Image Retrieval using Spatial Chromatic Histograms

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Abstract

In this work, a new method for color image indexation is proposed. First the color space and the spatial domain are both projected on a 1D space and partitioned in a fuzzy way. Then, the 2D histogram of the membership degrees to these two partitions is computed. This histogram can be used to index each image of a large database. Therefore, retrieval is simply performed by computing the Euclidean difference between the 2D histogram of the query image and the 2D histogram of a database image. This method is applied on a real database.

1. Introduction

As the size of multimedia databases increases, it becomes necessary to represent images with accurate and efficient descriptors. A lot of solutions have been proposed to address this problem [1], [2], [3], [4], [5], using generally color, texture and shape features. Among these features, color constitutes a powerful visual cue and is one of the most commonly used features in image retrieval.

Color features are generally resumed in color histograms which are easy to compute and invariant to rotation and translation of image content. However, Color histograms have two main drawbacks:

- first, to get a compact description, histograms are computed on a small number of different colors (typically 32 or 64). This coarse color quantization limits the performance of retrieval systems. It must be remained that in a classical 8-bits RGB image, the number of different colors is 256^3.
- second, color histograms do not take into account spatial information, and are therefore incompetent to deal with image retrieval based on local image contents.

In this paper we propose a new indexation method based on a double "fuzzy" partition: a first one in the color space (§2.) and a second one in the spatial domain (§3.). Then, the 2D histogram of the membership degrees to these two partitions is computed (§4.). This "fuzzy" histogram is used to index each image of a large database. Then, retrieval is simply performed by computing the bin to bin difference between the 2D histogram of the query image and the 2D histogram of a database image (§5.).

2. Fuzzy Color Histogram

2.1. Histogram definition

Let us take a set $C = \{c_1, c_2, ..., c_K\}$ of K color classes provided by the color quantization step. Let g_k denotes the centre of the class c_k. Let $x_{n,\ n=1,N}$ be the color vectors associated to each of the N pixels of an image. At each vector x_n is associated a fuzzy description considering the set C. So each color vector x_n belongs to each class c_k with a membership degree $u_{k,n}$. The membership degrees used in the following correspond to those proposed in the *Fuzzy-C-Means* algorithm [7] and are defined by a normalized distance between the colors x_n and the class c_k (Eq. 1). The normalization is performed to get membership degrees between 0 and 1. Of course, the more the color x_n is close to the centre g_k of c_k the more the membership degree $u_{k,n}$ is close to 1.

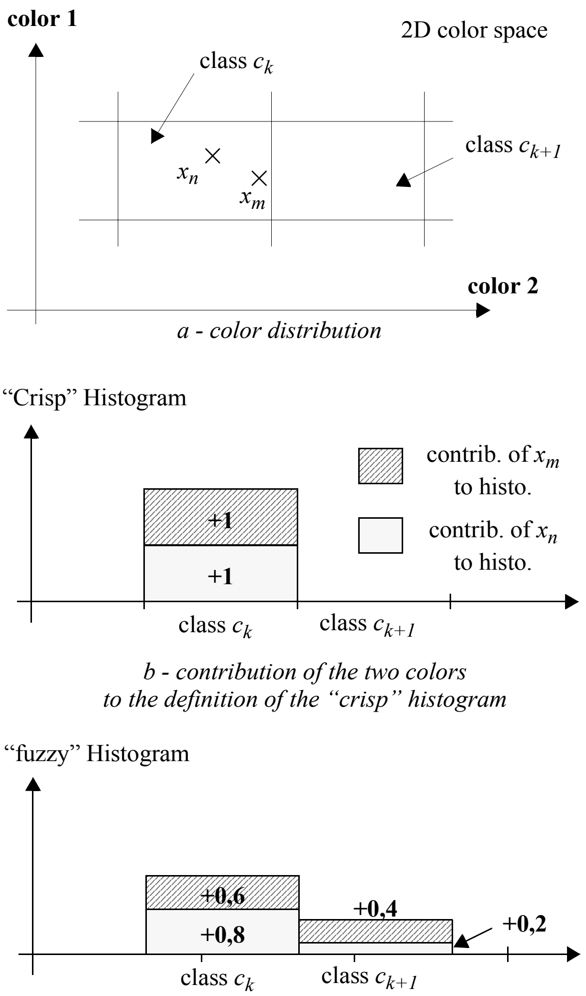
$$u_{k,n} = \frac{\left(\frac{1}{\|x_n - g_k\|}\right)^{\frac{2}{m-1}}}{\sum_{j=1}^{K}\left(\frac{1}{\|x_n - g_j\|}\right)^{\frac{2}{m-1}}} \qquad (1)$$

In Eq. 1 m denotes a parameter controlling the fuzziness degree introduced in the method and || . || denotes the L1 norm of the color vector difference.

The "fuzzy" color histogram is then defined by the set of the fuzzy cardinality, denoted $h(k)_{k = 1,K}$, of the different classes c_k, with:

$$h(k) = \frac{1}{N} \cdot \sum_{n=1}^{N} u_{k,n} \qquad (2)$$

This mechanism is illustrated en figure 1: the influence of two color vectors x_n and x_m on the histogram construction is represented in the case of a two dimensional color space.



a - color distribution

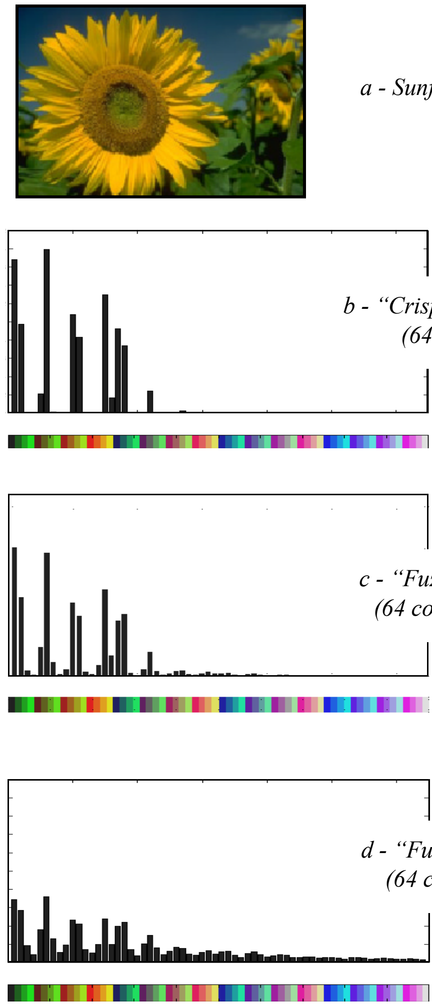
b - contribution of the two colors to the definition of the "crisp" histogram

c - contribution of the two colors to the definition of the "fuzzy" histogram

Figure 1. Comparison "crisp" Histogram / "fuzzy" Histogram

On this example, it can be seen that the distribution of the two colors is taken into account in a righter way thanks to the "fuzzy" histogram definition. Similar approaches have been proposed in [6] and [7].

The m parameter ($1 < m < \infty$) controls the *fuzziness* of the method. For $m \approx 1$, we get the "crisp" histogram. For a great value of m ($m \to \infty$), each color vector belongs to each class with the same membership degree. The effect of m is presented in the figure 2. In practise, a usual value is $m = 2$.



a - Sunflower image

b - "Crisp" histogram (64 colors)

c - "Fuzzy" histogram (64 colors m = 1,5)

d - "Fuzzy" histogram (64 colors m = 2)

Figure 2. Fuzziness effect on histogram

3. Fuzzy Location

The location, which is a 2D information, has to be also integrated in a compact way to insure quickness in image retrieval processing.

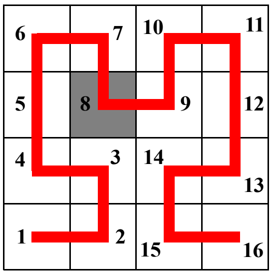
3.1. "Crisp" location definition

It is composed of three steps:

- First the image is divided in squared blocks (typically 8x8 or 16x16 blocks).

- Secondly, each block is coded by its number along a Peano curve, as illustrated in the following figure.
- Thirdly, each pixel is represented by the number, on the Peano curve, of the block it belongs to. It can be noted that the 2D location information is now a 1D information.

The following figure (Fig. 3) illustrates this coding for a 4x4 block image.

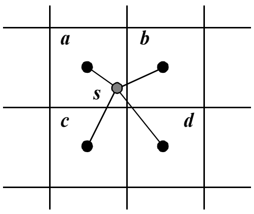


Peano Coding
For instance the block in grey is coded by the number 8. Each pixel within this block will be represented by the number 8.

Figure 3. Peano Coding

3.2. "Fuzzy" location definition

As for color space partition, this "crisp" solution has some strong quantization effects. Introduction of fuzziness limits the effects of this quantization. The "fuzzy" location is defined in the following way. Let us consider a pixel s which belongs to the block a. Considering the 3 blocks b, c and d in the neighborhood of block a (Fig. 4).



spatial domain

Figure 4. "Fuzzy" location definition

The pixel s belongs to the four blocks a, b, c and d with membership degrees $v_{s,a}$, $v_{s,b}$, $v_{s,c}$, $v_{s,d}$. The membership degrees are defined so that:

- their sum is equal to 1,
- the more the pixel s is close to the center of a block, the more its membership degree to this block is close to 1.

In this paper, $v_{s,a}$ is defined by:

$$v_{s,a} = \frac{\frac{1}{dist(s,a)}}{\frac{1}{dist(s,a)} + \frac{1}{dist(s,b)} + \frac{1}{dist(s,c)} + \frac{1}{dist(s,d)}} \quad (3)$$

where $dist(s,x)$ denotes the Euclidean distance between s and the centre of the block x ($x = a$, b , c or d).

4. Spatial Chromatic Fuzzy Histogram

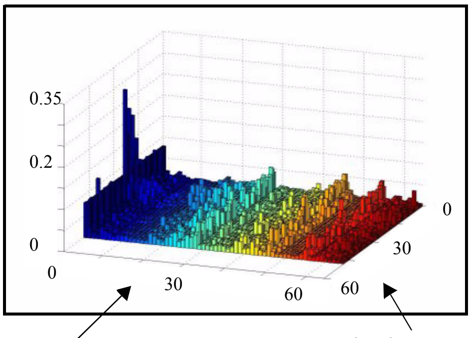
The 2D "fuzzy" Spatial Chromatic Histogram is then defined by:

$$h(k,l) = \frac{1}{N} \cdot \sum_{n=1}^{N} u_{k,n} \cdot v_{l,n} \quad (4)$$

where k denotes the color bin and l the location (number on the Peano curve).

The following figure presents such an histogram (Fig. 5).

Image of Annecy : the old town



k = color axis *l = location axis*

"Fuzzy" Histogram combining color and location

Figure 5. 2D "Fuzzy" Spatial Chromatic Histogram

This histogram looks like a grey level image where the two spatial axis x and y are respectively corresponding to the color and the location and where intensity of a "pixel" represents a membership degree. For a 512x512 color image, using 32 colors and 8x8 blocks provides a 32x64 2D histogram. Such an histogram could be compared to the image obtained by sub-sampling and color quantization. But in the fuzzy spatial chromatic histogram the information within the image is re-organized and compressed in a more efficient way.

To illustrate the interest of such histograms, they have been used as index for image retrieval.

5. Image retrieval

5.1. Similarity measure

One solution to image retrieval consists to find similar images by measuring their similarity according to a specific image index and a similarity measure. In our application, the index is the fuzzy spatial chromatic histogram and the similarity is simply performed by calculating the absolute difference between the 2D histogram of the query image and the 2D histogram of a database image. So the similarity between the query q and a database image d is defined by:

$$similarity(q, d) = \sum_{k=1}^{K} \sum_{l=1}^{L} |h_q(k, l) - h_d(k, l)| \qquad (5)$$

No inter-bin difference is used in this formula, as it is often used in such a measure [2], [3], [4], [5], [6]. Here, this is not necessary because the fuzziness introduction guarantees the inter-bin measure. Furthermore, the formula given by Eq. 5 is easier to compute than an inter-bin distance or a Earth Mover's Distance.

5.2. Test of the method

The method has been tested using the 5 images presented in Fig. 6. It can be noted that four of these images have the same color distribution with different spatial distributions.

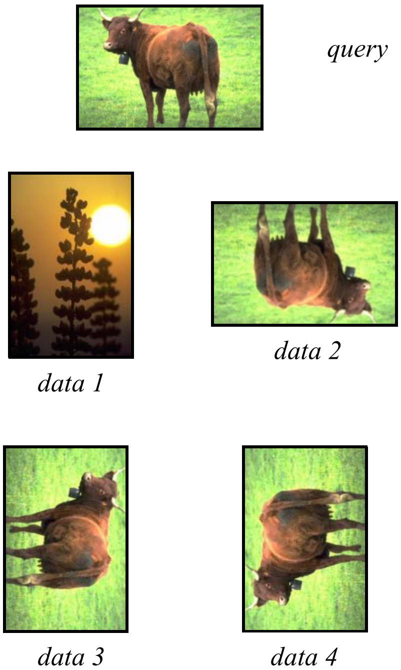


Figure 6. Images used for the test

The similarity measures have been performed using three strategies:

- strategy 1: by using fuzzy color histograms,
- strategy 2: by using crisp spatial color histograms,
- strategy 1: by using fuzzy spatial color histograms.

In these two last cases, the blocks used to define the fuzzy location are designed to get the same cutting of each image.
Results are presented in the following table (Table 1).

Table 1 : Similarity measures

sim(q,d)	Fuzzy color histogram	Crisp spatial-color histo.	Fuzzy spatial-color histo.
data 1	0.03	2.92	1.74
data 2	0.00	1.00	0.60
data 3	0.00	1.17	0.72
data 4	0.00	1.20	0.73

Of course the similarity with *data 1* is always the worst. Using only color information provides no difference between the query and the *data 2*, *3* and *4*, which contain the same colors than the query. Introducing spatial information allows to take into account the color location within the image. Fuzziness introduction tends to increase the similarity.

5.3. Application to a real database

The following figures give two different experiments in an image retrieval application. The different images presented are obtained using the request corresponding to the top-left image. Histograms are built using 64 colors and 64 locations (8x8 blocks), according to the Peano curve. The 64 colors which have been selected correspond to a uniform sampling of the RGB components. The database is composed of more than 3000 images of any type. The *fuzzy color histograms* have been used in the first experiment (Fig. 7) and the *fuzzy spatial color histograms* have been used in the second experiment (Fig. 8).

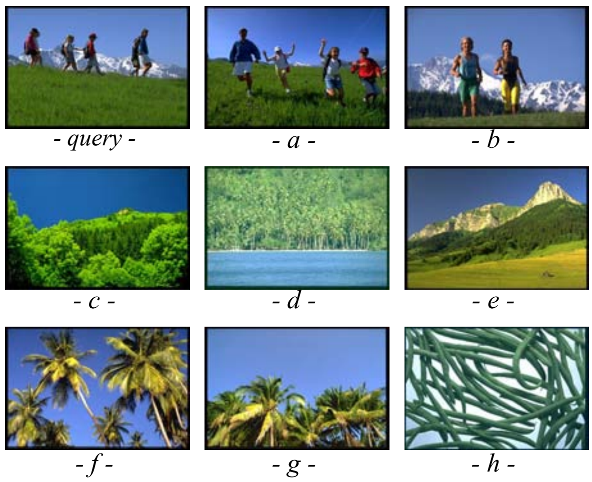


Figure 7. Image retrieval using fuzzy color histograms

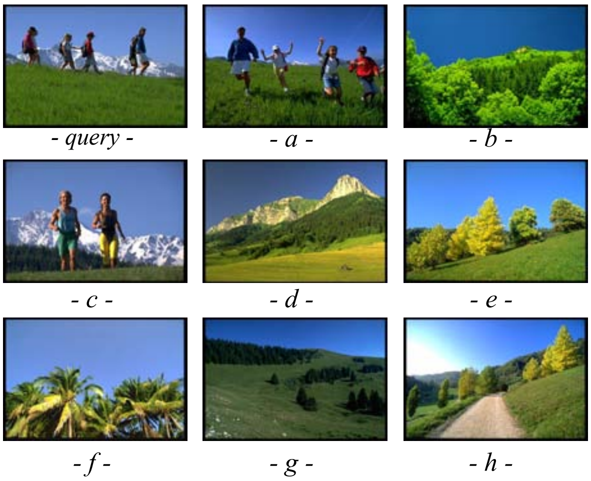


Figure 8. Image retrieval using fuzzy spatial color histograms

In the two experiments the retrieved images have nearly the same color composition. In the first experiment, some of the retrieved images have very different spatial color distribution : images 8-*d* (where large green and blue areas are permuted), 8-*f* and 8-*h* (where the green and blue colors are distributed all over the image). On the contrary, the images retrieved in the second experiment have similar color spatial compositions, with a large blue area at the top and a large green area at the bottom.

6. Conclusion

This paper propose a new method to define an image index combining color and spatial information. Contrasting with co-occurrence matrix, which are dedicated to texture characterization, this index acts as a compact description of the joint color and spatial distribution. It is defined as the 2D histogram of the joint membership degrees to two fuzzy partitions defined in the color space and in the spatial domain. The fuzziness introduction counterbalance the very strong quantization effect performed in the color and spatial domain. Of course the complexity is much higher than it is with the use of color histograms but some experiments have proved the efficiency of the proposed index for image retrieval.

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