A GENERIC RETRIEVAL METHOD USING PERCEPTUAL COLOR SPACE AND LOCAL DENSITY ESTIMATION

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ABSTRACT

In this work a color image retrieval scheme is proposed that combines color and shape statistical features for indexing. Concerning the color information, the perceptually uniform HSV color space has been employed. The shape feature is derived from the application of a non-parametric distribution modelling method on the original image. The weights of the color and shape fusion function were tuned using an objective evaluation method. The main advantages of this method are i) the modest computational complexity, ii) the small storage space requirements for feature indexing and iii) the efficient performance for various types of images.

1. INTRODUCTION

During the last few years several image databases are being created due to the low cost of digital storage and the rapid growth of computational power. Automatic retrieval of an image from a whole database set is a relatively new research field. The limitations of conventional keyword-based methods, guided to the development of content-based retrieval systems (IR), such as the QBIC system by IBM [1]. These systems use low-level features such as color, shape and texture to represent the image content.

Considerable research has been carried out on the basis of color and shape features. The comparison of images based on their histogram [2,3] is the most popular technique used for color retrieval. A lot of color spaces have been studied for retrieval purposes, that employ clustering [4] and segmentation [5] methods. These approaches although providing the overall system with better results in comparison to histogram-based techniques, are time consuming in the preprocessing stage. On the basis of shape retrieval, many recognition techniques have also been presented that use region- [6] or boundary-based methods [3,7]. The majority of the reported works deal with new methods for extracting color or shape information from an image. However, little attention has been given to the combination of low-level features [8,9], most of which has been carried out mainly on trademark and logotype image databases [3,10].

In our method, an integration of color and shape features was implemented to make a more flexible system and improve the retrieval performance, using a generic image database. A histogram technique was used on the perceptual HSV color space for color retrieval. The shape feature was extracted by means of an edge detection technique based on the estimation of the local density function (potential function), applied as a vector process [11,12].

2. THE PROPOSED RETRIEVAL METHOD

A typical retrieval system, in the preprocessing stage extracts the low-level features from the database images which are stored into indices. At the retrieval stage, an image usually queries the database and matching is calculated using a similarity function. The similarity measures are then ranked and the set of closest related images is presented as the output of the retrieval process. In order to build an efficient IR system, apart from performing well in the retrieval process we should take into consideration retrieval time, index-storage requirements and system's flexibility.

Histogram is used to describe the global pixel distribution of an image and its main advantage is attributed to its small sensitivity to variations in scale, rotation and translation of a given image. The use of histogram-based techniques yields in a simple retrieval model with little storage and computational time requirements. For the efficiency of our system, color and shape features are extracted from the database images using histogram techniques and the matching operation is performed using the histogram intersection (HI) operator [2] as a similarity measure, given by:

$$H(Q, I) = \frac{\sum_{j=1}^{n} \min(Q_j, I_j)}{\sum_{j=1}^{n} I_j} \quad (1)$$

where Q and I are the normalized histograms of the query and database images respectively, each containing n bins.

2.1. Color retrieval

Color is considered to be the most prominent low-level feature. For retrieval purposes, an appropriate color space must be specified along with a histogram representation of an image. Among several existing color spaces, the most common is the RGB where each pixel is represented by the intensities of red, green and blue wavelengths as defined by the CIE committee. However, these three components are highly correlated and do not incorporate the characteristics of human eye, due to the fact that the RGB space is perceptually non-uniform.

Several widely used three-dimensional color spaces i.e. RGB, CIE(La^*b^*), YUV and HSV, have been studied and tested. The image color information was represented by three 1-D histograms, regardless of the color space, and matching between two images was computed using the histogram intersection operator presented in (1). Experimenting on a subset of 20 images from the original database, the perceptual HSV color space was found to be the most appropriate for the particular retrieval technique. In comparison with the other representations, higher HI values were provided in the case of similar chromatic images and lower values concerning dissimilar images.

2.2. Shape retrieval

On the basis of shape retrieval, a fast vector edge detector is used based on the image density map to extract the shape information from a given image, with respect to its significant edges. Jain and Vailaya in their work [3] used the histogram of the edge directions to represent the shape attributes of the database images. In this approach, the histogram of the magnitude of the corresponding edge map is calculated, providing us with a rather indirect shape feature. Matching is again performed using the HI operator given by eq. (1). A brief discussion on the proposed edge detector is presented next.

The method employed here is the multivariate kernel density estimator, a nonparametric, vector-based method providing us with dimensionality reduction ($R^3 \rightarrow R$). It is based on the use of potential functions $K(\mathbf{X})$, also known as Parzen kernels [13]. Given a sliding 3x3 window containing 9 pixels $\mathbf{X}_i$, i = 1, 2, …, 9 the estimated probability density $P(\mathbf{X})$ is given by the relation:

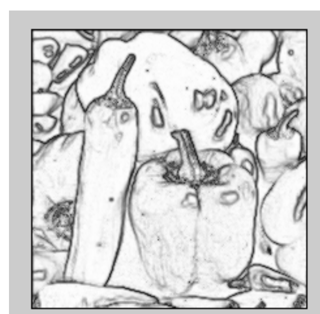
$$P(\mathbf{X}) = \frac{1}{Nh^p} \sum_{i=1}^{N} K\left(\frac{\mathbf{X} - \mathbf{X}_i}{h}\right) \quad (2)$$

where h is the bandwidth and p is the vectors' dimension (three in our case). A common choice for $K(\mathbf{X})$ is the multivariate Gaussian kernel of second order:

$$K(\mathbf{X}) = (2\pi)^{-p/2} \exp\left(-\mathbf{X}^2 / 2\right) \quad (3)$$

The output value of the edge detector, formed by (2) is estimated at the location of the sample *mean* vector. This value is high at the presence of a pixel-cluster forming a constant signal area. When bimodality exists, the sample mean is positioned in the low density area. Figure 1 displays the typical image "peppers" along with its corresponding edge map.

(a)



(b)

Fig. 1. (a) "Peppers" image and (b) the corresponding edge map.

2.3. Integration of color and shape

When an image contains both color and shape information, these features must be combined in order to increase the efficiency of the retrieval system. Given the similarity indices H_c and H_s of color and shape retrieval respectively, we integrated the results using a simple weighting sum function:

$$H_{cs} = \frac{w_c \cdot H_c + w_s \cdot H_s}{w_c + w_s} \quad (4)$$

where w_c and w_s are weights assigned to the color and shape similarity indices respectively.

3. EXPERIMENTAL RESULTS AND DISCUSSION

A new database was developed to evaluate this method. It comprises of 350 24-bit color depth images of different resolution, representing various subjects, eg. computer accessories, cars, sports and generic images. The digitized images of the database were replaced by color and shape histograms computed during the preprocessing stage, reducing storage requirements from 80MB to 320KB.

As it was mentioned in the previous section, the final similarity measure is estimated as the weighted sum of the color and shape indices, given by (4). In order to define these weights either a subjective or an objective method may be followed. According to the first perspective, the weights are set manually in relation to the most prominent feature of each query image. A more robust approach, is to test the performance of our system subsequent to small variations in scale, rotation and noise. For this reason, 20 images were arbitrarily rescaled, rotated and contaminated with 5% random noise, and then presented as queries. Our goal was to retrieve the original image in the first order of the similarity rank. The proposed system proved to be invariant in terms of scale and noise. However on the basis of shape retrieval, the rotated images were retrieved with relatively low index. This is attributed to the fact that the employed vector-based edge detection approach, takes only indirectly into consideration the orientation of an image. Rotated images were therefore excluded from the queries. It is our intention to resolve this pitfall by introducing the directional potential functions in the shape feature. Test results that were computed using histogram operator, provided us with 85% accuracy in the worst case on the basis of color and 55% on the basis of shape retrieval, both regarded to noisy query images. The corresponding weights were consequently set to w_c=8.5 and w_s=5.5. The relatively low shape retrieval index of 55% on the basis of noisy images is attributed to the fact that noise lies mainly on the high image frequencies. In this way, considering that an edge detector is a highpass filter, the corresponding edge map of a given image contains noisy pixels detected as edges.

An overview of the retrieval results is depicted in figures 2 and 3. These figures contain a query image along with the 7 most similar matches, according to solely color, shape or combination of these features. Figure 2 represents the case of a query image that contains superior color information, whereas fig. 3 is mostly characterized by shape. It becomes obvious that the integration of color and shape yields better results than considering each feature separately. In addition, considering the computational complexity of the proposed scheme, an average retrieval time of 6.5 seconds is required for the case of combined inference on a Pentium II (350 MHz) based platform.

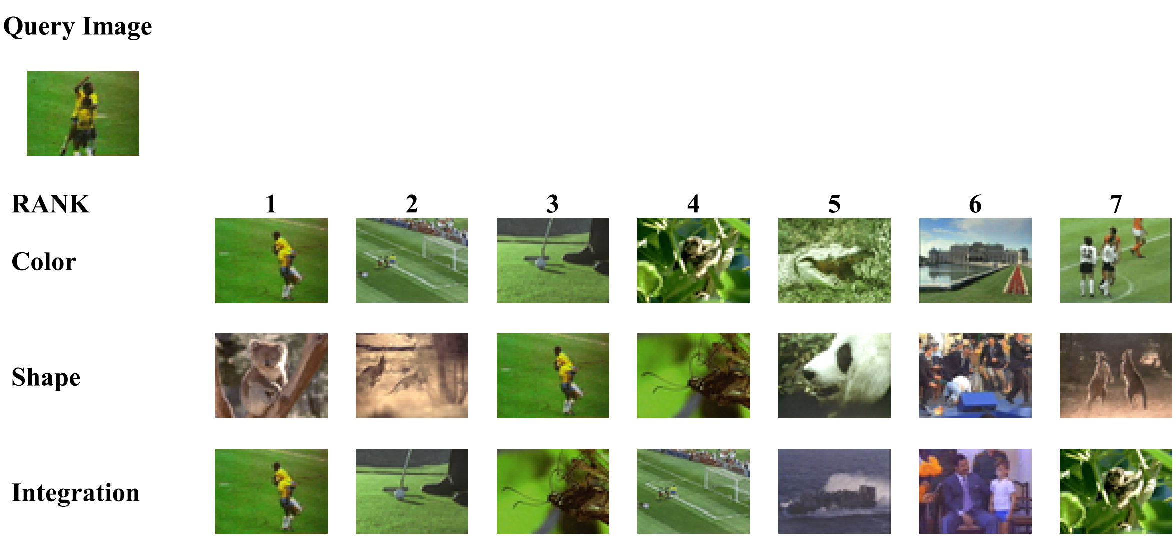


Fig. 2. Retrieval results using color, shape and integrated features of a query image containing superior color information.

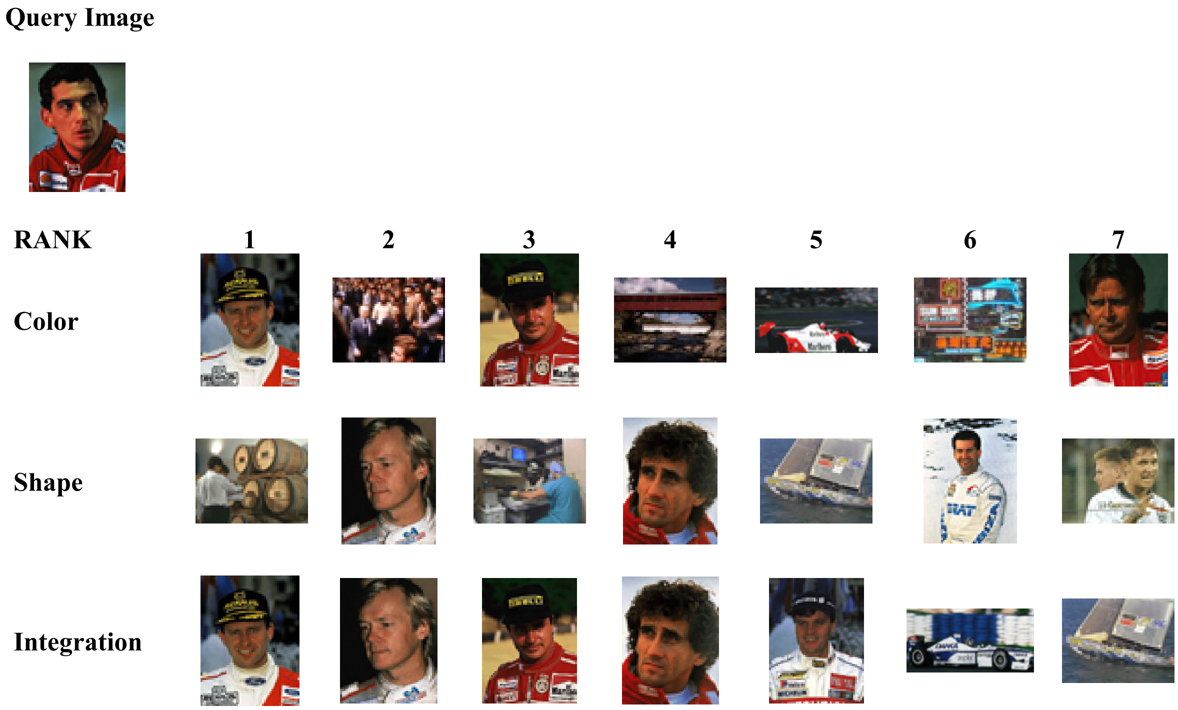


Fig. 3. Retrieval results using color, shape and integrated features of a query image containing superior shape information.

4. CONCLUSIONS AND FUTURE OBJECTIVES

A robust retrieval method was presented, that utilizes color and shape feature for histogram creation. Concerning color information, the perceptually uniform HSV color space is adopted. In addition to that, a non-parametric vector process is employed to detect the edges and derive the shape information. These features were combined by means of a weighted sum to produce the final similarity measure. Considering its performance, the proposed system is fast, requires little storage space for feature indexing, and produces efficient retrieval results for several types of images.

Our future objectives include the application of a previously reported segmentation method [12] in the proposed framework that will enable the integration of region-based features in the similarity process. This is expected to optimize the retrieval performance and reduce further the storage requirements. Another idea is to implement directional potential functions in order to make the system more robust to orientation variations. Finally, the database will be enriched with images of considerably different context to test more extensively the generic property of the retrieval process.

5. ACKNOWLEDGEMENTS

The above work was partially funded by the General Secretariat of Research and Technology of Greece in the framework of the bilateral cooperation between Greece and Romania ΕΠΑΝ-Μ.4.3.[code 2013555].

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