Color-based Image Retrieval using Color Segmentation and Histogram Reconstruction

Hyun-Sool Kim, Dae-Kyu Shin, Taek-Soo Kim, Tae-Yun Chung and Sang-Hui Park

Abstract - In this study, we propose the new color-based image retrieval technique using the representative colors of images and their ratios to a total image size obtained through color segmentation in HSV color space. Color information of an image is described by reconstructing the color histogram of an image through Gaussian modelling to its representative colors and ratios. And the similarity between two images is measured by histogram intersection. The proposed method is compared with the existing methods by performing retrieval experiments for various 1280 trademark image database.
Keywords - content-based image retrieval, color segmentation, histogram intersection

1. Introduction

Recently, many materials are being digitalized and made into multimedia data by the rapid development of multimedia technology, and through the spread of scanners and digital cameras and by the development of the large capacity of storage equipment, numerous multimedia databases and image libraries are being constructed. The medium that plays an important role in these multimedia data is an image data and it is a difficult and bothersome problem to search a desired image in these image databases by manual work. So the efficient and automatic image retrieval by image contents such as color, shape or texture is emerging as an important research area with application to these databases[1-2]. In this paper, only color-based image retrieval is considered.

In 1991, Swain and Ballard[3] have presented the histogram intersection method which uses the color histograms to create 3-D histogram bins for each query image. The 3-D bins are then compared with those of database images. Funt and Finlayson[4] have extended Swain's method to develop color constant color indexing, which recognizes objects by matching histograms of color ratios. On the other hand, Mehtre et al.[5] have proposed the distance method and reference color table method for the image retrieval.

In this paper, we propose the method using the representative colors of an image as the features. This approach is similar to what the human visual system does to capture color information of an image. When viewing the displayed image from a distance, our eyes integrate to average out some fine detail within the small areas and perceive the representative colors of image[6]. In this method, first, the representative colors and their region's ratios to a total image size are obtained by color segmentation in HSV(Hue, Saturation and Value) color space. Then through Gaussian modelling to extracted colors, new color histogram is reconstructed and the distance between new histograms is calculated. This proposed method can represent the color information of an image with a small number of indexes, and keep the original color values in an image because color quantization process is not performed.

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2. Color-Based Image Retrieval

Color is the most important low level feature for indexing images in database. Usually because image retrieval based on color histogram is easy to implement and is robust to rotation, shift, etc, it has been used widely. Swain's histogram intersection[3] is the commonest method and its many variants have been suggested. But it has a few disadvantages. First, it needs the quantization of color to reduce the feature size, and it leads to loss of color information. Furthermore there is no optimal procedure for color quantization. And because it doesn't use any spatial information but only global color information, it has a limited performance. Due to these defects, recently interests in retrieval based on color segmentation have been increased, which is a procedure of human visual processing. In this study, the method based on color segmentation in HSV color space is considered.

2.1 Color Segmentation

In order to extract the region with similar colors in an image, recursive color segmentation in HSV color space is used[7]. It was already proven in performance, and is done fast and automatically. In HSV color space, hue is a color attribute that describes a pure color, whereas saturation gives a measure of the degree to which a pure color is diluted by white light. The HSV color model owes its usefulness to two principal facts. First, the intensity component, V(value), is decoupled from the color information in the image. Second, the hue and saturation components are intimately related to the way in which human beings perceive color. These features make the HSV model an ideal tool for developing image processing algorithms based on some of the color sensing properties of the human visual system[8]. Colors with similar hue components are considered as similar color. Conversion from RGB to HSV space is like equation (1).

$$H=\begin{cases} H_1, & \text{if } B \leq G \\ 360^\circ - H_1, & otherwise \end{cases} \quad (1)$$

Where,

$$H_1 = \cos^{-1}\left(\frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right)$$

$$S = \frac{\max(R,G,B) - \min(R,G,B)}{\max(R,G,B)}$$

$$V = \frac{\max(R,G,B)}{255}$$

Color segmentation algorithm extracts the representative colors of an image by classifying colors as achromatic, chromatic and bright chromatic considering hue, saturation and value. The first step of segmentation is to build a hue histogram for all the bright chromatic pixels. And then the hue histogram is built and thresholded into n bright colors, where n is an image-dependent quantity determined by the number of peaks which the hue histogram exhibits.

From the remaining image pixels, saturation and value are used to determine which regions of the image are achromatic. Color with value<25% are classified as black, and colors with saturation<20% and value>75% as white. All remaining pixels fall in the chromatic region. However, there may be a wide range of saturation values. To account for this, we calculate the saturation histogram of all these remaining chromatic pixels. Assume that a saturation histogram exhibits m peaks, we threshold each of these peaks and calculate the hue histogram for the pixel contained in each given peak. Each resulting hue histogram, which exhibits n peaks, is thresholded accordingly to obtain n colors. The process is then repeated again for each of the m saturation peaks. The segmentation algorithm extracts $c = \sum_m n_m + n$ colors[7]. Finally, we calculate the average color of each of the c colors and use RGB value as each region's representative color vector. And the ratio to a total image size of each color region is calculated simultaneously. The flowchart of segmentation procedure is shown in Fig. 1[7]. Fig. 2 shows an example of color segmentation of an image I_n, where the number of representative colors is 3. Each representative color is expressed with R, G, B components and the ratio r of its region size to total image.

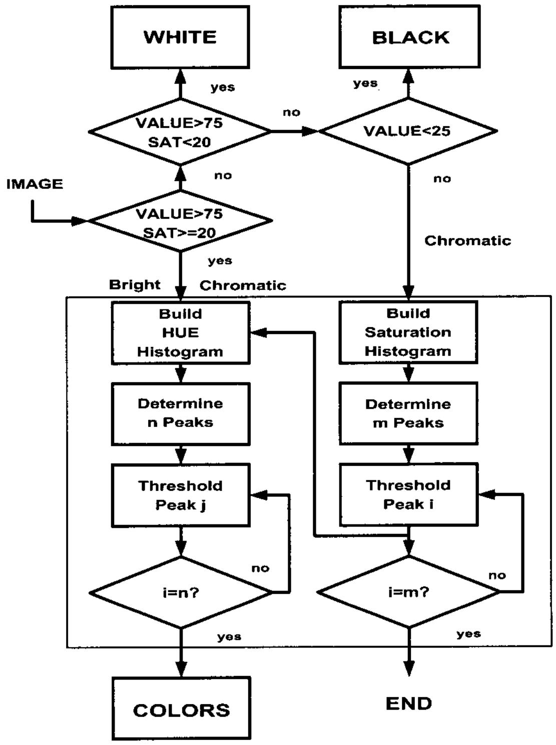


Fig. 1 The flowchart of color segmentation in HSV color space

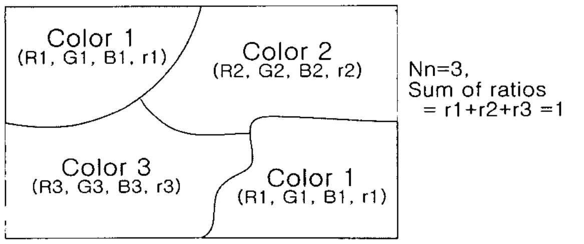


Fig. 2 Segmentation result of an image I_n (where, $N_n = 3$)

2.2 Retrieval Procedure

First of all, suppose the numbers of representative colors which are obtained through color segmentation for images I_n and I_m as N_n, N_m respectively. The representative colors and their ratios from each image can be represented like equation (2).

colors of I_n :

$$C(I_n) = \{C_i\} = \{R_i,\ G_i,\ B_i, r_i\} \qquad i = 1, 2, \cdots, N_n$$

colors of I_m :

$$C(I_m) = \{C_i\} = \{R_i,\ G_i,\ B_i, r_i\} \qquad i = 1, 2, \cdots, N_m \quad (2)$$

Where,

$C(I_n)$: representative colors and their ratios of an image I_n

C_i : ith color information vector composed of R,G,B components and its ratio

R_i : the red component of the ith segmented color of an image

G_i : the green component of the ith segmented color of an image

B_i : the blue component of the ith segmented color of an image

r_i : the ratio of the pixel number corresponding to the ith segmented color region to total image pixel number

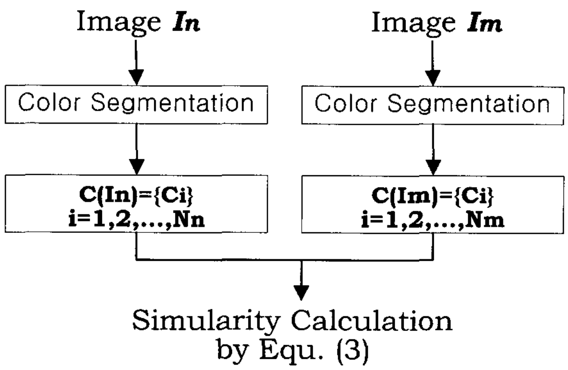


Fig. 3 Measuring procedure of color similarity between two images I_n, I_m

The comparison of color information of two images I_n, I_m is depicted in Fig. 3. We have to compare the N_n colors of $C(I_n)$ with N_m colors of $C(I_m)$ in order to calculate the similarity of two images, I_n and I_m. Each color C_i results from combining the color which is prominent in an image with its similar colors through the color segmentation. We can assume that there are similar colors around the C_i on a Gaussian distribution in an original image because C_i results from combining these similar colors. Under this assumption, we can obtain the new color histogram which has a Gaussian distribution around the representative colors of each image. In Gaussian modelling of each representative color, the area of Gaussian distribution curve centered on each representative color is equal to the ratio r of its representative color.

When we compare the color information of two images, $C(I_n)$ and $C(I_m)$, we calculate the similarity between each color C_i in $C(I_n)$ and all colors in $C(I_m)$ after we set an image I_n as a standard. It can be shown by the following equation (3).

$$Similarity = \sum_{i=1}^{N_n} S(C_i(I_n),\ C(I_m)) \qquad (3)$$

Here, $S(C_i(I_n),\ C(I_m))$ represents the similarity between a representative color C_i of I_n and all representative colors $C(I_m)$ in I_m and we can obtain this by calculating the common area between the histogram of C_i and the histogram of colors belonging to $C(I_m)$. Fig. 4 shows the way of calculating $S(C_i(I_n),\ C(I_m))$ in case that the number of the segmented colors of an image I_m is 2. The similarity of the color information of two images is obtained by the summation of similarities which we calculated between each color of $C(I_n)$ in the image I_n and $C(I_m)$ of I_m in the same way. We positioned each color of $C(I_m)$ on the location based on the Euclidian distance between the color C_i as a standard and each color in $C(I_m)$ at the color space of horizontal axis in the Fig. 4.

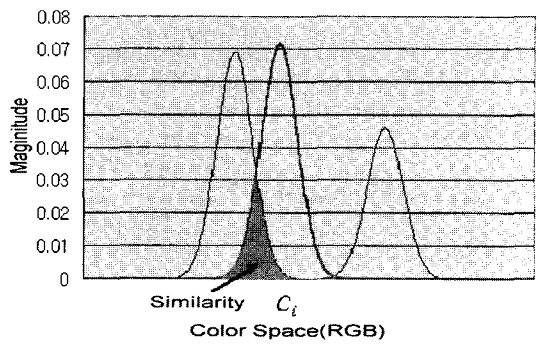


Fig. 4 Procedure of calculating $S(C_i(I_n),\ C(I_m))$

When we compare the color information of two images, the range of similarity is $0 \le Similarity \le 1$. The proposed method has several advantages over the conventional color histogram methods. First, it needs small memory to save the color information, that is, we save only the representative colors from color segmentation process and their ratios. The conventional methods need to save at least hundreds of histogram bins even though we perform color quantization procedure. Second, the proposed method doesn't need quantization to represent the colors in an image. The prominent colors maintain their original color values and only their similar colors are combined with the prominent colors after changing their values. Therefore, the colors which influence human eyes substantially maintain their values without loss. However, the conventional methods to build color histogram with quantization have a possibility that the similar colors belong to other bins and lose their own color values because most values are changed. Finally, the proposed method has a lot of applications for the retrieval, that is, we can offer an image as a query data, and moreover can search an image with the color values and ratios directly.

3. Experiments and Results

3.1 Experiments

In this study, we performed color-based image retrieval tests using 20 query images for 128 × 128 -sized 1280 trademark image database in various situations like lightness change, noise addition, and lightness change and noise addition. And we compared the performance of the proposed method with the existing methods using Histogram Intersection(HI), Color Moment(CM) and Cumulative Histogram(CH)[9]. As a criterion of evaluating performance, we used the average retrieval rank of the desired image like equation (4).

$$\textit{average retrieval rank} = \frac{1}{M}\sum_{i=1}^{M} rank(i)$$

$$\%\ rank = \frac{\textit{average retrieval rank}}{N} \times 100 \qquad (4)$$

3.2 Results

3.2.1 Color-based retrieval

For the red-colored query image, the retrieval results of color-based retrieval methods are shown in Fig. 5. We

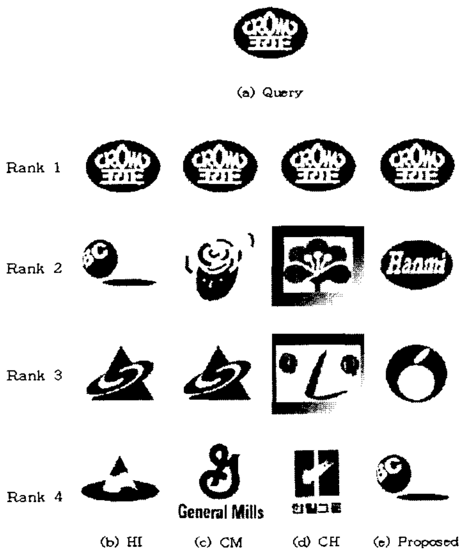


Fig. 5 Results of color-based image retrieval

can see that the proposed method and histogram intersection show the good retrieval results.

3.2.2 Retrieval for the queries with lightness change

We performed image retrieval for queries whose lightness was changed by 5%, 10% and 15%. Results are shown in Table 1. The proposed method showed the superior result to other existing methods. This is because the proposed method performs the representative color extraction using hue(H) component mainly in HSV color space, in which value(V) related to lightness and hue(H) and saturation(S) related to color are separated, and this procedure lessens the effect of lightness change. In the methods using histogram, color bins of histogram are shifted to other bins by lightness change, so the retrieval results are deteriorated.

Table 1 Retrieval results for lightness changed queries

Lightness Change	Histogram Intersection (HI)	Color Moment (CM)	Cumulative Histogram (CH)	Proposed
5%	2.95(0.23%)	6.00(0.47%)	2.24(0.18%)	1.20(0.09%)
10%	6.50(0.51%)	6.45(0.50%)	4.53(0.35%)	3.00(0.23%)
15%	15.00(1.17%)	7.85(0.61%)	9.71(0.76%)	12.61(0.99%)

3.2.3 Retrieval for the noisy queries

We performed image retrieval for queries whose 10%, 20%, and 30% pixels were contaminated by white Gaussian noise. Results are shown in Table 2. We can see that through the procedure of color segmentation the effect of noise addition is reduced, and so the proposed method produces good result.

Table 2 Retrieval results for noisy queries

Noise	Histogram Intersection (HI)	Color Moment (CM)	Cumulative Histogram (CH)	Proposed
10%	1.00(0.08%)	5.12(0.4%)	8.68(0.68%)	1.10(0.08%)
20%	1.00(0.08%)	15.45(1.21%)	32.39(2.53%)	1.84(0.14%)
30%	1.10(0.08%)	39.20(3.06%)	87.39(6.83%)	3.06(0.24%)

3.2.4 Retrieval for the queries with noise addition and lightness change

We performed image retrieval for queries with lightness change and noise addition. Retrieval results are shown in Table 3. The proposed method shows better performance than other methods.

3.2.5 Comparisons of required memory size and retrieval time

In retrieval system, two important factors - required memory size and retrieval time - are compared as an evaluating criterion for an efficient retrieval system. In Swain's histogram intersection a color histogram of an image was represented with 2048 bins in $16 \times 16 \times 8$ opponent color histograms and 9 moments(3 moments per each color channel) were used in color moment method. Also a histogram for cumulative histogram method consisted of 256 bins. Also this experiments were performed at 750 MHz pentium-III PC. The required memory size and retrieval time of each retrieval method are shown in Table 4 and Fig. 6.

Table 3 Retrieval results for noisy and lightness changed queries

Lightness & Noise	Histogram Intersection (HI)	Color Moment (CM)	Cumulative Histogram (CH)	Proposed
Lightness 5%, Noise 10%	4.35(0.34%)	10.63(0.83%)	14.94(1.17%)	4.83(0.38%)
Lightness 10%, Noise 10%	9.25(0.72%)	11.42(0.89%)	15.18(1.19%)	5.06(0.40%)

Table 4 Comparison of memory size required for saving color features

Method	Histogram Intersection (HI)	Color Moment (CM)	Cumulative Histogram (CH)	Proposed
Memory (Byte)	8192	36	1024	54

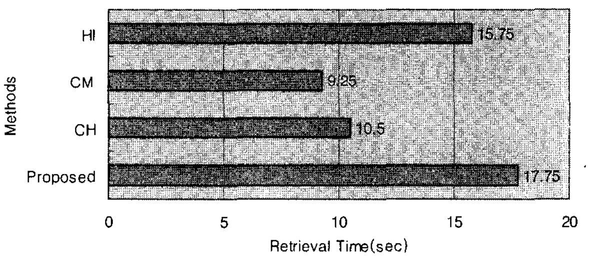


Fig. 6 Comparison of color-based retrieval time

4. Conclusion

In this study, we proposed new color-based image retrieval technique using the representative colors and their ratios obtained by color segmentation in HSV color space. Color information of an image is described by reconstructing the color histogram of an image through Gaussian modelling to its representative colors and ratios. And by histogram intersection the similarity between two images is measured. It was shown that this method retrieves the desired image well in case of noise addition, lightness change in a query image. Also this method has advantages that it keeps the original colors of image without loss, and can represent the color information with less indexes.

References

[1] J. Eakins and M. Graham, "Content-based Image Retrieval", JISC Technology Applications Report: 39, Oct., 1999

[2] A.K. Jain and A. Vailaya, "Image Retrieval using Color and Shape", Pattern Recognition, Vol. 29, No. 8, pp. 1233-1244, 1996

[3] M.J. Swain and D.H. Ballad, "Color Indexing", Int'l Journal of Computer Vision. Vol. 7, No. 1, pp. 11-32, July, 1991

[4] B.V. Funt and G.D. Finlayson, "Color constant color indexing", IEEE Trans. on PAMI., Vol. 17, pp. 522-529, May, 1995

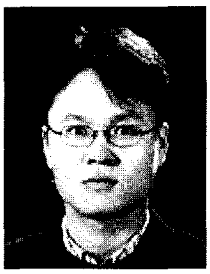
[5] B.M. Mehtre, M.S. Kankanhalli, A.D. Narsimhalu, and G.C. Man, "Color matching for image retrieval", Pattern Recognition Letter, Vol. 16, pp. 325-331, March, 1995

[6] S.C. Pei and C.M. Cheng, "Extracting Color Features and Dynamic Matching for Image Data-Base Retrieva l", IEEE Trans. on Circuits and Systems for Video Technology, Vol. 9, No. 3, pp. 501-512, April, 1999

[7] D. Androutsos, K.N. Plataniotis, and A.N. Venetsanopoulos, "A Novel Vector-Based Approach to Color Image Retrieval Using a Vector Angular-Based Distance Measure", Computer Vision and Image Understanding, Vol. 75, NO. 1/2, July/Aug., pp. 46-58, 1999

[8] R.C. Gonzalez and R.E. Woods, Digital Image Processing, Addison-Wesley, 1992

[9] M.A. Stricker and M. Orengo, "Similarity of Color Images". Storage and Retrieval for Image and Video Databases (SPIE), pp. 381-392, 1995



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