An Efficient Color Image Retrieval system using 2-D Representation of Color

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Abstract: *In this paper we describe an efficient retrieval method based on indexing in 2-D color space. The 2-D Y-C representation of color is obtained from a spiral approximation of UV color space. The spiral is made to vary along the luminance Y-axis, according to varying nature of color gamut, to improve the color qualities of reproduced images. The retrieval approach identifies the dominant colors in the image and uses them as a query for similarity retrieval. The dominant colors in the image are indexed in 2-D space thereby avoiding the problems associated with higher dimensional indexing space. A simple similarity measure for the new (Y-C) space is discussed. The dominant colors in an image are obtained by segmentation of the image into similar color regions and by identification of a dominant color for each region. We propose a segmentation algorithm based on homogeneity and features of the color signal C. The performance of the segmentation algorithm is also analyzed. The retrieval performance is shown for a database of 1000 images and retrieval accuracy is measured in terms precision and recall.*

Keywords: Spiral approximation; homogeneity; color descriptor.

Introduction

In recent years, the use of low level visual features to retrieve relevant information from image and video databases has drawn significant research attention. Color is one of the most dominant and distinguishing visual feature. Color histogram is widely used as a color descriptor in content based retrieval methods. While color histograms are easy to compute, they result in large feature vectors that are difficult to index and have high search and retrieval cost. In this paper we develop an efficient retrieval method based on indexing in 2-D color space Y-C where Y represents intensity and C a single color signal.

The component C is obtained from a spiral approximation of the U-V color space. The dominant colors in the image are obtained by segmentation of the image into similar color regions. The segmentation procedure proposed is based on homogeneity and the features of the color component C. For retrieval of images from database, a dominant color descriptor method is used. The descriptor consists of dominant colors and their percentage of color in the image. A color similarity measure in the Y-C color space is defined for the proposed color descriptor. The similarity measure takes into account the perceptual properties of human visual system. An efficient indexing scheme is developed for fast search and retrieval using the color descriptor.

The search procedure is fast, because it requires reduced number of comparisons, as the length of feature vector is much smaller than that used in traditional histogram approach.

The complexity of the indexing procedures is low since the indexing is done in 2D plane, unlike traditional schemes where a higher dimensional indexing space is needed.

Some Properties of UV Color Plane

In 3-D-RGB space, the RGB values of the colors define the coordinates of the corners of the unit cube shown in Figure (1). The cubic block formed by the planes R=0, G=0, B=0 and R=1,G=1,B=1,encloses all the color points which have valid combinations of R,G and B respectively. By transforming the RGB points on the surface of the cubic block into YUV values, we obtain a 3-D YUV valid color block which encloses YUV values corresponding to all valid RGB values. This is shown in Fig.(2). The hexagonal area of UV color plane is the top view of the 3-D YUV valid color space for all values of Y from 0 to 1, shown in Fig 3. The actual color gamut varies systematically as Y-varies and the nature of variations for different values of Y is understood from the 3-D signal space diagrams for RGB and YUV. Using the standard linear transformation of RGB to YUV it can be shown that the volume of the actual YUV signal space is only 25% of full YUV signal space. Similarly the variation of actual color gamut area as percentage of full area at important values of Y are listed in Table 1.

Table 1. Color Gamut area in for different Y values

Y	0.0	0.144	0.299	0.413 to 0.587	0.701	.886	1.0
area in %	0.0	7.674	32.59	40.25	32.59	7.67	0.0

Modified color Plane

The U and V axes of color plane are multiplied by (1/0.886) and (1/0.701) respectively to achieve nearly uniform radius value of 1.0 in all directions of the color plane. Such a modified color plane with new axes designated as UU and VV is shown in Fig.3.

Spiral Approximation of the Color Plane

In this section we describe a method to combine the chrominance signals U and V into a single signal by exploiting the perceptual redundancies inherent in the representation of color signals.

Let the color plane be scanned by an opening spiral starting at the origin and let L be the number of encirclements of the spiral (Figure 4). Radius (r) and phase (θ) of points in the color planes (U-V) are defined as follows:

$r = \sqrt{U^2 + V^2}$ and $\theta = \tan^{-1}\frac{V}{U}$.

Points on the color plane are mapped onto spiral by approximating radius and preserving phase. Any point on the UV color plane is mapped to the nearest point on the spiral. This mapping is done as follows: The radius of all the points in the color plane are approximated on to the nearest concentric circles approximating the spiral, whose center is at the origin of color plane and radius *n / L*, where *n*=1,2….*L*, and *L* is the number of encirclements of the spiral. The value of angle given by $(\theta/(2\pi L))$ is added to this approximated radius to get the final value of the point *C* on the spiral. Hence, *C*=approximated radius + $(\theta/(2\pi L))$. This C is now a point on the spiral corresponding to a color point with radius*(r)* in UV-plane. In this way color is represented by only two quantities luminance *(Y)* and color *(C)*. Mapping back from spiral color (C) to color plane *(U-V)* is obtained as: $U=C.\cos(2\pi(LC-\lfloor LC \rfloor))$ and $V=C.\sin(2\pi(LC-\lfloor LC \rfloor))$, where $\lfloor LC \rfloor$ gives integral part of the product.

Need for varying spiral

It is known that the actual color gamut varies with Y, and is very small compared to full color gamut for low and high values of Y. Therefore, at these values most of the spiral will lie outside the actual color gamut implying unwanted signal values. To overcome these problems it is essential that the spiral should lie within the actual color gamut for all values of Y.

To achieve this, it is neither desirable nor possible to vary the spiral for all Y values. Instead, U/V values of each pixel is modified in order that the simple spiral approximation performed on modified value will be equivalent to the desired varying spiral for given value of Y. Details available in [2].

Color Image segmentation in Y-C color space

We describe a color image segmentation method using new 2-D representation of color. In the first stage of segmentation, uniform intensity regions are identified via thresholding of homogeneity histogram as described in[4]. The calculation of homogeneity feature considers both the local as well as global information of the image. In the second stage, the pixels in a uniform intensity region are divided into one or more subregions having similar visualized colors. This is obtained by applying the histogram analysis on phase information obtained from C signal of each pixel in the same uniform region. The average color of each subregion is calculated and assigned to each pixel in that region. The segmentation of the uniform regions using phase histogram is computationally efficient compared to the RGB case, where all three histograms are considered for segmentation. The singularity problems that arise in case of hue are also eliminated in the proposed approach.

After the segmentation stage, over segmentation may occur when pixels in different homogeneity regions possess similar colors. Standard methods of color region merging in Lab space is used to produce a more concise set of regions.

Color Indexing and Retrieval

The use of color histogram as color descriptor in content based retrieval methods is expensive owing to the large dimensionality of the feature vectors. This leads to inefficiency in indexing and search process.

We adopt a compact color descriptor approach, and index the color features computed from the image in (2-D) Y-C space. The descriptor consists of dominant colors and their percentage in an image. A color similarity measure is defined for the proposed color descriptor. An efficient indexing scheme is developed for fast search and retrieval using this dominant color descriptor.

Dominant Color Descriptor

After segmentation we compute the representative color and its percentage for every segmented region. They form a pair of attributes that describe the color characteristics in an image. The dominant color region is defined as,

$$F = \{\{c_i, p_i\}, i = 1, \ldots, N\}$$

where *N* is the total number of dominant colors in image, c_i is a 2-D color vector, p_i its percentage, and $\sum_i p_i$ = 1.The percentage of color is defined as the number of pixels in the region over the total number of pixels in the image

Color Similarity

Let $F_1 = \{\{c_i, p_i\}, I = 1, \ldots, N_1\}$ and $F_2 = \{\{b_j, q_j\}, j = 1, \ldots, N_2\}$ be two color feature descriptors. The color similarity measure between F_1 and F_2 is given by,

$$D^2(F_1F_2) = \sum_{i=1}^{N_1} p_i^2 + \sum_{j=1}^{N_2} q_j^2 - \sum_{i=1}^{N_1} \sum_{j=1}^{N_2} 2S_{i,j}\, p_i q_j$$

where $S_{i,j}$ is the similarity coefficient between colors c_i and b_j.

Color Space Quantization

To build a database we need to obtain the indexing nodes. In this section we propose a quantization scheme in Y-C space. The quantization of C is given more importance as it contains the hue information that determines the color perceived by the human visual system [1]. For each encirclement of spiral the hue value changes from (0-360) degrees. The Hue circle consists of the primaries red, green and blue separated by 120 degrees. A circular quantization in steps of 20 degrees sufficiently separates the hue values such that the three primaries as well as yellow, magenta and cyan are each represented with three sub-divisions. We used the spiral approximation with L = 4 encirclements. The encirclements quantize the saturation values to 4 levels. Thus, we quantized C using 72 levels i.e. 18 levels for each of four encirclements. Finally, intensity Y is quantized to eight levels. Using these values we created 576 colors which form the lattice points in two dimensional Y-C color space required for indexing.

Table 2. Indexing Structure

Entry	Image ID	2-D color vector	% of color in the image
1	ID_1	c_1	p_1
2	ID_2	c_2	p_2
3	ID_3	c_3	p_3
…	…	…	…

Indexing Procedure

Each color in a segmented image is assigned to its nearest lattice point. Table [3] shows an example of the data structure for an indexing node. The image feature vector consists of dominant color (c_i) and its percentage (p_i) in the image, is identified by its unique ID. The entries at each indexing node are sorted by these ID numbers.

Search and Retrieval

The entire retrieval procedure is shown as flowchart in Fig. 5.

Experimental Results

In this section we discuss the results obtained for all the simulation experiments conducted.

Results on Y-C Transformed Images

We considered several color test images of sizes varying from 256X256 to 300 X 300 in the RGB color space. A spiral transformation was carried out for different number of encirclements L.A numerical evaluation of the processed image is made by computing the PSNR between the original and the reconstructed images respectively.

Table 4 shows the PSNR values of some of the test color images for different values of L. The color loss in processed images is indistinguishable. This is shown in Figure 6.

Table 3. The PSNR Values for Reconstructed Images

S.No.	Image	PSNR for (L=3)	PSNR for (L=5)	PSNR for (L=7)
1	baboon	25.983	30.317	32.5957
2	dna	26.906	31.3131	33.794
3	flowers	24.969	28.3445	29.994
4	aish	25.426	19.096	30.887

Performance Evaluation of The Segmentation Procedure

Figure 7 shows the results obtained using the proposed segmentation approach. It is seen that the resulting images preserve the main features of the objects with much smaller number of colors.

Experiments based on the segmentation using hue were also conducted for purpose of comparison. The performance of the Segmentation methods using C and hue are shown for few images in Fig (8).

Retrieval performance and Efficiency

For retrieval experiments we tested our method on a database of 1000 images. The color features (c_i,p_i) for all the images are computed and the corresponding images are indexed. We selected 20 images containing a variety of color combinations as queries. Figs.(9-11) show some retrieval examples. In each case only top five retrievals are shown. The top left image is the query image.

To evaluate the retrieval quality the precision and recall curves were obtained. As our approach is based only on color distributions in the image, for precision and recall calculation we consider only the color in the retrieved images and their distribution. The average precision and recall curves are shown in Figs. (12) and (13).

Conclusions

We conclude that using the new 2-D representation of color for retrieval,

1. The complexity of indexing is reduced to a great extent, as compared to traditional histogram methods where the complexity increases with the increase in number of bins.
2. The searching is done more efficiently in the new 2-D color space Y-C.

References

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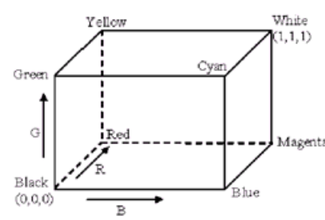

Figure 1. RGB color space

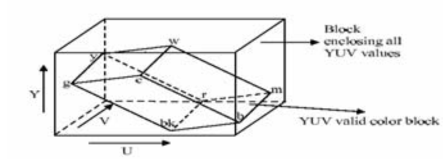

Figure 2. YUV color space

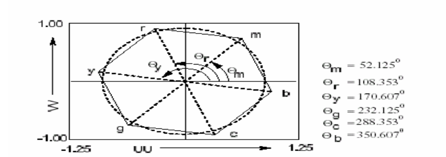

Figure 3. Modified YUV color plane

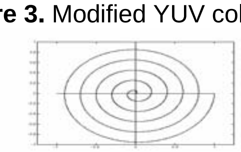

Figure 4. Spiral mapping for L=5

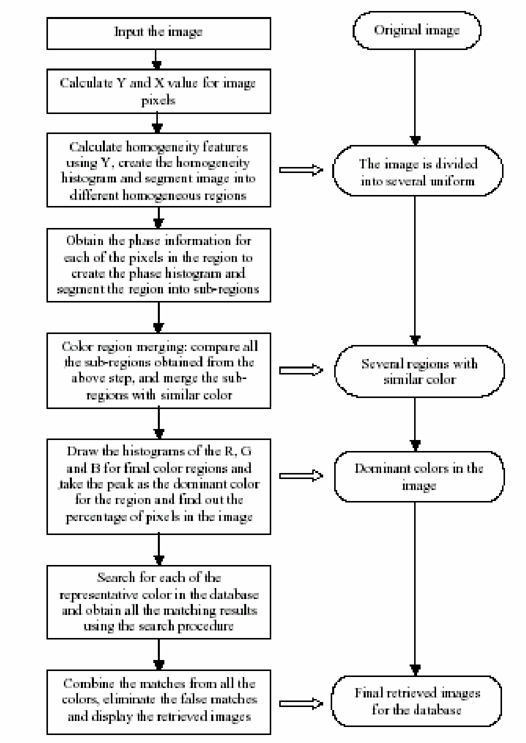

Figure 5. Flow chart for retrieval process

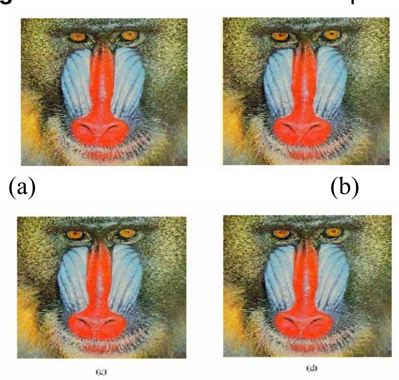

Figure 6. Reconstructed images (a) original (b) L=3 (c)L=5 (d) L=7

Figure 7. Beach image (a) original (b) segmented

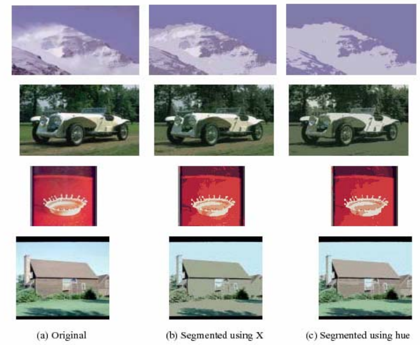

Figure 8. Performance comparison of segmentation

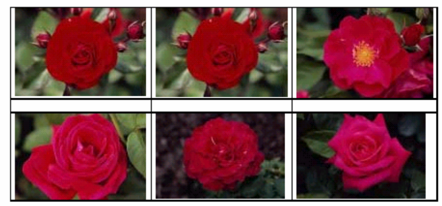

Figure 9. Top five retrieval for query on top-left

Figure 10. Top five retrieval for query on top-left

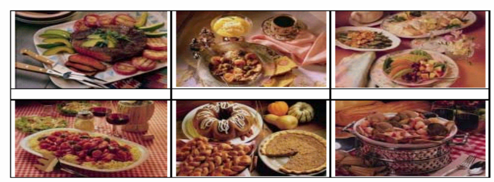

Figure 11. Top five retrieval for query on top-left

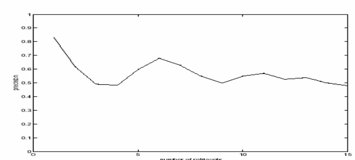

Figure 12. Average precision curve vs. number of retrievals

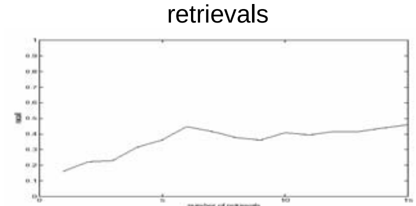

Figure 13. Average recall curve vs. number of retrievals