed above. After initialization process, a modified GLA is performed to further nonlinearly classify the large initialized color sets into smaller groups using overall distortion of each group. The number of clusters is set to be slightly larger than the actual need. The correctness of the estimation is not critical because cluster will be merged in the next step. After GLA, a large number of pixels having approximately the same color will have more than one cluster because GLA is aimed to the minimize the global distortion. An agglomerative clustering algorithm [7] is performed on the cluster centroids to further merge close clusters such that the minimum distance between two centroids satisfied a preset threshold. After classification, the quantized color pixels are assigned region labels. Then, color features are extracted from each region such as histogram and color correlogram [4,8]. Color correlogram is a spatial extension of the histogram. Given any pixel of color C_i in the image color correlogram gives the probability that a pixel at distance k away from the given pixel is of color C_j. In this paper, the autocorrelogram is adopted in addition to color histogram. The autocorrelogram provides spatial correlation between identical colors. The vectors of histogram and autocorrelogram features are used as indexes for each image in the database.

3. The Retrieval System

In the proposed retrieval system, users are allowed to impose their desired requirements on the query image using a rectangular box. The ROI selection area is then segmented into N regions using the same technique as in the indexing process. For each region in the ROI, color features, color histogram and corresponding autocorrelogram, are extracted as described in previous section. Matching between user's selected ROI and that of each target image from the database is performed using similarity comparisons between the extracted features. The similarity measure used in the proposed system is a modified L_1 distance (relative measure of distance [9]) of histogram and autocorrelogram as:

$$\left| I - I' \right|_{h_1 d_1} \triangleq \sum_{i \in [m]} \frac{\left| h_{c_i}(I) - h_{c_i}(I') \right|}{1 + h_{c_i}(I) + h_{c_i}(I')}$$

$$\left| I - I' \right|_{\gamma_1 d_1} \triangleq \sum_{i \in [m]} \frac{\left| \gamma^{(k)}_{c_i, c_j}(I) - \gamma^{(k)}_{c_i, c_j}(I') \right|}{1 + \gamma^{(k)}_{c_i, c_j}(I) + \gamma^{(k)}_{c_i, c_j}(I')}$$

where *I* and $I^{'}$ are the query and the indexing image. $h_{C_i}(I)$ and $h_{C_i}(I')$ are the color histograms and $\gamma^{(k)}_{C_i, C_j}(I)$ and $\gamma^{(k)}_{C_i, C_j}(I')$ are color correlogram of *I* and $I^{'}$ images, respectively.

To retrieve relevant images, hierarchical query is performed instead of static query, which searches for N query regions to retrieve N query results and uses all the retrieved results to produce a single query result. Static query requires a large amount of search time due to a large number of regions containing in each indexing image. Even though hierarchical query requires less amount of search time, it is possible that a mistake from one level can propagate to next levels and cause retrieval errors at the end of query. Therefore, in this paper, two-level search is proposed, which not only can reduce the search time compared to the static search algorithm but also can reduce the effects of the mistakes propagating from one level to the next. The proposed hierarchical search is a combination of the static search and the traditional hierarchical search. In the first-level query, the most important regions from user's query, usually the large regions at the center of user's query, are matched with the regions in the indexing images using the static search technique. The indexing images, which contain all the most important regions and have matching errors less than predefined thresholds, are retrieved from the database. The refinement search is performed in the second-level query to look for the remaining regions in user's query from first-level retrieved images.

4. EXPERIMENTAL RESULTS

We have experimented the proposed hierarchical query and indexing approach using several color features such as global color histogram, regional color histogram, and a combination of regional color histogram and its corresponding autocorrelogram. These features are extracted from regions in the indexing images and the selected ROI of user's query. The number of histogram bins used is 64 bins while the distance set k = {1, 3, 5, 7} is used for computing autocorrelogram feature. The database consists of 100 images, including animals, cars, peoples, flowers, pumpkins, etc. Each set of images in the database contains an object with different scales, points of view, and backgrounds. Our query set consists of 50 queries, each chosen to represent various situations such as different views of the ROI, spatial translations, and backgrounds. The retrieval performance of all the queries is shown in Fig. 1.

The retrieval performance is evaluated using average precision at each recall level [x] as follow:

$$\overline{P}(r) = \sum_{i=1}^{N_q} \frac{P_i(r)}{N_q}$$

where P(r) is the average the precision at the recall level r, Nq is the number of queries used, and Pi(r) is the precision at recall r for the i-th query. From figure 1, the experimental results show that the retrieval performance of the proposed features outperforms the other two techniques.

In addition, we also show examples of the retrieval results of the butterfly query using each type of color features are presented in Fig. 1.

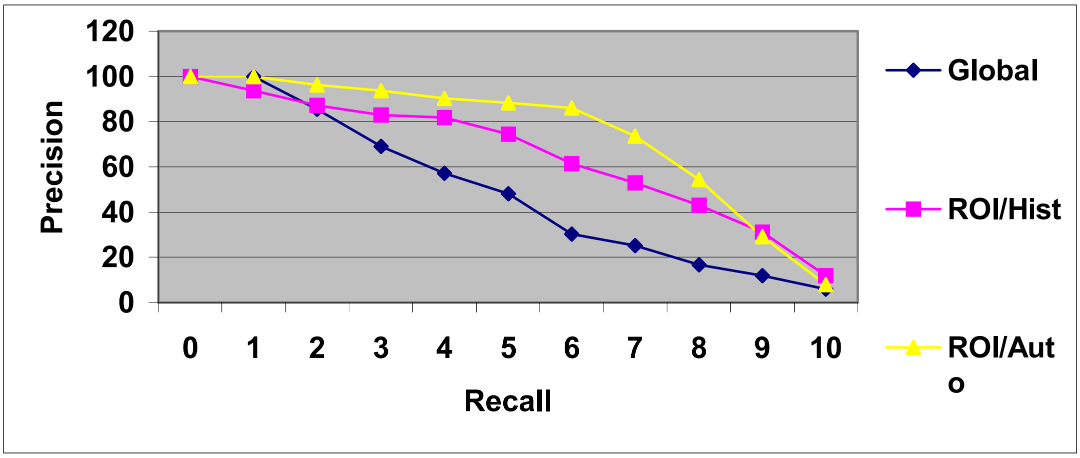

Fig. 1. The overall retrieval performance

Figure 1. The retrieval results from different color features, (a) global histogram, (b) regional histogram, and (c) combined regional histogram and autocorrelogram.

As we can see from Fig. 1, the retrieval results of using combined regional color histogram and autocorrelogram are better than those of using global histogram and regional histogram only even in the case where the query ROI is in different scales, points of view, and background or partially appears in the indexing images. This is due to the color distribution and color structure information supported by the combined feature.

5. Conclusion

In this paper, we have investigated hierarchical query and indexing using regional color histogram and autocorrelogram analysis compared with the global color histogram and regional color histogram only. Since the selected features provide both color distribution and spatial correlation of colors in ROI, it can be used effectively to discriminate between different types of ROI. The retrieval performance is very efficient even in the case of different points of view, partial occlusion, and totally different backgrounds. Moreover, by using the proposed hierarchical search, we can reduce the searching time while still maintain good retrieval performance. Even though color indexing seems to give reasonable retrieval results, in some cases, only color features may not be enough to distinguish different types of ROI having similar colors. In order to further improve the retrieval performance, other features such as texture or shape should be incorporated with color information. Moreover, the results from the segmentation process are also effect the retrieval performance. The improvement of segmentation algorithm can gives better and thus more meaningful retrieval results

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