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A Comparative Study on Color Based Approaches to Content Based Image Retrieval

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Abstract: *In order to resolve limitations of traditional methods of image indexing in large image dataset, techniques of retrieving images on the basis of features such as color, texture and shape-generally known as Content Based Image Retrieval (CBIR) have attracted tremendous research attention in recent years. CBIR has a wide range of applications such as face recognition, finger print matching, pattern recognition for biometric security etc. In this paper, a number of color based image retrieval approaches using (1) global color histograms; (2) local color histograms; (3) fuzzy linked histograms and (4) spatial chromatic histograms have been implemented and compared comprehensively with the help of a heterogeneous image database consisting of more than 1200 images. The algorithms are compared with respect to different standard performance measure and computational time*

Keywords: *Image retrieval, Color histograms, Fuzzy linking, Spatial-chromatic histogram, Precision-recall*

1. Introduction

In the early 1990s, CBIR has been a fast advancing research directions both in commercial and research fields, where remarkable progress has been made in both theoretical and system development due to the rapid development of information technologies and the advent of the web have accelerated the growth of digital media and, in particular, image collections. Long ago access to digital image collections were provided through manual assignment of text descriptors [1] using text based image retrieval (TBIR) systems; textual descriptors fail to capture the essence of perfection because is not only subjective and error-prone but also very time-consuming and laborious for large image collections. This is where the beauty of visual interpretation of images comes into existence; CBIR uses to search an image based on low level visual features like color, texture, shape extracted from the image itself. Images are then indexed by these features, and the similarity between images is measured so that relevant image can be retrieved from a widely diverse image collection.

Color has been an active area of research in image analysis and retrieval, more than any other branch of computer vision as color features are one of the most fundamental elements of the content of images enabling humans to recognize images. Among the methods that utilize color as a retrieval feature, the most popular one is that of color histograms [2]. A color histogram is the distribution of color in an image which is defined as a set of bins where each bin denotes the probability of pixels in the image being of a particular color. A histogram-based retrieval system requires a suitable color space such as RGB, HSV, L*a*b* and a similarity metric like (Euclidean Distance) or the Histogram Intersection method [3].

In this paper several color based image retrieval algorithms have been investigated, implemented and compared with respect to different well-established performance measures for checking their efficiency and effectiveness of retrieval; color extraction and comparison were performed using the three color histograms, conventional color histogram (CCH), fuzzy linked histogram (FLH) and spatial chromatic histogram (SCH).

This paper is organized as follows. We review the related work of color based approaches in section II, while the GCH, LCH, FLH, SCH algorithms are stated in section III. Section IV summarizes the experimental results and comparisons to all the methods, while conclusions are briefed in section V.

2. RELATED WORK

Color is one of the most widely used low-level visual features for CBIR and has been a very interesting field of research since 1991. Many eminent researchers have contributed actively in this arena. In 1991, work was done on color histograms for image indexing [3]. Research work was done on color constancy in 1996 [4]. Histogram intersection, an L1 metric (metric based on absolute values), is usually used as the similarity measure for the color histogram [3]. To take into account the similarities between similar but not identical color, M. Ioka [5] and W. Niblack et al. [6] introduced an *L*2-related metric (metric based on square values) in comparing histograms. Finally the color coherence vector [7] differs from the color histogram in that it manages to capture information about the distribution of the colors spatially within the image. Split histograms were introduced in the year 1996 by G. Pass, R. Zabih and J. Miller [7]. Spatial colors using color correlograms were implemented by J. Huang, S. Ravi Kumar, M. Mitra, W. Zhu and R. Zabih [8] in 1999. Since 2000 content based image retrieval using fuzzy techniques has been a very interesting field of research. A one-dimensional fuzzy color histogram proposed by K. Konstantinidis, A. Gasteratos and I. Andreadis [9] which gave quite good retrieval rates.

3. METHODOLOGY

In Conventional Color Histogram (CCH) each color space consists of three components leads to 3-dimensional histograms. There are two conventional techniques for color-based image retrieval: Global Color Histograms (GCH), that represent images with single histograms; and Local Color Histograms (LCH) that segment images into fixed blocks and, for each block, obtain its color histogram [10].

A. Algorithm-I the Global Color Histogram (GCH)

1. A query image Q is selected
2. For the query image Q and all Database images I repeat steps 3 to 5
3. Q and individual database image I is encoded with its color histogram GCH in RGB color space using

$$GCH_Q = \sum_{i=1}^{N} H_Q[i] \quad (1)$$

4. The similarity between Q and I is computed using Euclidean distance metric as follows

$$d_{GCH}(Q,I) = \sqrt{\sum_{i=1}^{N} \left(H_Q[i] - H_I[i]\right)^2} \quad (2)$$

where N is total number of bins present in the image

5. Store the similarity values obtained in previous step in ascending order in the image database and according to them first m images are displayed using a threshold value on the basis of human perceptual judgments

B. Algorithm-II the Local Color Histogram (LCH)

1. A query image Q is selected
2. For the query image Q and all Database images I repeat steps 3 and 4
3. Segment query image and database image I into equal sized blocks and obtain the LCH for each block using

$$LCH_Q = \sum_{k=1}^{M} \left(\sum_{i=1}^{N} H_Q^k [i] \right) \quad (3)$$

4. The similarity between the query image Q and the Database image I is computed using Euclidean distance and the overall distance in between two images Q and I is obtained by calculating the sum of the corresponding regions as follows

$$d_{LCH}(Q,I) = \sum_{k=1}^{M} \sqrt{\sum_{i=1}^{N} \left(H_Q^K[i] - H_I^k[i] \right)^2} \quad (4)$$

   where M is total number of regions and N is total number of bins present in the image

5. Store the similarity values obtained in previous step in ascending order in the image database and according to them first m images are displayed using a threshold value on the basis of human perceptual judgments

Although the appealing aspect of the conventional color histogram is its simplicity, ease of computation, efficiency, and insensitivity to small changes in camera viewpoint, conventional global color histogram lacks discriminatory power in retrieval of large image databases and does not match human perception very well. This paper extends the approach of global color representation and includes regional information by computation of LCH which is usually computationally demanding and gives better performance in terms of better retrieval effectiveness. However, a histogram is a coarse characterization of an image as the images with very different appearances can have similar histograms; the colors represented by neighboring regions can have relatively small differences, so the similar colors problem appears and the large variations between neighboring bins also exists in CCH. So the aim of this paper is to explore even more efficient techniques in fuzzy approaches in CBIR as fuzzy system deals with such imprecise information by converting RGB color space to L*a*b* color space and then linking 3-D histograms into a single-dimension histogram consisting of only 10 bins, called histogram linking according to the 27 fuzzy rules in [9].

L*a*b* color space is used since this approximates the way that humans perceive color and is useful for sharpening images and removing artifacts in JPEG images or in images from digital cameras and scanners [9]. It was created to serve as a device independent model to be used as a uniform color space. In L*a*b*, L* stands for luminance, the a axis extends from green (-a) to red (+a) and the b axis from blue (-b) to yellow (+b). The brightness (L) increases from the bottom to the top of the three-dimensional model.

C. Algorithm-III Creation of Fuzzy Linked Histogram(FLH)

1. Fuzzification of the input is accomplished by using triangular shaped built-in membership functions (MF) for the three input components (L*, a*, b*)

2. Using Mamdani type of fuzzy inference, the output MFs are combined through the aggregation operator which is set to max
3. The implication factor is set to min and the OR and AND operators are set to max and min, respectively.
4. Resulting fuzzy set is defuzzified to produce the output of the system. The output of the system has only 10 equally divided trapezoidal MFs

The histogram of the FLH scheme, have proved to be an efficient tool for accurate image retrieval. In order to retrieve similar kind of images from the image database, the similarity metric used over here is that of histogram intersection [3] which belongs to the interval [0, 1] can be expressed through the following equation:

$$H(H_Q, H_C) = \frac{\sum_{i=1}^{N} \min(H_Q(i), H_C(i))}{\min(\sum_{i=1}^{N} H_Q(i), \sum_{i=1}^{N} H_C(i))} \quad (5)$$

where H_Q and H_C are the FLHs of the query image and individual database images respectively.

In FLH very few bins are used to describe the color distribution of the image resulting in much faster comparison between the histograms. Unfortunately pixel histograms do not provide spatial information about their arrangements, so very different images can have similar color distributions. Thus, histogram based image retrieval method can be enhanced by insertion of spatial information. This paper aims to present a more robust (with respect to the retrieval accuracy) chromatic representations based on spatial arrangements of the similarly colored pixels, which allows a software system to automatically perform image indexing, based on image content[11].

Thus, in this paper a novel, effective methodology called Spatial-Chromatic Histogram (SCH), integrating color and spatial information of the similarly colored pixels [11] is described and implemented.

D. Algorithm-IV Implementation Steps Using Spatial Chromatic Histogram (SCH)

1. Feature Extraction

1.1. Let I be an n*m query image

1.2. $\Lambda^I_k := \{(x, y) \in I : I[x, y] = k\}$ is the set of pixels having same color k.

1.3. $h_I(k) = \frac{|\Lambda^I_k|}{n \times m}$ is the ratio of pixels having color k in image I gives the idea of the color distributions in I.

1.4. $b_I(k) := (\overline{x_k}, \overline{y_k})$ is a normalized mean center gives the idea of the position of the pixel having same color, termed as Baricenter given in relative coordinates, of the pixels in Λ^I_K, where

$$\overline{x_k} = \frac{1}{n} \frac{1}{|\Lambda_k|} \sum_{(x,y) \in \Lambda_k} x \quad (6)$$

$$\overline{y_k} = \frac{1}{m} \frac{1}{|\Lambda_k|} \sum_{(x,y) \in \Lambda_k} y \quad (7)$$

2. Feature Properties

2.1. Compute the standard deviation of pixels in Λ_K^I $\sigma_I(k) = \sqrt{\frac{1}{|\Lambda_k|}\sum_{p \in \Lambda_k}(d(p, b_I(k))^2}$ to refine spatial information about the regions by giving an idea of the pixels spread from the baricenter; baricenter gives rough approximation of the pixels' spatial properties as different arrangement can have close baricenters. Here p be any generic pixel having relative coordinate (xp,yp) and $d(p, b_I(k))$

is the euclidean distance between two pixels. A compact representation of the spatial-color image content is defined as a SCH vector: $S_I(k) = (h_I(k), b_I(k), \sigma_I(k))$

(8)

3. Similarity function

3.1. Comparison of query image with individual database images by means of similarity function $f_s(Q, I)$ is performed which separately considers color and spatial information:

$$f_s(Q, I) = \sum_{i=1}^{k} \min(h_Q(i), h_I(i)) \times (\frac{\sqrt{2} - d(b_Q(i), b_I(i))}{\sqrt{2}} + \frac{\min(\sigma_Q(i), \sigma_I(i))}{\max(\sigma_Q(i), \sigma_I(i))}) \quad (9)$$

4. EXPERIMENTAL RESULTS

A. Test Image Database

The performance of SCH approach is measured and experimental trials on an image database are shown and compared with most standard techniques like GCH, LCH and FLH method. Several experiments are conducted and we have tested the performance with a widely diverse image collection consisting of more than 1200 test images of different categories taken from [12] to show the effectiveness and accuracy of retrieval of the method. The representative images of different categories of the image database used for experimentation purpose are given in Fig. 5. In this paper the color image retrieval systems have been implemented in MATLAB 2010 environment with 1 GB of RAM on a Pentium 4 (2.80 GHz) PC.

B. Results Evaluation and Comparative Study

In order to quantify SCH methodology's performances with respect to GCH, LCH and FLH methods we have evaluated the performance measures. The retrieval performance measurement used is the average precision-recall values, F-measures and accuracy measures [13] in order to compare all the above mentioned four color based algorithms.

Fig. 1 shows the color image retrieval results using the GCH method. The image at the top of left-hand corner is the query image; other 19 images are the query results with their similarity values in ascending order as lower the similarity values higher is the similarity between query and database images. Fig. 2 also shows top 19 matches with the given query image using LCH method. It is not difficult to see that the LCH algorithm can effectively retrieve more similar images corresponding the demonstration image. As GCH does not include the color distribution of the regions, though 6th image in GCH having the lower visual similarity with query image, it still gives lower $d_{GCH}(Q, I)$ values compared to 7th image in GCH which is more similar to the query image, still gives higher $d_{GCH}(Q, I)$ value; LCH method overcomes this disadvantages where the new distances $d_{LCH}(Q, I)$ between images are more reasonable than those obtained using GCH as last five retrieved images having the lower visual content similarities among all the stored database images, they give higher $d_{LCH}(Q, I)$ values, indicating the retrieval accuracy of the LCH method. Fig. 3 shows a query example using FLH method, where a spring flower picture used as query and first 19 most similar pictures retrieved, are presented with their similarity values in descending order as larger the similarity values higher is the similarity. All the images were scaled to a 64 * 64 pixel in order to make the algorithm faster and to avoid later normalization of the histograms, which might result in loss of color quantity information. Experimental results shown in Fig. 3 proves FLH focuses on retrieving the original as well as most similar images from the image database and evaluate the relevancy of retrieved images; only last three images are not relevant to the query image. Fig. 4 shows the query image along with top 19 retrieved images using SCH method which resembles the query image. The first retrieved image has the highest similarity score because the color percentage as well as the spatial arrangements of the pixels is quite similar with respect to the query image at the top left corner of Fig. 4.

C. Observations

We have tested the performance of all the color based algorithms with the help of several query images from the image database. The retrieval performance measurement used in order to compare the four algorithms is the average precision (%)-recall (%), which is produced for the forty first most similar

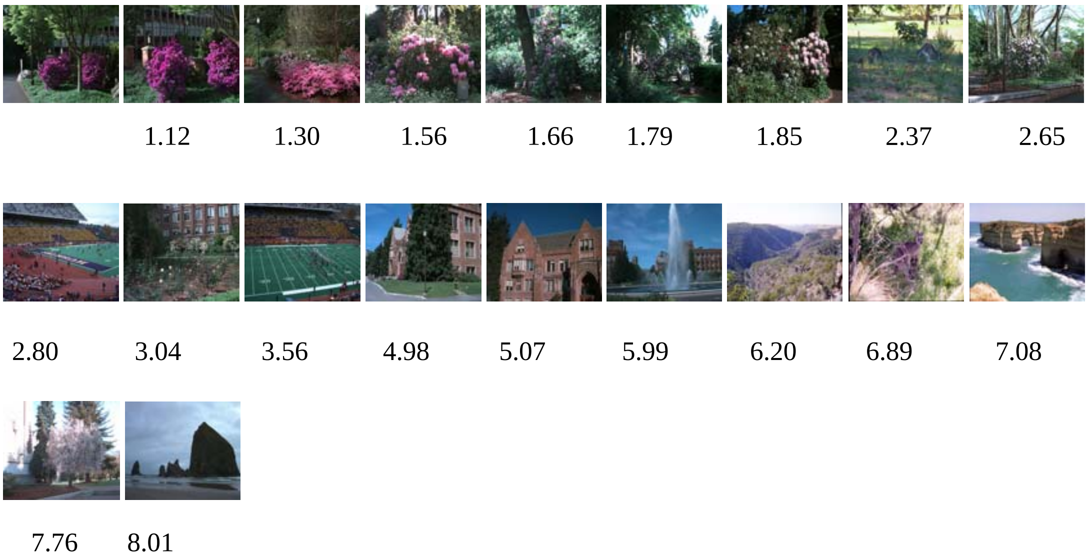

Figure 1. *Query image with top 19 similarly retrieved images* of GCH Method

Figure 2. *Query image with top 19 similarly retrieved images of LCH Method*

Figure 3. *Query image with top 19 similarly retrieved images of* FLH Method

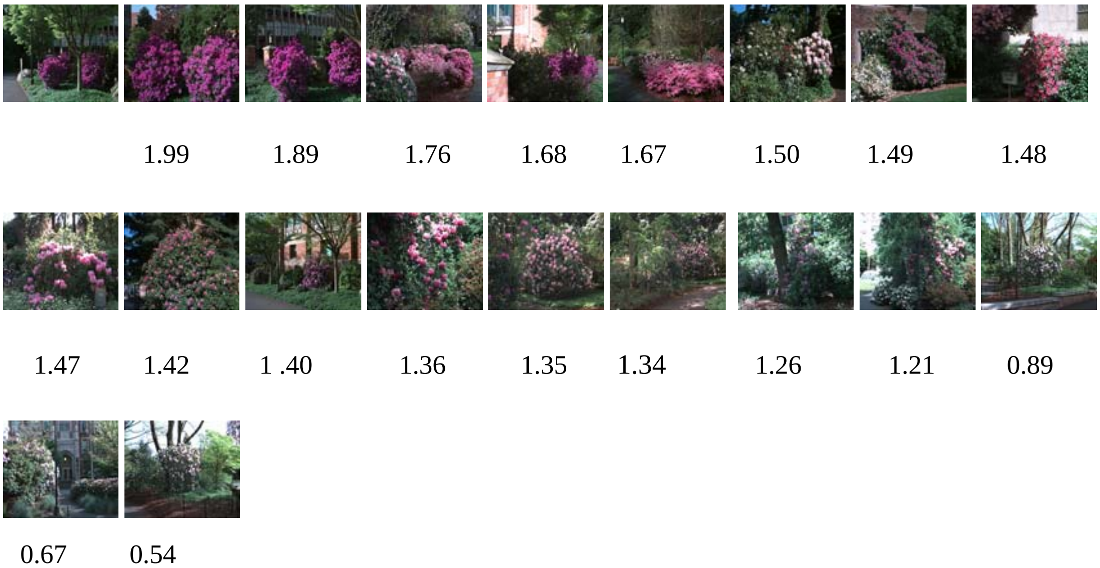

Figure 4. *Query image with top 19 similarly retrieved images of* SCH Method

images retrieved by the CBIR system. Precision is defined as the ratio of the number of relevant retrieved images to the total number of retrieved images where as recall is defined as the ration of the number of retrieved relevant images to the total number of relevant images in the whole database. Fig. 6 and Fig. 7 show the precision (%) and recall (%) graphs respectively plotted against the number of images retrieved. The precision curve of the SCH method has higher values as compared to the other methods. The recall graph also shows that

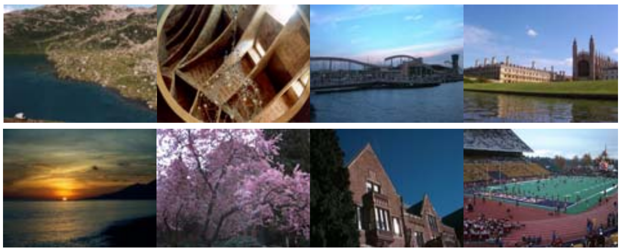

Figure 5. *Categorical images in image database*

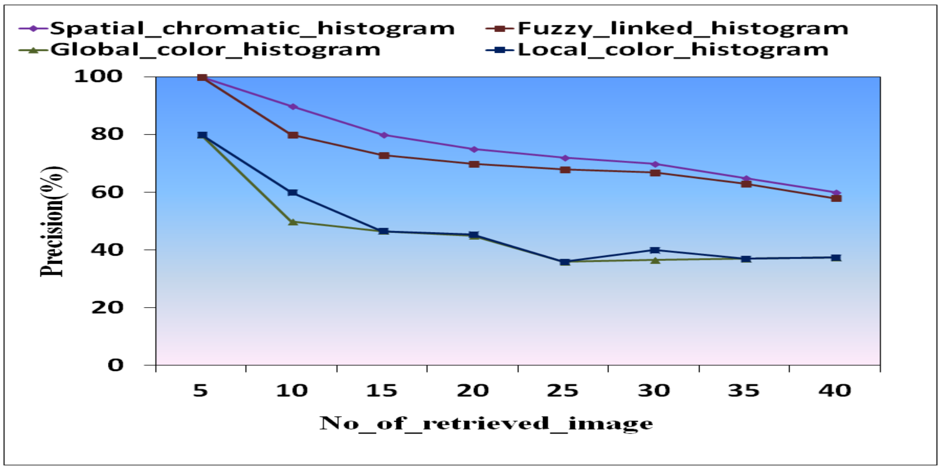

Figure 6. *Comparison results of the four methods. Precision(%) versus no of retrieved images*

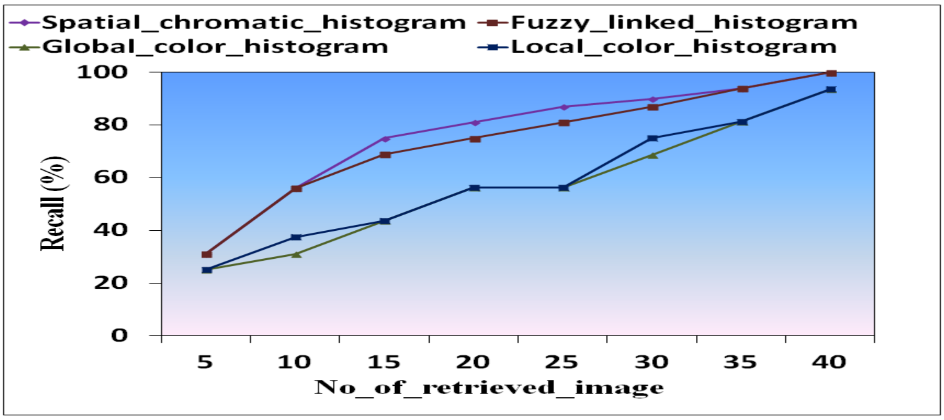

Figure7. *Comparison results of the four methods. Recall (%) versus no of retrieved images*

the performance of the SCH method is better than all the other methods under consideration till about 35 images retrieved after which the performance of FLH is slightly better. Generally, precision and recall are used together in graphs in order to point out the change of the precision with respect to recall by means of F-measure [13] against the number of retrieved images. Fig. 8 shows the drastic improvement in the F-measure values in terms of effective and accurate image retrieval for SCH method compared to GCH, LCH and FLH methods.

In addition to the precision-recall, another aspect of retrieval performance is the accuracy [14] which is the average precision-recall values that shown in Fig. 9, where the average precision-recall-accuracy for the SCH method produces highest values stating the clear advantages in retrieval accuracy of the SCH method over the rest.

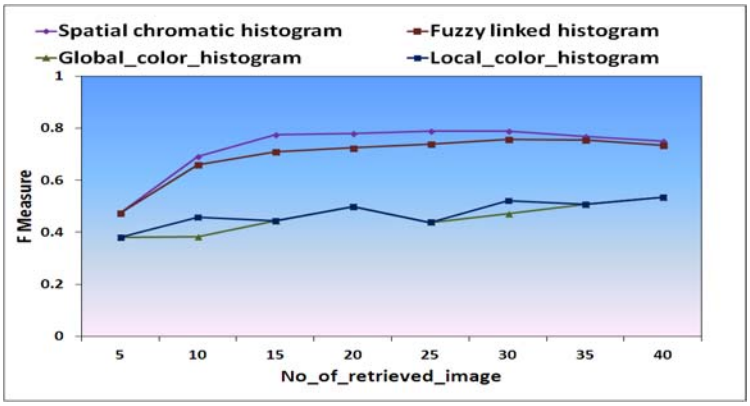

Figure 8. *Comparison results with respect to F-Measure*

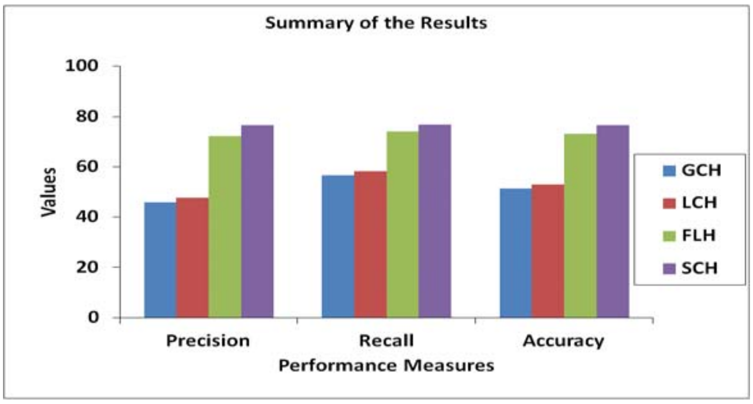

Figure 9. *Consolidated performance measure comparison*

Table 1. *Retrieval Accuracy*

	GCH METHOD	LCH METHOD	FLH METHOD	SCH METHOD
TIME (S)	83.78	98.02	364.88	512.44

Table I shows the retrieval efficiency of GCH and LCH methods with respect to times(s) they take in order to produce the desired images; both the FLH and SCH methods taking more time to execute but produce much more accurate results which proves the relevancy of both the methods. Moreover, for FLH method, this drawback with respect to performance time becomes an advantage, when the color histograms are produced beforehand to check the similarity between images using only 10 bins.

On Table II, one can see a synopsis of the comparisons of the four methods' performances for the first forty retrieved images and notice clearly that precision drops as recall increases for SCH. An image retrieval system is said to be effective if the precision values are higher at the same recall ones, which is the case in the SCH method for the top10, top 35 and top 40 retrieved images shown in Table II.

5. CONCLUSIONS

In this paper, conventional color histogram based image retrieval using GCH and LCH method is investigated. As the images with very different appearances can have similar histograms; color histogram is a coarse characterization of an image. So an efficient FLH technique of projecting the 3D histogram onto one single-dimension histogram has been presented on the L*a*b* color space and compared to the GCH, LCH methods proves to be much more accurate and robust in terms of performance evaluation with respect to average precision-recall-accuracy-F-measure values and plots. Finally a novel, effective and sophisticated approach to content based image retrieval using SCH method allows a software system to automatically perform image indexing, based on image content. As is evident from the experimental results, the SCH method provides a fairly good tool for retrieving similar images from the database. The outputs (average precision. average recall, F-measure, accuracy) of the technique have proved that it gives better performance than some well established methods of CBIR like GCH, LCH and FLH.

Table II. *Comparison for Average Precision-Recall*

Image	**GCH Method**		**LCH Method**		**FLH Method**		**SCH Method**	
Retrieval	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**	**Recall**
Top 5	0. 80	0. 25	0. 80	0. 25	1	0. 31	1	0. 31
Top 10	0. 50	0. 31	0. 60	0. 37	0. 80	0. 56	0. 90	0. 56
Top 15	0. 46	0. 43	0. 46	0. 43	0. 73	0. 69	0. 80	0. 75
Top 20	0. 45	0. 56	0. 45	0. 56	0. 70	0. 75	0. 75	0. 81
Top 25	0. 36	0. 56	0. 36	0. 56	0. 68	0. 81	0. 72	0. 87
Top 30	0. 36	0. 68	0. 40	0. 75	0. 67	0. 87	0. 70	0. 90
Top 35	0. 37	0. 81	0. 37	0. 81	0. 63	0. 94	0. 65	0. 94
Top 40	0. 375	0. 93	0. 375	0. 93	0. 58	1	0. 60	1
Average	**0 .459**	**0. 566**	**0 .476**	**0 .582**	**0 .723**	**0 .741**	**0 .765**	**0 .767**

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