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Web Based Image Retrieval System Using Color, Texture and Shape Analysis: Comparative Analysis

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Abstract

The internet is one of the best media to disseminate scientific and technological research results [1, 2, 6]. It deals with the implementation of a web-based extensible architecture that is easily integral with applications written in different languages and linkable with different data sources. This paper work deals with developing architecture which is expandable and modular; its client–server functionalities permit easily building web applications that can be run using any Internet browser without compatibility problems regarding platform, program and operating system installed. This paper presents the implementation of Content Based Image Retrieval using different methods of color, texture and shape analysis. The primary objective is to compare the different methods of image analysis.

Keywords

Web based retrieval system, image retrieval, fuzzy connectedness, image segmentation, shape analysis.

1. Introduction

For extracting similar images from image database Content-based image retrieval (CBIR) [1, 2] technique is used. Storing large amounts of high quality images has been made possible because of the advances in digital photography, storage capacity and networks speed. Medical, virtual museums, military and security purposes, and personal photo albums are some of the applications where digital images are used. Organizing and searching large numbers of images in databases is found difficult [17]. An efficient way for image retrieval is desired to minimize such difficulties. In order to respond to this need, researchers have tried extending Information Retrieval (IR) techniques used in text retrieval to the area of image retrieval [23]. A set of keywords are assigned to each image to apply this approach. There are significant limitations to apply approach. As each object needs to be manually annotated with keywords and/or textual descriptions, making it impractical for large data sets therefore the approach is not scalable. The annotations may not be consistent or complete which negatively effects retrieval performance due to the subjectivity of the human annotator. It may be infeasible to describe visual content (e.g., shape of an object) simply using words.

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To overcome the above problems, researchers applied advances in image processing, database management, and information retrieval to the area of image retrieval and introduced Content-Based Image Retrieval (CBIR). In CBIR systems, image processing techniques are used to extract visual features such as color, texture and shape from images. Instead of representing images by pure textual annotations, images are represented as a vector of extracted visual features. An object model is defined to represent images based on visual features. A user formulates a query by providing examples of images similar to the ones s/he wishes to retrieve. The system uses a query model to convert the image into an internal representation of query, based on features extracted from input images. A retrieval model performs image retrieval by computing similarities between images in object and the query representations, and the results are ranked based on the computed similarity values.

Due to the fact that web-based image search engines [3] are blind to the actual content of images, the result of querying for a specific object is often cluttered with irrelevant data. Most web image search engines provide a text input interface (like HTML tag <INPUT>) that users can type keywords as a query. The query is then processed and matched against the indexed web images, and a list of candidate images are ranked in the order of relevance before results are returned to users. However, textual representation of an image is often ambiguous and non-informative of the actual image content. All these factors confound the web image retrieval system. The image contents should be taken into account for getting exact search results.

2. Literature Review

The integration of software services and web-based platforms are found in most of the information system evolution [5]. This trend has affected the development of groups and research centers so that new client–server applications are under development. Zhong and Chang [4] developed a Java applet that holds the last version of their segmentation algorithm for color images. The JDK 1.1.x technology is used by them. This technology is needed for the user, in addition to an Internet browser [5]. User can upload an image in various formats (Graphics Interface Format, JPEG, Portable Pixmap, and Portable Graymap) and sizes (the images must be smaller than 480 × 400) [5]. After this, the uploaded image is down sampled and the user should set three parameters that are used to adjust the segmentation, namely color threshold, luminance weight and minimum region size. The user must choose the wanted object in a preliminary result view; finally, he gets the object of interest.

R. Henkel [4] developed a web-based solution where a number of image-processing algorithms are deployed. In particular, the available algorithms range over different fields of applications, such as stereovision, segmentation, characteristic lines, texture, color separation and histogram manipulations. In addition to well-known algorithms, the newest Henkel's algorithms are also available, i.e. scale-space segmentation and coherence detection [5] in stereovision.

The University of Amsterdam provides some collection of Internet-based image-processing systems such as PicToVision, PicToSeek and PicToSegment [5]. PicToVision is a web-based tool that furnishes a set of state-of-the-art image processing algorithms. The user can upload his image on the system to execute one of the available algorithms. PicToSegment is a segmentation tool based on the RGB space and contour extraction algorithm. Finally, PicToSeek is a CBIR system. Other interesting Internet applications (Query by Image Content (QBIC) [6], WebSeek [5] and Netra [7]) are able to manage image and video-sequence archives at the same time. To allow accurate characterization of relevant information a content representation based on color, shape, texture and motion descriptors is exploited [5]. QBIC is the most complete CBIR system, where indexing, filtering and similarity techniques cooperate to quickly retrieve multimedia. The user can focus first on the query by providing keywords and subsequently selecting images as examples, thus allowing us to choose image portions and/or image attributes. An Internet application is offered by QBIC [5] to query the multimedia library of Hermitage Museum, St. Petersburg, Russia; by selecting a thumbnail, which is available on the graphic interface, it is possible to retrieve similar pictures on the basis of color or layout.

The Netra image-management system, which was developed by the Image Processing and Vision Research Laboratory, University of California, performs content analysis (color, shape, texture and spatial coordinates) only locally. The extracted features are indexes that in addition to enabling fast retrieval provide a very flexible query mechanism. This mechanism, which is based on multiple images, allows constructing the query by selecting the shape of an object and the color of another one. Netra, which was developed in Java, can guarantee platform independence and high web accessibility.

Previous research works has carried out a segmentation application called Isocontour [3]. Isocontour segmentation is based on the fuzzy connectivity theory and it requires only two simple user actions to provide accurate segmentation. Due to the generality of the inner algorithms, Isocontour is able to deal with various kinds of images. The already existing Isocontour stand-alone implementation was completely developed in C++ code language and with the support of the Microsoft Foundation Class.

Kingfisher [3] is one of the content based image retrieval (CBIR) desktop applications used to manage image databases. Kingfisher by applying image-processing techniques such as segmentation and feature extraction, allows the user to scan image databases by means of an image query through a search for similar data.

3. Proposed Methodologies for Web Based Texture, Shape and Color Analysis

Texture [10, 15] is the natural property of all surfaces, which describes visual patterns each having properties of homogeneity. A texture is characterized by intensity properties and spatial relationships. This is a feature that describes the distinctive physical composition of a surface. Six visual features are used in CBIR and they are: Coarseness, Contrast, Directionality, Regularity, Roughness, Linelikeness.

Texture is one of the most important features of an image in the field of CBIR [3, 4]. The second order statistics is essential over gray level information of image it is characterized by the spatial distribution of gray levels in a neighbourhood [3, 4]. A two-dimensional dependence texture analysis is taken into consideration to capture the spatial dependence of gray- level values, which contribute to the perception of texture. A two-dimensional matrix is obtained by decoding the image file e.g. jpeg, bmp, dcm.

Retrieve images on the basis of texture similarity may not seem very useful [2]. The areas of images can be distinguish by using the ability to match on texture similarity. A variety of techniques has been used for measuring texture similarity; the best-established rely on comparing values of what are known as second-order statistics calculated from query and stored images. Essentially, these calculate the relative brightness of selected pairs of pixels from each image. Measures of image texture can be calculated. Texture can be analyzed by using any of the three ways: Statistical Approaches, Structural Approaches, Spectral Approaches.

Statistical approaches [10] characterize textures using the statistical properties of the gray levels of the pixels of the image. Typically, these properties are computed using the gray level co-occurrence matrix (GLCM), or the discrete wavelet transformation (DWT) [10] of the image.

Gray level co-occurrence matrix (GLCM) [10, 15], one of the most known texture analysis methods, estimates image properties related to second-order statistics. Each entry (i, j) in GLCM corresponds to the number of occurrences of the pair of gray levels i and j which are a distance d apart in original image.
In order to estimate the similarity between different gray level co-occurrence matrices, there are 14 statistical features [10] that can be extracted from them. To reduce the computational complexity, only some of these features are selected. The description of 5 most relevant features that are widely used is given in Table 1.

Table 1: Features extracted from gray level co-occurrence matrix

Maximum Element	$\max_{ij} P_d(i,j)$ (1)
Energy	$\sum_i \sum_j P_d^2(i,j)$ (2)
Entropy	$-\sum_i \sum_j P_d(i,j) \log P_d(i,j)$ (3)
Contrast	$\sum_i \sum_j (i-j)^2 P_d(i,j)$ (4)
Inverse Difference	$\sum_i \sum_j \frac{P_d(i,j)}{\lvert i-j \rvert^2}, i \neq j$ (5)

Energy [10], also called Angular Second Moment and Uniformity (Equation 2), is a measure of textural uniformity of an image. Energy reaches its highest value when gray level distribution has either a constant or a periodic form. A homogenous image contains very few dominant gray tone transitions, and therefore the P matrix for this image will have fewer entries of larger magnitude resulting in large value for energy feature. In contrast, if the P matrix contains a large number of small entries, the energy feature will have smaller value.

Entropy (Equation 3) can be used to measures the disorder of an image and it achieves its largest value when all elements in P matrix are equal. Many GLCM elements have very small values when the image is not texturally uniform; it means that the entropy is very large. Therefore, entropy is inversely proportional to GLCM energy.

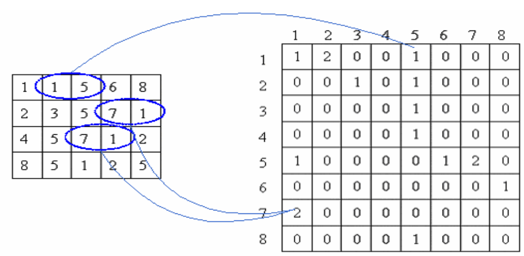


Figure 1: GLCM Calculation

Contrast (Equation 4) [10] is a difference moment of the P and it measures the amount of local variations in an image. The image homogeneity is measured by using the inverse difference moment (IDM) (Equation 5). When most of the occurrences in GLCM are concentrated near the main diagonal this parameter achieves largest value. Inverse Difference Moment and Contrast are inversely proportional. The figure 1 shows how to calculate the GLCM. The 4 x 5 data (or image intensity values) and the 8 x 8 gray level co-occurrence matrixes computed from data matrix are used.

Figure 2 shows a 2D image composed of two regions corresponding to two objects O_1 and O_2. O_2 is the background object. As object of interest is O_1, O_2 may consist of multiple objects which are not of interest in distinguishing.. Determine an affinity relation that assigns to every pair of nearby pixels in the image a value based on the nearness of pixels in space and in intensity (or in features derived from intensities). Affinity represents local "hanging togetherness" of pixels. To every "path" connecting every pair of pixels, such as the solid curve p_{co1} connecting c and o_1 in figure 4.1 a "strength of connectedness" is assigned which is simply the smallest pair wise affinity of pixels along the path. The strength of the strongest of all paths between o_1 and c is the strength of connectedness between any two pixels such as o_1 and c. Let, p_{co1} represents the strongest path between o_1 and c. If the affinity is designed properly, then p_{co1} is likely to have a higher strength than the strength of any path such as the dotted curve between c and o_1 that goes outside O_1.

In the original fuzzy connected [8] method, an object such as O_1 is segmented by setting a threshold on the strength of connectedness. This threshold defines a pool of pixels such that within this pool the strength of connectedness between any two pixels is not less than the threshold but between any two pixels, one in the pool and the other not in it, the strength is less than the threshold. The basic idea in relative fuzzy connectedness [3, 8] is to first select reference pixels o_1 and o_2, one in each object, and then to determine to which object any given pixel belongs based on its relative strength of connectedness with the reference pixels. If pixel c's strength of connectedness with respect to o_1 is likely to be greater than that with o_2 pixel c would belong to O_1. This relative strength of connectedness offers a natural mechanism for partitioning pixels into regions based on how the pixels hang together among themselves relative to others. A pixel a in the boundary between O_1 and O_2 will be grabbed by that object with whom a hangs together most strongly. This mechanism eliminates the need for a threshold required in the original method. This mechanism also offers potentially more powerful segmentation strategies as it allows more direct utilization of the information about all objects in the image in determining the segmentation of a given object and considering from a point of view of thresholding the strength of connectedness, it allows adaptively changing the threshold depending on the strength of connectedness of objects that surround the object of interest.

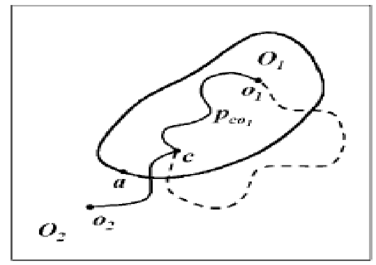


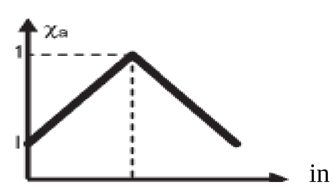
Figure 2: Illustration of the main ideas behind relative fuzzy connectedness The membership of any pixel, such as c, in an object is determined based on the strength of connectedness of c with respect to the reference pixels o_1 and o_2 specified in objects O_1 and O_2. c belongs to that object with respect to whose reference pixel it has the highest strength of connectedness [2].

The fuzzy topology theory states that, a field $H = \{\eta(p)\}$ can be derived from any digital image by simply normalizing the pixel-intensity value [2]. For each pixel p a fuzzy-connectedness degree can be computed. This measure refers to the absolute maximum membership value.

However, with the aim of image processing, one can extract a fuzzy-connectedness measure with respect to any image pixel a, given the appropriate transform that is applied to each pixel p. For the sake of clarity, such a transformation, which gives rise to the modified field X^a (Equation 6), is given as

$$x^{a}(p) = 1 - |\eta(p) - \eta(a)| \quad \textbf{(6)}$$

Pixel a – seed point assumes the maximum value in the modified field, as shown in figure 3.



Seed gray level

Figure 3: Modified X^a value as a function of the original value (in)

If we define P (q, p) as connected path of points from a pixel q to a pixel p and if the seed point represents and belongs to a structure of interest, it is possible to measure the connectivity (Equation 7) associated with the structure by applying, for every *p*, the following

$$C_{X^a} = c_{X^a}(p) = conn(X^a, a, p) = \max_{P(a,p)}\left[\min_{z \epsilon P(a,p)} X^a(z)\right] \quad (7)$$

The max is applied to all paths *P* (*a*, *p*) from *a* to *p* and thus refers to the optimum path connecting *p* to the seed point, while the min is applied to all points *z* along the optimum path *P* (*a*, *p*).

Above equation is named "χ-connectivity" or "intensity connectedness," [2, 3] and its application results in an image where every pixel value represents the degree of membership to the searched object. The new image produced is called the "connectivity map," where each image element has a gray level that is dependent on the degree of connectivity with respect to seed point *a*.

Isocontour segmentation is an interactive application that exploits the power and generality of the fuzzy intensity connectedness theory. It is able to deal with various kinds of images, and it shows better performance with objects affected by low contrast.

Color, which represents physical quantities of objects, is an important attribute for image matching and retrieval. Many publications focus on color indexing techniques based on global color distributions. However, these global distributions have limited discriminating ability because they are unable to capture local color information. Color correlogram and color coherence [9] vector can combine the spatial correlation of color regions as well as the global distribution of local spatial correlation of colors. These techniques perform better than traditional color histograms when used for content-based image retrieval. However, they require very expensive computation.

Color moments [9, 15] have been successfully used in content based image retrieval systems, especially for retrieval of images only containing the objects of user's interest. Because most information can be captured by low-order moments, i.e. the first moment (mean equation 8), the second and the third central moments (variance equation 9 and skewness equation 10), color moments can be effectively used as color features. Although simple, these features are inexpensive to calculate.

If the value of the *i-th* color channel at the *j-th* image pixel is p_{ij}, then the color moments are defined as:

$$\mu_i = \frac{1}{n}\sum_{j=1}^{n} p_{ij} \quad (8)$$

$$\sigma_i = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(p_{ij} - \mu_i\right)^2} \quad (9)$$

$$s_i = \sqrt[3]{\frac{1}{n}\sum_{j=1}^{n}\left(p_{ij} - \mu_i\right)^3} \quad (10)$$

where *n* is the number of pixels in an image. These moments may be calculated in different color spaces. Mean can be understood as the average color value in the image. The standard deviation is the square root of the variance of the distribution. Skewness can be understood as a measure the degree of asymmetry in the distribution. For each image, a 9-dimensional color feature vector (Equation 11) is obtained. These color feature vectors are defined as:

$$CV = [\mu_{ci} ; \sigma_{ci} ; s_{ci}] \quad \mathbf{(11)}$$

where *i* = 1, 2, 3 is the three channels of a color space. A function of the similarity (Equation 12) between two image distributions is defined as the sum of the weighted differences between the moments of the two distributions. Formally this is

$$d_{mom}(H, I) = \sum_{i=1}^{r} w_{i1}\left|\mu_i^1 - \mu_i^2\right| + w_{i2}\left|\sigma_i^1 - \sigma_i^2\right| + w_{i3}\left|s_i^1 - s_i^2\right| \quad (12)$$

Where:

(H, I) : are the two image distributions being compared

i : is the current channel index

r : is the number of channels (e.g. 3)

μ_i^1, μ_i^2 : are the first moments (mean) of the two image distributions

σ_i^1, σ_i^2 : are the second moments (variance or standard deviation) of the two image Distributions

s_i^1, s_i^2 : are the third moments (skewness) of the two image distributions

w_i : are the weights for each moment

Pairs of images can be ranked based on their d_{mom} values. Those with greater values are ranked lower and considered less similar than those with a higher rank and lower d_{mom} values.

It should be noted that the d_{mom} value is a similarity function and not a metric. It is very possible that the comparison of two different pairs of distributions can result in the same d_{mom} value. In practice this leads to false positives being retrieved along with truly similar images. For an image retrieval system, this drawback is considered negligible. $\boldsymbol{w_i}$ values are user specified weights. Depending on the application, or the condition of the images, these values can be tuned so that different preferences are given to different features of an image.

4. Implementation Details

For the implementation of the application Java [2] is selected as platform so that application can get the feature of platform independence. The various java tool kits that are used until now: Java Development Kit 7, Java Advance Imaging 1.1.4, Java Activation Framework for Java Beans, Oracle 11g.

Some of the packages used in building the application are org, com and contrib. Initially user selects the URL from the server side where all images are stored. After selecting URL all the images present on that location are indexed using feature extraction methods (Color Moments, Co-occurrence, LCH, GCH and Geometric Moments). Then the user selects a query image which s/he wants to search from an image database and also specifies the image class in which s/he wants to search that image. The images are classified into different image classes as: Bus, Beaches, Building, Barcelona, Dinosaur, Elephant, Flower, Food, Horses and Mountain.

After specifying particular class user selects one of the methods out of Color Moments, Co-occurrence, LCH, GCH and Geometric Moments [2] for retrieval. Then the features are extracted from the query image according to the selected retrieval method. These features are then matched with the features of the indexed images in the database and then the best matched images are provided as an output of query.
All the features extracted from images are stored in the table named FEATURE_TABLE. This table contains following four fields:
ID – The unique identifier for images.
Feature_Name – This stores the name of the extracted feature. It has one of the following values: Color_Moments, Cooccurrence, Local_Color_Histogram, Global_Color_Histogram, Geometric_Moment
Image – The URL where the image is stored.
Vector – This field contains the values of the extracted features. If the feature name is Color_Moments then vector will contain nine values (i.e. three for each channel) of mean, standard deviation and skewness.

For retrieving the features the query is fired in the following format on the database:

"SELECT * FROM {4} WHERE {1}=?"

To add the features into the FEATURE_TABLE the following query is fired:

“INSERT INTO {4} ({1},{2},{3}) VALUES (?,?,?)”

Different packages are created to make programming and application development more modular. The packages action, db, image, query, ui and util are developed. These all packages are used in the main application program file “CBIRIS.java”. Using this prior information, we go for the design and implementation of the Content Based Image Retrieval and Image Segmentation (CBIRIS).

5. Experimental Results and Discussion

An extensive experimental evaluation is carried out during the proposed research work; these results are described in this section. The algorithms were initially executed on a database of 100 images. After successful execution the algorithms were executed on specific database, in which images are classified into different classes, of 1000, 6000 and 10000 images. All the experiments were performed on a Personal Computer running at 3.00 GHz with 4 GB of memory and 500 GB hard disk. All the algorithms are implemented in Java language.

After running CBIRIS user selects the image database directory from the server where all the images are stored. After that CBIRIS starts extracting the features and indexing of the image. These features are then stored in the myDB database. CBIR contains Query Form to provide queries, Painter provide an user interface to provide the query as sketch, Viewer to view the results, Ranking shows the rank of an image and last is Status Bar where all the activities taken by user and the processing going in application is shown.

Initially database of size 100 images is used. After that I used the database of larger size containing 1000, 6000 and 10000 images. This database is downloaded from the ftp ftp://db.stanford.edu/pub/wangz/ [18]. The images in this database are classified into different classes namely Bus, Beaches, Building, Barcelona, Dinosaur, Elephant, Flower, Food, Horses and Mountain. So along with the query image user can provide the class in which s/he wants search that image.

The performance is evaluated based on retrieval time, number of images retrieved and precision. The implemented methods of CBIRIS are compared on the basis of these parameters.

Precision (Equation 13) [1] is calculated as the ratio of number of relevant images retrieved to the total number of images retrieved.

$$\text{Precision} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of images retrieved}} \quad \textbf{(13)}$$

Precision values are calculated for implemented methods and compared with Histogram Based [13, 14] and SIMPLICITY [15] Method.

Following figure 4 shows the total images retrieved from the database and figure 5 shows time required to retrieve images from the database using different methods. These results are obtained by taking the average of the results of firing different input query image on the database. For taking the average ten sets of the results are taken. These ten sets are obtained by firing the different type of input query image on the same type of image database class.

From the following results it can be observed that number of images retrieved and the time required for the retrieval goes on increasing as number of images in the database are increased. Geometric moment method is more time consuming because it includes very complex operations such as image segmentation and calculating the second order geometric moment. Figure 6 shows the total number of images retrieved from the database containing different classes of images. Each class contains 100 images. Total thousand images are there in the database. Figure 7 shows the comparison of implemented methods on the basis of precision values.

From the graphs it can be observed that co-occurrence method gives more precise results for all image classes as compared to the other methods. Local color histogram gives the precise results in case of some image classes such as beaches, dinosaur, elephant and horses.

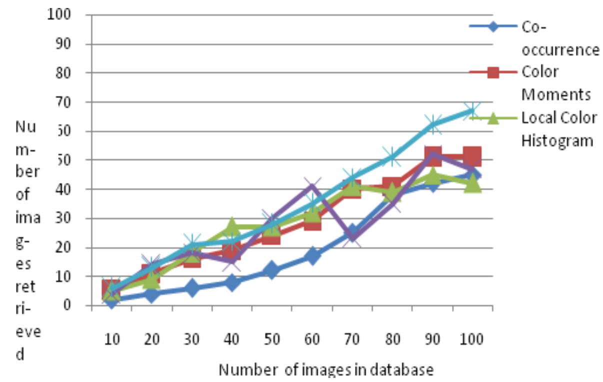


Figure 4: Total number of images retrieved from the database

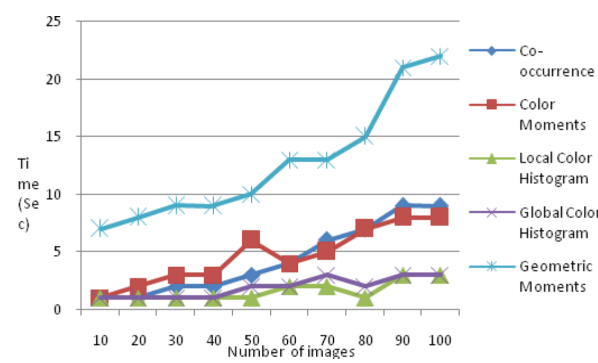


Figure 5: Time require for retrieving images from the database

Color moments include calculation of three different moments namely mean, variance and skewness. Color pixel values are used for calculating these moments so it require more time as compared to co-occurrence method. In co-occurrence five statistical features are calculated. Gray level co-occurrence matrix is used for calculating these features. As computation is not on the individual pixel value but on the values in the matrix it takes less time compare to color moment, local color histogram and global color histogram. Local color histogram and global color histogram method takes nearly same time for retrieval. Shape analysis includes vast computation like image segmentation and geometric moment calculation, therefore the time complexity of geometric moment method is more compared to all other implemented methods. This can be observed from the above given results.

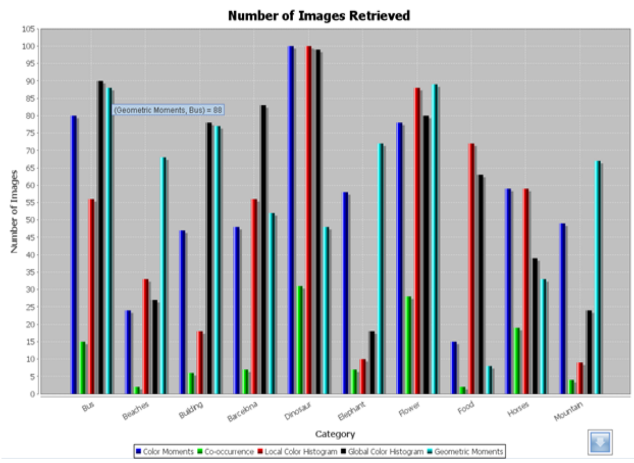


Figure 6: Total number of images retrieved from the database

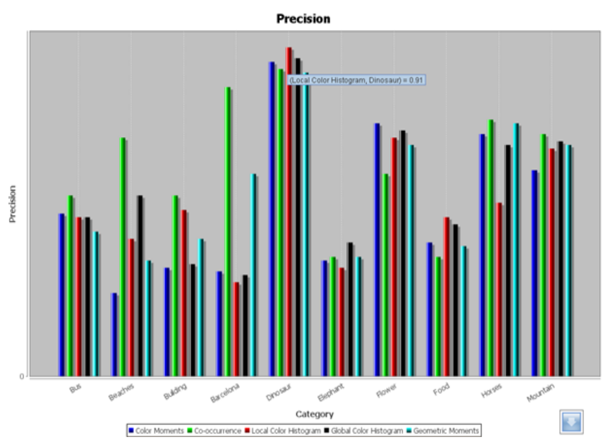


Figure 7: Precision value comparison

6. Conclusion and Future Work

In this paper content based image retrieval system is presented which combines shape, color and texture features [2] for content based image retrieval. Color moments, local color histogram and global color histogram methods [2] are used for color feature extraction while co-occurrence method is used for extracting texture features from image. The image segmentation and geometric moment [2] are used for shape analysis. The co-occurrence method is found to be more precise for all image classes as compared to other methods. The CBIR system architecture is independent of the underlying system architecture, because java is used for its development.

Currently implemented methods are tested on the image database containing 1000, 6000 and 10000 images. For indexing the images it takes more time, if the database is larger. For searching time goes on increasing in proportional with the number of images. The time required for indexing and searching depends on the underlying hardware configuration. Not only does the effectiveness but also the efficiency (measured in terms of retrieving time) needs to be taken into account during the design of CBIR systems. Usually, fast searching strategies rely on the use of effective indexing schemes. One of the commonly approaches used for indexing is applying dimension reduction techniques, such as Principal Component Analysis (PCA), and then using a traditional multidimensional indexing structure. Among all the multi-dimensional indexing structures quad trees, grid files and binary trees can be useful for improving the indexing and retrieval of images.

Complete architecture can be extended for automatically annotating images in database. Visual assessment of results becomes cumbersome for large image databases. The primary objective was to compare the different methods of image analysis and there still remains a need in the future to derive an objective performance measure that would yield absolute results. Image ranking is provided for analyzing the results. This feature provides the rank to the output image according to the similarities between input query image and stored images. This ranking scheme can be further extended to the relevance feedback method.

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