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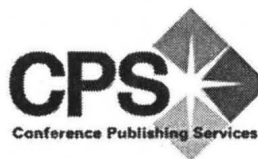
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Performance Comparison between Color and Spatial Segmentation for Image Retrieval and Its Parallel System Implementation

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Abstract—In this paper segmentation on both color and spatial space is implemented to compare their influence to the performance of content-based image retrieval (CBIR) system. Firstly, images are converted from RGB color space to HSV space. And then cumulative histograms on H component are extracted from four segmented blocks as one color feature of the image. At the same time, the HSV color space is further divided into H2SV space. Local accumulative histograms on H1 and H2 components are sequentially extracted as the other color feature of the image. Finally, both color features combined with the texture feature are taken to evaluate their performance of retrieving images. In addition, some parallel techniques are applied to construct an image retrieval system based on the cluster architecture. Experimental results have demonstrated that spatial segmentation has done more influence on the performance of CBIR system. And the parallel techniques can improve the retrieval efficiency significantly.

Keywords— content-based image retrieval; local accumulative histogram; H2SV color space; parallel technique

I. INTRODUCTION

Recently, with the development of the internet and the availability of image capturing devices such as digital cameras, images scanners, there has been a rapid increase in the size of digital image collections. Everyday, both military and civilian equipment generate gigabytes of images. A huge amount of information is out there. However, we can not access or make good use of the information unless it is organized so as to allow efficient browsing, searching, and retrieval. For this reason, image retrieval has been a very active research area since the 1970s. Plenty of research works [1, 2] have been undertaken in the past decades to design efficient image retrieval techniques from the image or multimedia databases. Although great advances have been obtained, there are still no universally accepted feature extraction, indexing and retrieval techniques available [2].

Since CBIR was proposed in the early 1990s, many ingenious techniques have been developed and many retrieval systems, both research and commercial, have been built. Among these techniques, image feature extraction is the basis of CBIR system. The advances in this area are mainly contributed by the computer vision community. Therein, color is one of the most widely used features in image retrieval [1], and it has been exploited most thoroughly. Almost all color models have been used in CBIR

to simulate human perception, from RGB, LAB, LUV, and HSV to HNMD [2]. At the same time, other scholars believe that spatial location is also very important in CBIR [2]. It has been found that users are usually more interested in specific regions rather than the entire image, so they decide to segment the image into regions before retrieving images. Therefore, many region-based image retrieval methods have been proposed [3]. However, considering the richness in both color and texture of the natural scenes, up to now automatic image segmentation is still a difficult task [2].

It has been demonstrated that HSV color space is able to obtain better retrieval results for histogram-based methods, whilst subdividing images into blocks has also been a basic technique in CBIR [3]. Therefore, in this paper we implement a further segmentation to the HSV color space and divide images into four overlapped blocks. Then, four different features are designed to compare the influence of color and spatial segmentation to the performance of CBIR systems. In addition, a parallel technique based on the cluster architecture is applied to construct the retrieval system. A series of experiments have illustrated that the spatial segmentation can do more influence to the performance of CBIR systems than the color space segmentation. At the same time, it has also been demonstrated that significant improvement on efficiency can be obtained by using the parallel techniques.

II. ARCHITECTURE OF OUR RETRIEVAL SYSTEM

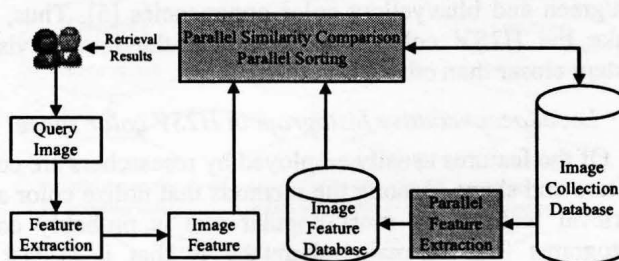


Figure 1. Architecture of our retrieval system.

Fig.1 shows the architecture of the presented CBIR system. As illustrated, the image collection database contains the raw images for visual display purpose, whilst the image feature database stores the visual features extracted from the raw images using different techniques that will be described in Section 3. Both databases creation and updating is an

offline procedure. Another character of our system is the parallel techniques, which are used in feature extraction and similarity comparison. The implementation procedure will be described detailedly in Section 4.

III. RETRIEVAL ALGORITHM DESIGN

A. H2SV color space

One of the difficulties in image retrieval in color is finding the right color space to approximate human vision perception. It is well known that RGB color space has the difficulty that as lighting conditions change, the RGB color values will all change. Thus, small lighting changes can completely change the color feature of the images in RGB color space. A basic solution is to use the HSV color space, which is arguably more intuitive than the RGB model [4]. Using HSV color space the feature extraction algorithm can depend more on the hue component and less on the intensity value component. This is more similar to the human vision.

However, HSV also has its own difficulties. One of the largest obstacles is that the hue component is modulus. Since the 3D representation of HSV model is a hexcone, in HSV space the value of hue component ranges from 0 to 360. At a value of 0, hue is basically red while if hue is set to 360 it is also red. When trying to compute the statistical properties of hue, this can create difficulties. For instance, if a target is reddish, some of its pixels will range in value from 330 to 360 while others will range from 0 to 30. This means that the reddish object will give us a bi-modal distribution if we histogram its hue pixel values.

To address this problem, we have found that it is convenient to transform hue from radial coordinates to Cartesian coordinates. This gives us a H1 and H2 value [5]. With this kind of translation, hue is now bounded from 0 to 1. Another advantage can also be seen with H2SV color. When the transformation is adjusted by a small amount, H1 becomes a red/green color opponency with red being 1 and green being 0, while H2 becomes a blue/yellow color opponency with blue being 0 and yellow being 1. This is pleasing because the human visual system also works in red/green and blue/yellow color opponencies [5]. Thus, we make the H2SV color space resemble the human visual system closer than otherwise.

B. Local accumulative histogram in H2SV color space

Of the features usually employed by researchers are color, texture and shape. Among the methods that utilize color as a retrieval feature, the most popular one is probably color histograms [6]. Its main advantage is that it is fast to manipulate, store and compare and insensitive to rotation and scale. On the other hand, it is also quite unreliable as it is sensitive to even small changes in the scene of the image.

To overcome this disadvantage, a so-called local accumulative histogram was proposed in [4, 6]. It was demonstrated that the research results in [4] had more advantages than the conventional histogram approach, including the cumulative histogram. Therefore, in this paper we also adopt the local accumulative histogram of two hue components in H2SV color space as the image feature.

The local accumulative histogram is an improved version of the cumulative histogram, so here we introduce the cumulative histogram firstly. The cumulative histogram is a variation of the histogram in which the vertical axis gives not just the counts for a single bin, but rather gives the counts for that bin plus all bins for smaller values of the response variable. It can be concluded as following.

$$I(k) = \sum_{i=0}^k \frac{n_i}{N} \quad k = 0, 1, \dots, L-1$$

Therein, k is an index for representing a histogram bin. n_i is the number of pixels, which belong to the bin k . Apparently, N is the total number of pixels of the whole image. The cumulative histogram $I(k)$ of the image is a 1-D discrete function.

Comparably, the local accumulative histogram can be calculated as following. First, the whole color spectrum of image is divided into several sub-ranges according to human perceptive characteristics. And then, we calculate the cumulative histogram in each sub-range. All histograms from each sub-range are finally connected as the feature of the whole image.

In our method, the range of each hue is firstly extended to $[0, 360]$ for calculating the color bin. Then we divide the H1 component uniformly into six ranges.

$$[60k, 60(k+1)], k = 0, 1, \dots, 5$$

So we take ten H1 values as a bin and get the cumulative histogram in each sub-range. Secondly, we subdivide the H1 component into another six ranges.

$$[30 + 60k, 30 + 60(k+1) \bmod 360], k = 0, 1, \dots, 5$$

And the cumulative histogram in each sub-range is also calculated. Finally, the average of both local accumulative histograms is taken as the image feature for retrieval. The local accumulative histogram of H2 component is calculated by the same steps as H1.

C. Cumulative histogram in divided blocks

Traditional histogram methods often pay more attention to the statistical information of colors of the whole image. Therefore, some important spatial distribution information has been discarded. However, it is very important for image retrieval to use the spatial distribution character of different colors. So in this paper we adopt an improved color-histogram method to represent the spatial distribution information [7].

To get the spatial distribution character of colors, some existing retrieval methods usually divided the images uniformly into 3×3 blocks. Then the color histograms built on each block were combined as the feature to represent one special image. However, generally speaking, the photographer often puts their target, focus or the main part onto the centre of the image. The other small part is left for the background. Therefore, the traditional uniform dividing algorithms do not reflect the difference between the focus and the background fully. In addition, 9 blocks also impose more burdens on the feature calculation.

So in this paper an improved method based on four overlapped blocks is used. As illustrated in Fig.2, we divide

the image into 3×3 blocks. The Letters A, B, C and D represent four overlapped blocks. It is easy to see that the center part of the image P22 is calculated four times when building the histograms. The edge parts P12, P21, P23 and P32 are calculated twice. In this way, the difference between the centre and the background of the image can be reflected effectively.

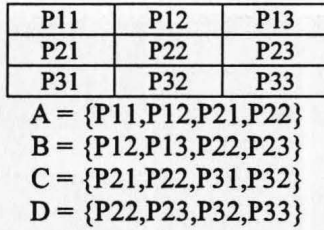


Figure 2. Spatial segmentation of images.

When calculating the histograms, we also take ten hue values in HSV space as a bin. Then four 36-D cumulative histograms are obtained as the other color feature of the image.

In our method, we have also taken the texture feature as a supplement to the color features. Five statistic variables originated from a 64-D gray level co-occurrence matrix are employed as the texture features [6]. They are energy, entropy, inertia quadrature, correlation and local calm.

D. Similarity measure

Before similarity comparison of the image feature vectors, we have used Gaussian normalization and linear transformation to normalize the range of every feature value to [0,1].

$$f_{new} = \frac{f - \bar{f}}{3\sigma} + 1$$

Therein, f is one value of the image feature vector. $\bar{f}$ is the mean of this value in all image feature vectors. σ represents the standard deviation of f .

Ref. [4] illustrated that taking Euclidean distance as the similarity metric, the Local accumulative histogram could obtain better retrieval results than the other histogram methods and the central moment method. Therefore, in the proposed algorithm we also employ the Euclidean distance as the similarity measurement.

IV. PARALLEL IMPLEMENTATION OF OUR SYSTEM

To improve the efficiency of CBIR system, as depicted in Fig.1, during the implementation procedure of our method, some parallel techniques are used to finish the image feature extraction and similarity comparison [8].

A. Parallel extraction of image features

The purpose of image feature extraction is building a feature vector that can be used to identify the image uniquely. As shown in Fig.3, we have applied a parallel technique to accelerate this process, which is designed based on a named manger-worker pattern.

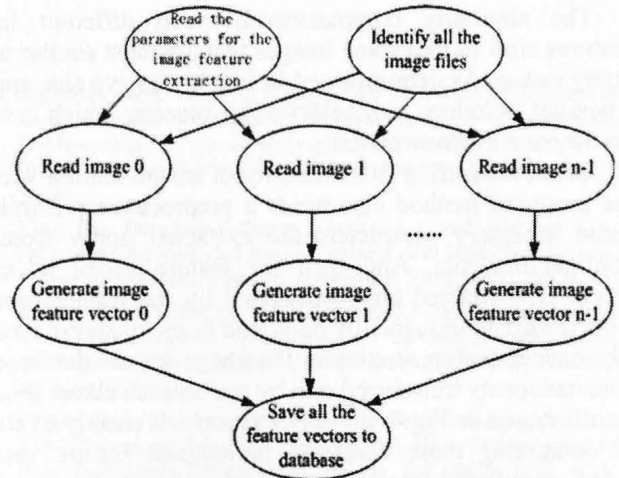


Figure 3. Architecture of parallel feature extraction.

In the presented method, there are two inputting data. One is a configuration file that defines all variables used in the process of feature extraction. The other is the image database directory. When abstracting image features, all variables are firstly extracted from the configuration file by the manager process. And then the manager process scans the image database directory to get all raw image files. These image documents are sequentially delivered to each worker process one by one to extract their feature vectors. This delivering will not stop unless finishing all images feature exaction. Then, the manager process will write the extracted feature vectors into a user-named file.

B. Parallel comparison of image features

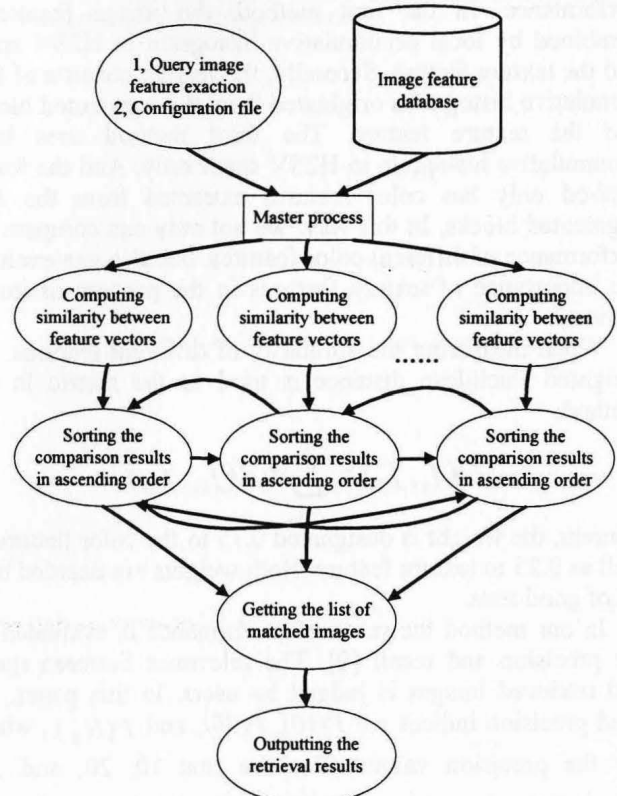


Figure 4. Architecture of parallel similarity comparison.

The similarity comparison between different image features aims to find some images that are most similar to the query image. As demonstrated in Fig.4, we have also applied a parallel technique to accelerate this process, which is based on the master-slaver pattern.

When measuring the similarity of image feature vectors, the proposed method also needs a preprocessing. Similarly, some necessary parameters are extracted firstly from the configuration file. And then the feature vector of query image is abstracted and normalized by the master process. This feature is sequentially delivered to every slaver process. The existed feature vectors in the image feature database are simultaneously transferred one by one to each slaver process. As illustrated in Fig.4, the slaver process is mainly in charge of comparing these Gaussian normalized feature vectors. After similarity measurement, the comparison results between all slaver processes are also sorted parallel. This operation can reduce the online retrieval time greatly. Finally, the master process gathers all sorted matching results and writes them into an outputting file.

V. EXPERIMENTAL RESULTS

To compare the influence on performance of the CBIR system between color and spatial segmentation, a series of experiments have been implemented using the 24-bit true color pictures selected from the Corel Image Gallery. These pictures total up to 13091 and include all kinds of sophisticated sceneries, such as people, landscape, animals, buildings, and plants, etc.

In our method, the employed low-level visual features are combined into four methods to compare the retrieval performance. In the first method, the image feature is combined by local accumulative histogram in H2SV space and the texture feature. Secondly, the feature consists of four cumulative histograms originated from the segmented blocks and the texture feature. The third method uses local accumulative histogram in H2SV space only. And the fourth method only has color features extracted from the four segmented blocks. In this way, we not only can compare the performance of different color features, but also can evaluate the importance of texture features in the process of image retrieval.

When measuring the similarity of different features, the weighted Euclidean distance is used as the metric in our method.

$$D(f_1, f_2) = \sum_{i=1}^n w_i d(f_{1i}, f_{2i})$$

Therein, the weight is designated 0.75 to the color feature as well as 0.25 to texture feature. Both weights are decided by a lot of good tests.

In our method the retrieval performance is evaluated by the precision and recall [9]. The relevance between query and retrieved images is judged by users. In this paper, the used precision indices are $P(10)$, $P(20)$, and $P(N_R)$, which are the precision values after the first 10, 20, and N_R documents are retrieved, where N_R is the number of relevant documents for this topic. The employed recall

indices are $R_p(0.5)$ and $R_p(0.7)$. They are the recall values at the rank where precision drops below 0.5 and 0.7. Fig.5 is a result illustration of retrieving "Greenlake" image, where the first 20 documents are listed. The image at the top left corner is the query example. Table 1 is a statistics of precision and recall values of ten tests using four different features.



Figure 5. Illustration of image retrieval result.

It is easy to find from Table 1 that the retrieval results, obtained by using the texture and spatial segmentation color feature, are better than other results. Even the results using spatial segmentation only are better than the texture with color features in H2SV space. Although the H2SV color model is more similar to human vision perception than other models, its influence on the performance of image retrieval is still less than the spatial segmentation. That is to CBIR systems the features built on region level are more important than the color model improvement. It can be concluded easily that the region-based method is closer to people's perception system since users are usually more interested in specific regions rather than the entire image.

TABLE I. PERFORMANCE COMPARISON BETWEEN DIFFERENT VISUAL FEATURES

Query image	Greenlake			
	H2SV	Block	H2SV Texture	Block Texture
$P(10)$	0.75	0.82	0.82	0.93
$P(20)$	0.63	0.75	0.74	0.84
$P(N_R)$	0.58	0.70	0.65	0.82
$R_p(0.5)$	0.84	0.90	0.88	0.95
$R_p(0.7)$	0.77	0.82	0.81	0.87
Query image	Redbus			
	H2SV	Block	H2SV Texture	Block Texture
$P(10)$	0.73	0.81	0.77	0.92
$P(20)$	0.64	0.77	0.71	0.85
$P(N_R)$	0.61	0.75	0.68	0.82
$R_p(0.5)$	0.80	0.88	0.88	0.94
$R_p(0.7)$	0.73	0.81	0.80	0.88

We have also recorded the running time of parallel feature extraction and similarity comparison with different number of CPUs. As shown in Fig.6, the left sub-image is the running time of feature extraction with CPUs from 1 to 16. The right is the similarity comparison with CPUs from 1 to 16. It is evident that significant improvement on efficiency of CBIR system can be obtained by using the parallel techniques. The parallel cluster system can greatly reduce the retrieval time, which is very important to the massive CBIR systems.

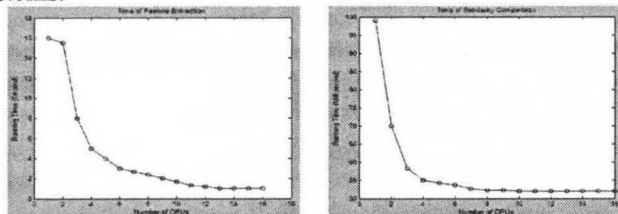


Figure 6. Running time of parallel feature extraction and similarity comparison.

VI. CONCLUSION

In this paper we have compared the influence of color and spatial segmentation to the performance of image retrieval systems. Experimental results have demonstrated that representation of images at region level is more similar to human perception system. That is the feature extracted by using spatial segmentation is more robust and sensitive than otherwise. In addition, a series of experiments have also proved that the parallel computing techniques can be applied to significantly improve the efficiency of retrieval systems. The response time of retrieving images from massive image databases can be reduced greatly.

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