Comparison of Color Features for Image Retrieval

S.R. Kodituwakku[1]
Department of Statistics & Computer Science, University of Peradeniya
salukak@pdn.ac.lk

S.Selvarajah
Department of Physical Science, Vavuniya Campus, University of Jaffna
sahiselva@yahoo.com

Abstract

Content based image retrieval (CBIR) systems are used for automatic indexing, searching, retrieving and browsing of image databases. Color is one of the important features used in CBIR systems. An experimental comparison of a number of different color descriptors for content-based image retrieval is presented in this paper. Color histograms, color moments and color coherent vector (CCV) are considered for retrieval. The primary goal is to determine which color descriptor or combination of color descriptors is most efficient in representing the similarity of color images. In this paper, we first present the comparison of individual color descriptors and then the comparison of combined color descriptors. For the experiments, five different publicly available image databases are used and the retrieval performance of the features is analyzed in detail. This allows for a direct comparison of all features considered in this work and furthermore it will allow a comparison of newly proposed features to these in the future. The article is concluded by stating which features perform well for what type of data.

Keywords

Image Retrieval, Feature Representation, Color Histogram, Color Moments, Color Coherent Vector

1. Introduction

In CBIR systems[1-9], images automatically indexed by summarizing their visual features. A feature is a characteristic that can capture a certain visual property of an image either globally for the entire image or locally for regions or objects[5]. Color, texture and shape are commonly used features in CBIR systems. A key function in any CBIR system is the feature extraction. Mapping the image pixels into the feature space is known as feature extraction. Extracted features are used to represent images for searching, indexing and browsing images in an image database. Use of feature space is more efficient in terms of storage and computation. Most of the CBIR systems represent the feature space as a feature vector. Once the features are represented as a vector it can be used to determine the similarity between images. CBIR systems use different techniques to measure similarity.

In retrieval stage, query image is also represented as a feature vector and the similarity between the query vector and stored feature vectors is computed[8]. The similarly measure is used to determine the distance between the query image and stored images. After that images are ranked according to the distance and retrieved.

Visual indexing techniques can be categorized into two groups. Pixel domain and compressed domain techniques. Pixel domain techniques are used to index visual features such as color, texture and shape[9]. We have considered color feature which is extracted in Pixel domain.

In this paper, we represent images by color descriptors. Color histograms, color moments and color coherent vector (CCV) are considered as descriptors. We compare the effectiveness and efficiency of these color descriptors in representing visual features.

2 Methods and Materials

There are several color models in used. We use the RBG color model for this work. In order to evaluate the effectiveness and efficiency of color features the following color descriptors are considered.

2.1 *Color Features*

Color is a widely used important feature for image representation. This is very important as it is invariant with respect to scaling, translation and rotation of an image. Color space, color quantification and similarity measurement are the key components of color feature extraction.

Color moments

The mean, variance and standard deviation of an image are known as color moments[10]. Following equations define the mean, variance and standard deviation of an image of size $n \times m$.

$$mean = \sum_{i=1}^{n} \sum_{j=1}^{m} x_{ij} / mn \qquad (1)$$

$$\text{var}iance = \frac{1}{nm} \sum_{i=1}^{n} \sum_{j=1}^{m} \left(X_{ij} - mean \right)^2 \qquad (2)$$

$stddev = \sqrt{\text{var}iance}$, where X_{ij} is the Pixel value of the i^{th} row and j^{th} column.

Color Histogram

A histogram is the distribution of the number of pixels for an image[1]. The number of elements in a histogram depends on the number of bits in each pixel of an image. For example, if we consider a pixel depth of n bit, the pixel values will be in between 0 and $2^n - 1$, and the histogram will have 2^n elements.

For very large data sets, color, moments can be computed based on color histogram as follows.

$$mean = \sum_{i=o}^{255} i * h(i) / \sum_{i=o}^{255} h(i) \qquad (3)$$

$$\text{var}iance = \sqrt{\frac{\sum_{i=o}^{255} h(i) * (i - mean)^2}{\sum_{i=o}^{255} h(i)}} \qquad (4)$$

Where h is the histogram of the image.

Color Coherent Vector (CCV)

Color histogram does not consider the spatial information of pixels. This may result in similar color distribution for different images. Color coherent vector addresses this problem. In CCV each histogram bin is partitioned into two types: coherent and incoherent. Pixel value belongs to a large informally colored region falls into coherent type. Otherwise it falls into incoherent type. A color coherent vector represents this classification for each color in the image.

Similarity measurements

Eight similarity measurements have been proposed[9]. In this work, we use Sum-of-Squared-Differences (SSD) and sum-of-Absolute Differences (SAD). Several researchers have reported that these two methods are the most effective and efficient. Equations given below define SSD and SAD respectively [2].

$$SSD\left(f_q, f_t\right) = \sum_{i=o}^{n-1} \left(f_q[i] - f_t[i] \right)^2 \qquad (5)$$

$$SAD\left(f_q, f_t\right) = \sum_{i=o}^{n-1} \left(1 f_q[i] - f_t[i] \right) \qquad (6)$$

Where $f_q \, f_t$ represent query feature vector and database feature vectors and n is the number of features in each vector.

A general purpose image database that consists of 14500 images drawn from different categories is used to evaluate the effectiveness and efficiency of the selected color features. The images are stored in JPEG format with size

384x256 and the RBG color model in used. For each image color feature vectors have separately been computed and stored in a database.

In this work, color features are evaluated by means of the ratio of relevant retrieved images to the total number of retrieved images (precision) and the ratio of retrieved relevant images to the total number of relevant images in the database (Recall).

2.2 *Methodology*

Before starting the processing of images, the images are quantized to reduce the number of colors from 2^{24} to 256. Then the relevant images are identified based on different color features and their combinations.

The histogram based image retrieval consists of two techniques: Global Color Histograms (GCH) and Local Color Histograms (LCH). The GCH represents images with single histogram. First the GCHs of database images are computed and stored them in a database. Then the GCH of the query image is computed. The Euclidian distance metrics is used to measure the similarity between the query image and the database images. In order to identify the relevant images a fixed threshold is used. In case of LCH, images are divided into fixed blocks of size 8x8. For each block, its color histogram is obtained. The same procedure followed for GCH is applied for identifying the relevant images.

The next visual feature representation is extracted by incorporating the color histograms and color moments as described by the equations (1), (2), (3) and (4). First the mean and standard deviations of database images are calculated and stored in a database. Then it is compared with the mean and standard deviation of the query image. The relevant images are ranked by using a fixed threshold value of the difference of the mean and standard deviation of query image and the database images.

Our coherence measure classifies pixels as either coherent or incoherent. A coherent pixel is a part of a sizable contiguous region, while an incoherent pixel is not. Pixel groups are determined by computing connected components. The connected components are computed using 8-connected neighbors within a given discretized color bucket. Pixels are classified as either coherent or incoherent depending on the size in pixels of its connected component. A pixel is classified as coherent if the size of its connected component exceeds a fixed value region. In other words a pixel is coherent if its area is about 1% of the image. Otherwise, the pixel is incoherent. A color coherence vector is used to represent this classification for each color in the image. First the image is slightly blurred by replacing pixel values with the average value in a small local neighborhood. The Gaussian filter is used for this purpose. Then the color space is discretized so that there are only 3 distinct colors (R, G and B) in the image. In the next step, the pixels within a given color bucket is classified as either coherent or incoherent. Relevant images are retrieved by computing the similarity between the query vector and image vectors.

After retrieving images based on individual color features, combinations of such features are also considered. In comparing the combination of image features, sum-of-Absolute Differences (SAD) similarity measurement is used.

3. Results and Discussion

A general purpose image database consists of 14500 images is used for experimentation[11-15]. The database consists of different categories such as Africans and villages, Beaches, Buildings, Buses, Dinosaurs, Elephants, Flowers, Horses, Mountains and glaciers, Food, Faces, Objects, Drawings, Textures and Natural scenes. All the categories are used for retrieval. These images are stored in JPEG format with size 384x256 and each image is represented with RGB color space. In order to measure retrieval effectiveness for an image retrieval system, precision and recall values are used. Five different images of each category are used as query images. These images are selected so that some of them have uniform colour distribution, some others have non-uniform colour distribution and the other having average colour distribution. Table 1summarizes the experiment results.

Table 1 – Summary of test results

Category - Africans

Descriptor	Recall	Precision
CM	0.10062069	0.497612551
	0.099586207	0.543879473
	0.096551724	0.623330365
	0.095586207	0.66442953
	0.092551724	0.82129743
GCH	0.10062069	0.595267238
	0.09862069	0.616645106
	0.095586207	0.641963872
	0.088551724	0.652107669
	0.085517241	0.702549575
LCH	0.09862069	0.645015787
	0.096551724	0.652985075
	0.091517241	0.659215102
	0.087517241	0.669303797
	0.082482759	0.6949448
CCV	0.10062069	0.327938863
	0.10062069	0.355940473
	0.097586207	0.360601427
	0.092551724	0.367973677
	0.090551724	0.379809083

Category - Red Buses

Descriptor	Recall	Precision
CM	0.10062069	0.390733798
	0.09862069	0.462334303
	0.097586207	0.521562846
	0.095586207	0.620967742
	0.092551724	0.766419189
GCH	0.099586207	0.317292903
	0.09862069	0.32678245
	0.096551724	0.334368283
	0.094551724	0.370040486
	0.092551724	0.457708049
LCH	0.096551724	0.413711584
	0.093586207	0.406165819
	0.091517241	0.459487535
	0.088551724	0.470674487
	0.082482759	0.496884088
CCV	0.10062069	0.390733798
	0.09862069	0.403385049
	0.095586207	0.411275964
	0.091517241	0.459487535
	0.090551724	0.481304985

Category - Dinosaurs		
Descriptor	Recall	Precision
CM	0.100137931	0.698748797
	0.09862069	0.754219409
	0.097586207	0.815092166
	0.095586207	0.931451613
	0.092551724	0.919808088
GCH	0.099586207	0.529325513
	0.09862069	0.580121704
	0.096551724	0.615114236
	0.094551724	0.661999034
	0.090551724	0.647435897
LCH	0.097586207	0.5
	0.095586207	0.508064516
	0.093586207	0.534672971
	0.090551724	0.588261649
	0.087517241	0.674282678
CCV	0.10062069	0.555597867
	0.099586207	0.585801217
	0.096551724	0.631483987
	0.090551724	0.642997062
	0.086551724	0.651609553

Category - Africans		
Descriptors	Recall	Precision
GCH &CCV	0.088531187	0.871287129
	0.08249497	0.872340426
	0.079476861	0.877777778
	0.078470825	0.906976744
	0.078470825	0.951219512
LCH & CCV	0.100603622	0.487804878
	0.099597586	0.5
	0.097585513	0.510526316
	0.088531187	0.511627907
	0.08249497	0.522292994
CCV, CM, LCH & GCH	0.095573441	0.95959596
	0.09054326	0.97826087
	0.088531187	0.988764045
	0.088531187	0.988764045
	0.080482897	0.987654321
GCH, LCH & CCV	0.098591549	0.439461883
	0.096579477	0.507936508
	0.095573441	0.50802139
	0.095573441	0.513513514
	0.093561368	0.550295858

4. Conclusions

An experimental comparison of a number of different color descriptors for content-based image retrieval was carried out. Color histograms, color moments and color coherent vector (CCV) are considered for retrieval. The retrieval efficiency of the color descriptors was investigated by means of recall and precision. According to the results obtained it is difficult to claim that one feature is superior to others. The performance depends on the color distribution of images. The test results indicate that color histogram performs well compared to other descriptors when images have mostly uniform color distribution. In most of the images categories color moments also show better performance. CCV shows better comparison rate for images those have widely scattered colors. The combination of color descriptors produced better retrieval rate compared to individual color descriptors.

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