Color Image Descriptor using Wavelet Correlogram

Seung-Jun Lee[1], Yong-Hwan Lee[2], Hyochang Ahn[3] and Sang-Burm Rhee[4]
[1,2,3,4] Department of Electronics and Computer Engineering, Dankook University
Jukjeon, Yongin, Korea
E-mail: [1]drmpu@hanmail.net, [2]hwany1458@empal.com

Abstract: Image descriptor performs two major tasks of the extracting algorithm. One is to encode image into feature vectors and the other is to measure for comparing a query image and the images in database. This paper proposes a new efficient image descriptor that uses the color feature based on wavelet color-spatial information of an image. In order to evaluate the proposed descriptor, we perform the comparative analysis of existing methods such as color histogram, correlogram, Scalable Color Descriptor (SCD) and wavelet correlogram. Experimantal results provide that the proposed method shows a slightly improvement in the retrieval effectiveness. Especially the proposed image descriptor is more efficient in the search and retrieval of multi-resolution images.

1. Introduction

The recent advances in digital imaging and computing technology have resulted in a rapid accumulation of digital media in the personal computing and entertainment industry. Event at present time, the large collections of images already exist in many scientific application domains such as digital library, trademark imaging, satellite imaging and medical imaging. Thus, the research of CBIR (Content-based Image Retrieval) has received much attention, and is one of the most exciting and fastest growing research areas in the field of multimedia technology [1,2]. CBIR is an automatic process for searching relevant images to a given query image based on the primitive low-level image features such as color, texture, shape and spatial layout [3].

Color is one of the most widely and extensively used visual feature in the image retrieval. Descriptors for the color feature are mostly the statistics of color distribution, average color and color moments. Histogram is one of the most frequently used color descriptor that characterizes the color distribution in an image, and gives also equally an important cue in human visual perception [4]. While the histogram does not include any spatial correlation of color, Correlogram takes into consideration the spatial correlation of color and can be implemented with the small size of index [5]. Although the performance of correlogram has much been improved by considering the spatial correlation between different colors in the images, it still has the problem of computational cost.

In this paper, we propose a new efficient image descriptor based on wavelet color-spatial for image search and retrieval, which is simply called as Weighted Wavelet Correlogram (WWC) descriptor.

The remainder of this paper is organized as follows. In the next section, the general image search descriptor, which is discussed by JPSearch Ad-hoc group, is presented. We describe our image search algorithm in section 3. In section 4, we then present some experimental results of the proposed scheme, and in the last section, we make the conclusions from the experiments.

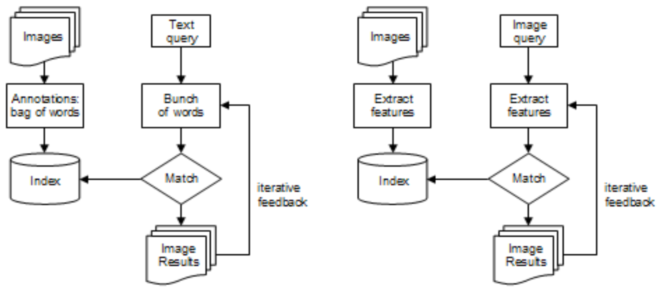
2. Related Works

Several general-purpose image retrieval engines have been developed from the market (commercial) or from the research laboratories (academic). We can not survey all the related works in allocated space. Instead, we try to focus on some of the works related to the standard, mentioned especially by JPSearch AHG. This search descriptor involves two steps [6];

Step1. Extracting image features to a distinguishable extent;

Step2. Matching these features to yield a result that is visually similar;

Figure 1 show the traditional approaches to digital image searching. The image search and retrieval system, shown in Figure 1(a), requires each image to be associated with one or more keywords entered by human. The image search system, shown in Figure 1(b), uses an image as a query and attempts to retrieve a similar image among the images. The system provides automatic indexing and querying with visual features such as color, texture, shape and spatial information. This is accepted as a state-of-the-art in content-based image retrieval system from JPEG standardization JPSearch [2].



(a) Image Search and Retrieval using Annotation (e.g., keyword)
(b) Image Search and Retrieval using an Image as query (i.e., CBIR)

Figure 1. Navie System View of Image Search and CBIR [2]

3. Proposed Image Search Descriptor

Typical CBIR system requires the construction of an image descriptor, which is characterized by (1) extraction algorithm to encode images into feature vectors and (2) similarity measure to compare two images [7].

3. 1 Weighted Wavelet Correlogram Descriptor

The proposed weighted wavelet correlogram (WWC) descriptor extracts feature vectors in five steps. Figure 2 shows the block diagram of WWC extraction.

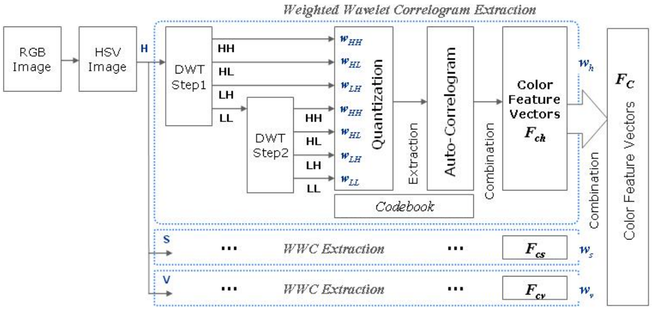


Figure 2. Weighted Wavelet Correlogram Extraction

First, color space conversion and channel separation for a query image are performed. Second, the discrete wavelet transform of input image is calculated in two consecutive scales using Daubuchies 9/7 tap filters. Third, wavelet coefficients are quantized to different levels for each sub-bands and scales. During the processing, we generate the quantized *codebook* as color lookup table to reduce the computation time of correlation. After those processing, horizontal, vertical and both directional correlograms of quantized coefficients are calculated for LH, HL and LL sub-bands in each scale respectively. Finally, the extracted feature vectors are combined with different weights for the three channels.

The correlogram of wavelet coefficients for LL sub-band is computed as follows.

$$\Gamma_{c_i}^{k}(W_{LL}) = probability\left[\ p_2 \in W_{LL}, \left|\ p_1 - p_2\ \right| = k\ \right] \qquad (1)$$

$$\Gamma_{c_i}^{k}(W_{LL}) = \frac{\left|\ \{(x,y)|\ W_{LL}(x,y) = c_i; W_{LL}(x \pm k, y \pm k) = c_i\}\ \right|}{8k \times \left|\ \{x,y\}|\ W_{LL}(x,y) = c_i\}\ \right|}$$

where W_{LL} is the wavelet decomposed image of LL sub-band, c_i is quantized color and k is correlation distance for $k \in \{1,3,5,7\}$ in this paper.

Wavelet coefficients of LH sub-band correspond to low pass filter and high pass filter in horizontal and vertical directions respectively [8]. Correlogram calculation of LH sub-band could logically take only in a horizontal direction (low pass filtering). Thus, the horizontal correlogram of LH sub-band coefficients is computed as follow.

$$\Gamma_{c_i}^{k}(W_{LH}) = \frac{\left|\ \{(x,y)|\ W_{LH}(x,y) = c_i; W_{LH}(x, y \pm k) = c_i\}\ \right|}{2k \times \left|\ \{x,y\}|\ W_{LH}(x,y) = c_i\}\ \right|} \qquad (2)$$

Similarly, the vertical correlogram of HL sub-band coefficients is computed in the same way, but vertical direction. However, the correlogram of HH sub-band would not be computed, since the spatial correlation of wavelet coefficients of HH sub-band is not significant. It reduces the computational time during extraction feature vectors. Figure 3 represents the neighboring pixels of point *p*, used in this proposed method.

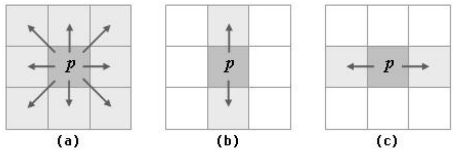


Figure 3. Neighboring pixels; (a) 8 directions for LL, (b) 2 directions for LH and (c) 2 direction for HL

3. 2 Similarity Measure

For similarity matching, we compute a distance measure as a color feature. The distance N1 is used for WWC, which is the sum of normalized color feature difference between two images, calculated as follows [9].

$$D(q,t)_{WWC}^{N1} = \sum_{i=1}^{m} \frac{\left|\ C_{c_i}^{q(d)} - C_{c_i}^{t(d)}\ \right|}{1 + C_{c_i}^{q(d)} + C_{c_i}^{t(d)}} \qquad (3)$$

where d is the correlation distance between two pixels, m is the number of correlogram, C^q and C^t are the correlogram of query image q and target image t in the database.

4. Results

We implement all the approaches using Matlab 7.0.1, using a PC running Windows XP Professional OS with 2.6 GHz Pentium IV CPU and 512 MB main memory.

4. 1 Test Image Dataset

We use a subset of MPEG-7 common color dataset (CCD) for evaluation of the proposed descriptor, which consists of 387 images and 50 query categories. In this database, there are different sizes (each of 12KB~95KB) and different resolutions (320*240, 384*256, 352*288 and 768*512) of JPEG formatted images. In addition, we create 387 re-sampled images with 240*x (variables x is a variable length, cause to higher width or height of original images). Thus, there are 744 images in total.

4. 2 Search Effectiveness

The most common evaluation measure used in Information Retrieval (IR) is recall and precision, usually presented as a Precision and Recall Curve [9]. *Precision* is the probability of retrieving a image that relevant to query, and *recall* is the probability of relevant being retrieved. Assume that A is as a set of relevant images and B is a set of retrieved images. Then, the recall and the precision are defined as the following conditional probabilities respectively [11].

$$recall = P(B \mid A) = \frac{P(A \cap B)}{P(A)} = \frac{a}{a+c} \quad (4)$$

$$precision = P(A \mid B) = \frac{P(A \cap B)}{P(B)} = \frac{a}{a+b} \quad (5)$$

where a is the number of retrieved relevant images, b is the number of retrieved ir-relevant images and c is the number of un-retrieved relevant images.

4. 3 Experimental Results

Since each image of the semantic categories serves as the query image in turn, all of the images in the database are queried. For example, 744 queries are performed. In this way, we obtain more reliable estimation on the search performance, when compared to experiments where the results are based on a small number of queries, like MPEG7.

The results of the experiment (as shown in Figure 4) presents the retrieved results of ranking through 3%, 6%, 9%, 12% and 15% of whole image database with the recall and precision curves. Test dataset has 744 images, thus the number of retrieved results with ranking are 23, 46, 70, 93 and 116, respectively. Since the ways of composing feature vectors in search methods are quite different, therefore it is necessary to fix all their dimensions of feature vectors to the same values for fair comparison. In an experiment, we choose vector dimensions of around 100, which is a closer dimension of extracted feature vector for proposed descriptor.

Figure 4 shows that the proposed WWC (weighted wavelet correlogram) descriptor improves the search effectiveness, when compared to other methods such as color histogram (LCH), color correlogram (CCQ), wavelet correlogram (WC) and scalable color descriptor (SCD) [4],[5],[12],[13]. We observed that in the top ranking 46 images of recall (6%), which is relevant in practical evaluation. The descriptors are ranked in the following order; (1) WWC, (2) SCD, (3) LCH, (4) WC and (5) CCQ.

In Figure 4, the proposed WWC is truly outperformed that other descriptors within the top 90 rankings. There is not considerable value in retrieved results being larger than 90, since the largest number of images in a category is 64.

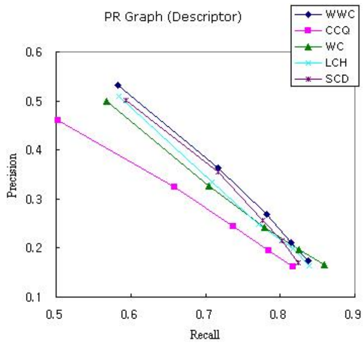


Figure 4. Comparison of Search Effectiveness

Figure 5 shows a test query image (on the left upper) and its retrieved result images that are searched by the proposed WWC with 12 top rankings. The orders of searching ranking and the name of retrieved images are attached at the upper of images.

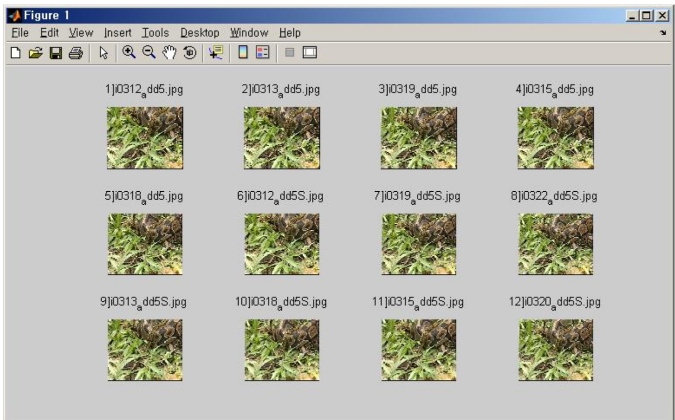
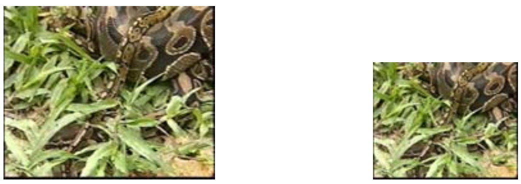


Figure 5. Example of Search Results using WWC

Figure 6 illustrates a test query image and its reduced resolution image placed in same category (it means that two images are relevant for user's query). And Table 1 shows the retrieved ranking orders of the query image



(a) Query image with 352*288 resolution (72dpi)

(b) Relevant Image with 240*196 resolution (36dpi) in same category of (a)

Figure 6. Example of (a) Query Image and (b) its Relevant Image

Table 1. Search Ranks for a Query Image in Figure 6

Descriptor	Ranking
LCH [4]	8
CCQ [5]	18

WC [12]	13
SCD [13]	42
Proposed WWC	6

From the result, the search order of the WWC has higher ranking than other methods between the different resolutions of relevant images. Thus, we could say that the proposed WWC descriptor is more efficient in multi-resolution image retrievals.

Table 2 shows the computational characteristics of each method collected from the average of five times of the retrieval.

Table 2. Computational Characteristics of the Methods; Computation is made on a PC using Matlab. In first right column, R is recall rate and P is precision rate at top 6% search

	Feature Extracting Time [sec/image]	Searching Time [sec]	Vector Dimensions (32bins)	PR-rate (top 5%)
LCH	0.463	0.234	96	R=0.70 P=0.33
SCD	0.729	0.359	64	R=0.71 P=0.35
CCQ	3.416	0.320	96	R=0.66 P=0.32
WC	8.050	0.244	96	R=0.70 P=0.32
Our WWC	6.485	0.726	72	R=0.72 P=0.36

5. Conclusions

In this paper, we propose a new efficient image search descriptor using the color features based on wavelet color-spatial information of image. Precisely, when using a correlogram as color feature, more computational time is needed than histogram-based method. For this reason, as well as supporting multi- resolution approach, we incorporated the wavelet transform, whose coefficients provide information independent of original image resolution, and give the weight on each of LL, LH and HL sub-bands. Further more, the computing time is reduced by using the color codebook.

Experimental results provide that the proposed descriptor shows a slightly improvement in retrieval effectiveness. Especially, the WWC, we proposed, is more efficient in multi-resolution image search. However, it requires additional computing time and memory buffer for multiple descriptors which are combined to texture feature such as Gabor wavelet texture.

References

[1] Recmo C. Veltkamp, Mirela Tanse, "Content-based Image Retrieval System: A Survey", *Technical Report UU-CS-2000034*, Oct., 2000.

[2] Mun-Kew Leong, Wo Chang, "Framework and System Components" *ISO/IEC JTC1/SC29/WG1N3684*, July, 2005.

[3] Arnol W.M. Smeulders, Marcel Worring, Simone Santini, Amarnath Gupta, Ramesh Jain, "Content-based Image Retrieval at the End of the Early Years", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.22, no.12, 2000.

[4] Bongani Malinga, Daniela Raicu, Jacob Frust, "Local vs Global Histgram –based Color Image Clustering", *Technical Report TR06-010*, DePaul Univ., 2006.

[5] Jing Huang, S. Ravi Kumar, Mandar Mitra, Wei-Jing Zhu, Ramin Zabih, "Spatial Color Indexing and Applications", *International Journal of Computer Vision*, vol.35, no.3, pp.245~268, 1999.

[6] Thomas Seidl, Hans-Peter Keiegel, "Efficient Use-Adaptable Similarity Search in Large Multimedia Database", *Proceedings of the 23rd International Conference on Very Large Database(VLDB)*, Greece, Aug., 1997.

[7] Zijun Yang, C. Jay Kuo, "Survey on Image Content Analysis, Indexing and Retrieval Techniques and Status Report of MPEG-7", *Tamkang Journal of Science and Engineering*, vol.2, no.3, pp.101~118, 1999.

[8] Taghuveer M. Rao, Ajit S. Bopardikar, *Wavelet Transforms – Inroduction to Theory and Applications*, Addition-Wesley, 1998.

[9] Vittorio Castelli, Lawrence D. Bergman, *Image Databases – Search and Retrieval of Digital Imagery*, Wiley Inter-Science, 2002.

[10] Detlef Zier, Jens-Rainer Ohm, "Common Datasets and Queries in MPEG-7 Color Core Experiments", *ISO/IEC JTC1/SC29/WG11M5060*, Melbourne, Oct., 1999.

[11] John R. Smith, Shih-Fu Chang, "Tools and Techniques for Color Image Retrieval", *IS&T/SPIE Symposium on Electronic Imaging Science and Technology – Storage and Retrieval for Image and Video Database* IV, vol.2670, Feb., 1996.

[12] H. Abrishami Moghaddam, T. Taghizadeh Khajoie, A. H. Rouhi, "A New Algorithm for Image Indexing and Retrieval using Wavelet Correlogram", *Proceedings of International Conference on Image Processing* (ICIP), vol.3, pp.III.497~5000, 2003.

[13] Akio Yamada, Robert Ocallaghan, Sang-Kyun Kim, "MPEG-7 Visual Part of eXperimental Model Version 27.0" *ISO/IEC JTC1/SC29/ WG11N7808*, Thailand, Jan., 2006.