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A Novel Mathematical Model for Image Retrieval

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Abstract –**The paper addresses the problem of access to databases based on images in indexes calculated from the content of the image itself, known as Content Based Image Retrieval (CBIR). Perform a review of the state of the art in this topic. With the help of colour, texture and shape features different set of pattern stored in database, and according to query image, the similar image categories of images are extracted out. Colour Similarity Metric is measured using Chi-Square, while Texture Similarity Metric and Shape Similarity Metric is measured using Euclidian Distance Metric. Image recovered using the colour, shape and texture measure and is done with Euclidian distance. The accuracy achieved nearly 90% of accuracy with Corel dataset.**

Keywords – **CBIR, Corel, Euclidian distance, texture, shape.**

I. Introduction

Due to the excessive increase in the collection of digital images, efficient searches of images, navigation and retrieval tools by users of different domains are required [1].

This work will focus on content-based Image Retrieval (CBIR) retrieval, that is, the search will analyze the actual contents of the image. The term 'content' refers to colours, shapes, textures or any information derived from the image.

CBIR systems are based on visual characteristics of images such as colour, brightness, textures and spatial distribution (describing image content) to recognize similar patterns in different images [2].

A. Fundamentals

The CBIR systems perform the queries using a reference image, which contains the visual characteristics that we wish to look for. With this image, the system performs the necessary processing to extract the vector of characteristics which is no more than a set of descriptors which form the 'index of the image. This vector is compared to the characteristic vectors of each of the images that make up the database. The comparison is made by a metric or similarity function that allows retrieving a list of images that are better approximated to the query made [9].

Figure 1 illustrates the diagram of the query process, which represents the basic structure of a CBIR system.

The main components that make up a CBIR system are:

User interface: must allow queries and visualize the results of the queries. Queries can be made using reference images given to the system. This allows the user interaction to refine the search process from the values feedback to obtain the desired result.

Image analysis: it is responsible for performing the image processing, its analysis and extraction of the characteristics by means of vision techniques. This calculates and quantifies the information regarding the colour, textures or shapes present in the image.

Comparison and similarity functions: this is a fundamental aspect and is related to the definition of the feature vectors. Similarity metrics or functions allow comparing the vector of characteristics of the reference image with the characteristic vectors of the images stored in the system database and establish which ones are closer or similar to the given query.

II. Related Research

Various approaches have been defined for CBIR system, D-EM (Discriminant-EM) Algorithm the D-EM algorithm [3, 4] is used as a way of exploiting an unlabelled data in Content Based Image Retrieval system. The Expectation-Maximization (EM) [5, 6] approach can be applied to this learning task, since the labels of unlabelled data can be treated as missing values [7]. In this learning method [8] is processing the unlabelled image with the probability manner. The high probability issued to identify the unlabelled images from the whole image database.

There are various method has been proposed to extract the features of images from very large database. In this paper various algorithms are discussed to retrieve the image:

a) Jisha. K. P, Thusnavis Bella Mary. I, Dr. A. Vasuki [8]: proposed the semantic based image

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retrieval system using Gray Level Co-occurrence Matrix (GLCM) for texture attribute extraction. On the basis of texture features, semantic explanation is given to the extracted textures. The images are regained according to user contentment and thereby lessen the semantic gap between low level features and high level features.

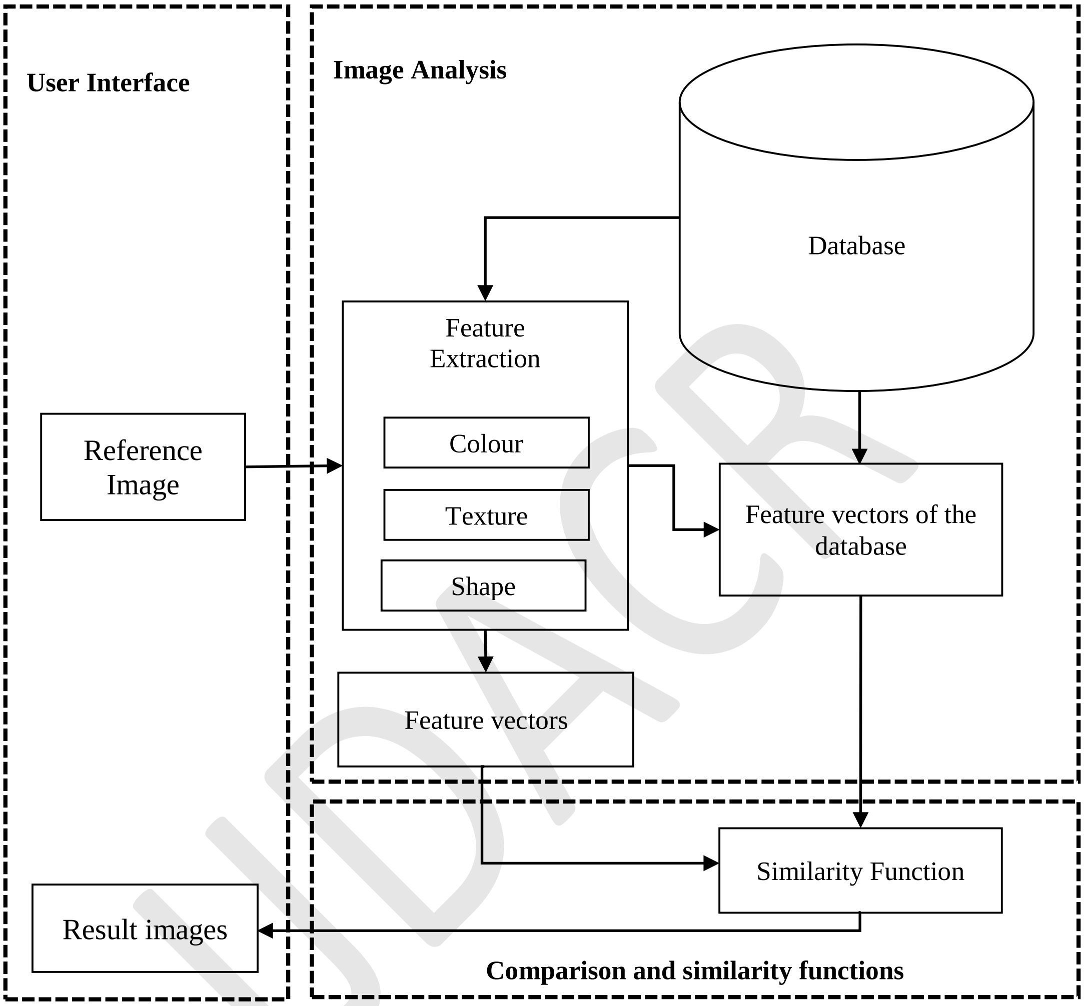

Figure 1: Schematic of a query in a CBIR System

b) Swati Agarwal, A. K. Verma, Preetvanti Singh [9]:
The proposed algorithm is enlightened for image retrieval based on shape and texture features not only on the basis of color information. Firstly the input image is decomposed into wavelet coefficients these wavelet coefficients give generally horizontal, vertical and diagonal features in the image. Subsequent to wavelet transform (WT) and Edge Histogram Descriptor (EHD) is then used on preferred wavelet coefficients to gather the information of foremost edge orientations.
c) Xiang-Yang Wang, Hong-Ying Yang, Dong-Ming Li [10]: proposed a new content-based image retrieval technique using colour and texture information, which achieves higher retrieval effectiveness. Initially, the image is altered from RGB space to adversary chromaticity space and the individuality of the colour contents of an image is incarcerated by using Zernike chromaticity distribution moments from the chromaticity space. In next, the texture attributes are extracted using a rotation-invariant and scale-invariant image descriptor in contour-let domain. Lastly, the amalgamation of the colour and texture information provides a vigorous feature set for colour image retrieval.
d) S. Manoharan, S. Sathappan [12]: They Implemented the high level filtering wherever they are using the Anisotropic Morphological Filters, hierarchical Kaman filter and particle filter proceeding with feature extraction method based on

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color and gray level feature and subsequent to this the results were normalized.

e) Heng Chen and Zhicheng Zhao [11]: authors described relevance feedback method for image retrieval. Relevance feedback (RF) is an efficient method for content-based image retrieval (CBIR), and it is also a realistic step to shorten the semantic gap between low-level visual feature and high-level perception. SVM-based RF algorithm is proposed to advances the performance of image retrieval. In classifier training, a model expanding method is adopted to stability the proportion of positive samples and negative samples. After that a fusion method for multiple classifiers based on adaptive weighting is proposed to vote the final query results. SVM-based RF scheme is proposed to improve performance of image retrieval. In classifier training, a sample intensifying scheme is accepted to balance the proportion of positive and negative samples and then fusion scheme for multiple classifiers based on adaptive weighting is anticipated to vote the final query results.

f) Monika Daga, Kamlesh Lakhwani [13]: Proposed a new CBIR classification was being developed using the negative selection algorithm (NSA) of ais. Matrix laboratory functionalities are being used to extend a fresh CBIR system which has reduced complexity and an effectiveness of retrieval is increasing in percentage depending upon the image type.

g) S. Nandagopalan, Dr. B. S. Adiga, and N. Deepak [15]: They proposed a novel technique for generalized image retrieval based on semantic contents is offered. The grouping of three feature extraction methods specifically color, texture, and edge histogram descriptor. There is a prerequisite to include new features in future for better retrieval efficiency. Any combination of these techniques, which is more suitable for the application, can be used for retrieval. This is presented through User Interface (UI) in the form of relevance feedback. The image properties analyzed in this work are by using computer vision and image processing algorithms. Anticipated for colour the histogram of images are calculated, for texture co-occurrence matrix based entropy, energy etc. are calculated and for edge density it is Edge Histogram Descriptor (EHD) that is found. To retrieval of images, a new idea is developed based on greedy approach to lessen the computational complexity.

h) G. Pass [16]: They proposed a novel method to describe spatial features in a more precise way. Moreover, this model is invariant to scaling, rotation and shifting. In the proposed method segmentations are objects of the images and all images are segmented into several pieces and ROI (Region of Interest) technique is applied to extract the ROI region to enhance the user interaction.

i) Yamamoto [17] proposed a content-based image retrieval system which takes account of the spatial information of colours by using multiple histograms. The proposed system roughly captures spatial information of colours by dividing an image into two rectangular sub-images recursively.

III. Proposed Work

Our approach to image retrieval is divided into two parts. First, training phase and second testing phase. In training phase, each image of the training set is labelled and low level features like colour, texture and shape are extracted. Then these features are stored in variables. The training phase involves following steps:

1. Read database from image folder
2. Define labels of images
3. Extract colour feature, texture feature and shape feature from database
4. Save features in variable according to data read.

In the testing phase given shape, texture and color features of query image is extracted. Then Chi-square between color histogram of database and query image is Calculate and afterward Euclidian distance between database and query images for texture and shape features is calculated. The sum of the three values indicates, less the value of the sum more the two images are similar. The sum is sorted for the minimum and according to indexed list, images are extracted from database. The testing phase involves following steps:

1. Read data from image folder
2. Extract shape, texture and colour features of query image
3. Calculate Chi-square between colour histogram of database and query images.
4. Calculate Euclidian distance between database and query images for texture and shape features.
5. Sort for minimum Euclidian distance and consider that as final index.
6. According to index achieved, extract images from database.

IV. System Architecture

Now we describe the methods used in the process of extracting primitive characteristics of the image, which is the key aspect in CBIR systems.

A. Color

This feature is one of the most representative aspects of the image. Although the majority of the images

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are in the RGB colour space, this is not the most suitable for obtaining their chromatic characterization, since it is the colour space more alien to the perception of the human being.

Colour Histograms: One way to extract this colour feature is by using histograms. Colour histograms are a form that represents the distribution of colour in images, where each bin of the histogram represents a colour in the colour space [20].

Colour Space: The colour space determines how we represent the different colours. There is a wide variety of colour spaces, in this work we used the HSV (Hue-Saturation-Value) space that defines colours based on hue, saturation and value, this choice was made on the basis of the results in [21] where HSV is better than RGB in the context of changes of illumination, and in this space the colour differences are closer to the differences found in the perception of humans.

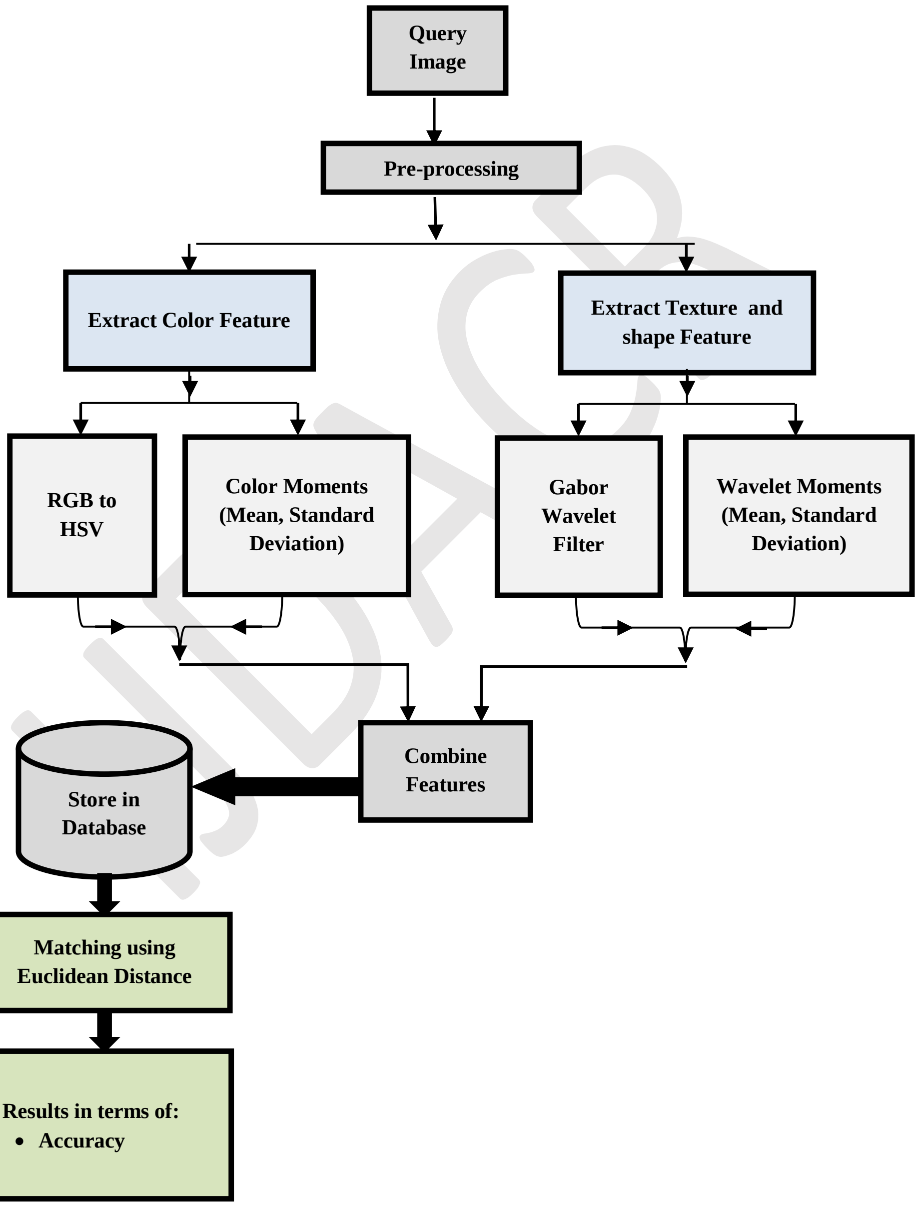

Figure 2: System architecture of proposed CBIR system

Colour Similarity Metric: One of the many metrics used to measure the similarity between histograms is the chi square [5] which is used in this work, this metric gives a small value if the images are similar

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and a large value otherwise. In two identical images gives a value of 0.

$$d_{chi\ square}(H_1, H_2) = \sum_{i=1}^{n} \frac{[H_1(i) - H_2(i)]^2}{H_1(i) + H_2(i)} \quad (1)$$

Where, n is the total number of bins, $H_1(i)$ is the value of i^{th} bin of first histogram and $H_2(i)$ is the value of i^{th} bin of second histogram.

The steps involved in the procedure are:

1. Read an database image
2. Read total number of colors for the image
3. Split colors into fixed intervals that determine total number of bins
4. Allocate every pixel's color into a specified bin and increment the value of bin by 1
5. Repeat step 4 for all pixels
6. Repeat step 1 to 5 for query image.
7. Calculate chi-square distance (d) for the corresponding values of bin for database image and query image.
8. If the distance (d) is zero then the two images are identical and as the value grows, the similarity between two images is less.

Figure 3 shows, quantized H, S and V images by using MATLAB *imquantize* function and quantized H, S and V images by proposed system.

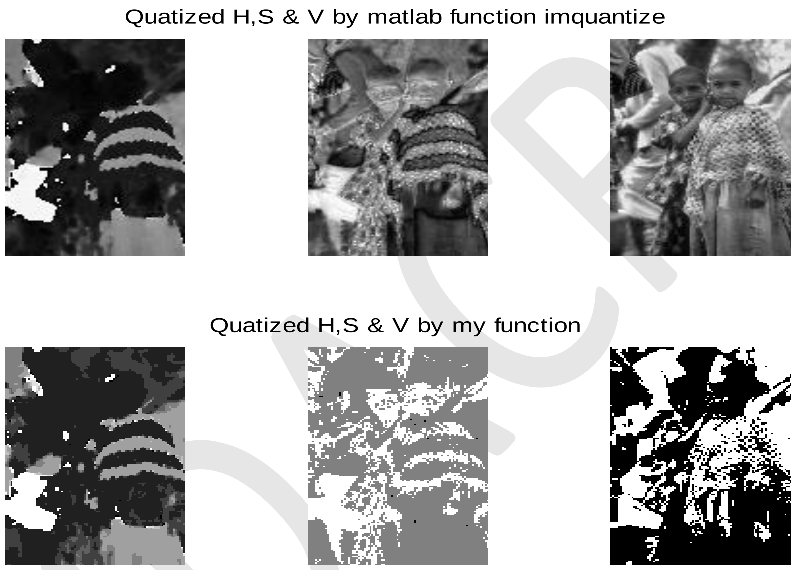

Figure 3: HSV converted Image

B. Texture

Texture is another important feature of objects that allows us to measure the regularity of an image. The texture is defined by a set of pixels, i.e. a single pixel does not define some type of texture [22].

Characteristics of Image: The characteristics of image are total 6, and their authors found that there are three of them that strongly correlate with human perception: coarseness, contrast and directionality. In his original work in [23] he presents how to calculate the 6 characteristics to obtain a scalar value for each processed image.

1. <u>Image Coarseness</u>: Coarseness provides information about the size of the textures in the image. When the textures have a micro-pattern and a macro pattern, procedure considers the pattern bigger, and the way to do it is applying operators of different sizes as follows:

Let I be an image; I (x, y) the value of the pixel at the position (x, y).

a. For each pixel (x, y) the average A is calculated over a defined neighbourhood which must be of a power size of two, for example 2×2,4×4, ..., 32×32:

$$A(x,y) = \frac{1}{2^k}\sum_{i=1}^{2^k}\sum_{j=1}^{2^k} I(x - 2^{k-1} + i, y - 2^{k-1} + j) \quad (2)$$

b. For each point (x, y) the difference between non-overlapping neighbourhoods on opposite sides of the point in the horizontal and vertical directions is calculated:

$$D_h^k(x,y) = |A_k(x + 2^{k-1}, y) - A_k(x - 2^{k-1}, y)| \quad (3)$$

And

$$D_h^v(x,y) = |A_k(x, y + 2^{k-1}) - A_k(x, y - 2^{k-1})| \quad (4)$$

c. For each point (x, y) select the value with the largest difference:

$$S(x,y) = Max_{d=h,v}\{E_k^d(x,y\}, k = \{1 \ldots 5\} \quad (5)$$

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d. Finally take the 2^S average as a measure of roughness for the image:

$$F_{crs} = \frac{1}{nm}\sum_{x=1}^{n}\sum_{y=1}^{m} 2^{S(x,y)} \qquad (6)$$

2. Contrast of image: Contrast is influenced by grey levels, polarization in black and white levels, edge definition and pattern repetition period. This is calculated using the mean and variance of the intensity values in a given neighbourhood as follows:

$$F_{con} = \frac{\sigma}{\alpha_4^z} \; where \; \alpha_4^z = \frac{\mu_4}{\sigma_4} \qquad (7)$$

Where,

$$\sigma_4 = \frac{1}{XY}\sum_{x=1}^{X}\sum_{y=1}^{Y}[I(x,y) - \mu]^4 \qquad (8)$$

$z = 0.25$, is recommended as the best texture discriminate.

3. Directionality of image: The presence of direction in the image is more interesting, than the orientation. To calculate the directionality, the horizontal and vertical derivatives are calculated by convolving the I image using the following 3×3 operators:

$$\Delta_H = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \text{ and } \Delta_V = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \qquad (9)$$

Then, for each position(x, y), the orientation angle is calculated using:

$$\theta = \frac{\pi}{2} + \tan^{-1}\frac{\Delta_V(x,y)}{\Delta_H(x,y)} \qquad (10)$$

With the definition of the database characteristics presented above, three texture measurements are obtained by image, with which the vector of characteristics containing information of the textures can be constructed, to construct a vector of database.

Texture Similarity: The measure of texture similarity between two images is represented in a quadratic way between the characteristic vector of the input image and the vector characteristic of an image of the image database (Euclidean Distance)[24], which is defined as:

$$d = \sqrt{(f_{11} - f_{12})^2 + (f_{12} - f_{22})^2 + \cdots + (f_{1n} - f_{1n})^2} \qquad (11)$$

Where, f_{ij} is defined as a characteristic of database.

C. Shape

For the analysis of form there is the use of related invariant moments which are invariant to translational, rotational, scale and related transformations.

Related Invariant Moments: The interest of general moments is that the contours can be modelled as a special type of bounded functions and calculate the moments of the same, that is why it is applied in the recognition of forms, classical invariants moments were presented by [25]. In [26] they derived a new set of invariant moments that are invariant under related transformations; this work makes use of 4.

Geometrical Moments and Central Moments: The definition of 2-D geomorphic moments of order $(p + q)$ of a density distribution function $f(x, y)$ such as the following:

$$m_{pq} = \sum\sum x^p y^q f(x, y) \qquad (12)$$

The moments that have the property of invariant translation are called central moments and are defined as:

$$\mu_{pq} = \sum\sum(x - \bar{x})^p (y - \bar{y})^q f(x, y) \qquad (13)$$

Where x and y are the coordinates of the centroid of the image function $f(x, y)$.

$$\bar{x} = \frac{m_{10}}{m_{00}}, \bar{y} = \frac{m_{01}}{m_{00}} \qquad (14)$$

Related invariant moments implemented:

$$Inv_1 = \frac{1}{\mu_{00}^4}(\mu_{20}\mu_{02} - \mu_{11}^2) \qquad (15)$$

$$Inv_2 = \frac{1}{\mu_{00}^6}(\mu_{40}\mu_{04} - 4\mu_{13}\mu_{31} + 3\mu_{22}^2) \qquad (16)$$

$$Inv_3 = \frac{1}{\mu_{00}^7}(\mu_{20}\mu_{21}\mu_{30} - 4\mu_{20}\mu_{12}^2 - \mu_{11}\mu_{03}\mu_{30} + \mu_{11}\mu_{21}\mu_{12} + \mu_{02}\mu_{30}\mu_{12} - \mu_{02}\mu_{21}^2) \qquad (17)$$

$$Inv_4 = \frac{1}{\mu_{00}^{10}}(\mu_{30}^2\mu_{02}^2 - 6\mu_{21}\mu_{12}\mu_{30}\mu_{03} - 4\mu_{30}\mu_{12}^3 + 4\mu_{03}\mu_{21}^3 - 3\mu_{21}^2\mu_{12}^2) \qquad (18)$$

Shape Similarity Metrics: The metric used to calculate two shape vectors is the Euclidean Distance. If the variation approaches 0 means that they are similar, otherwise they are not alike.

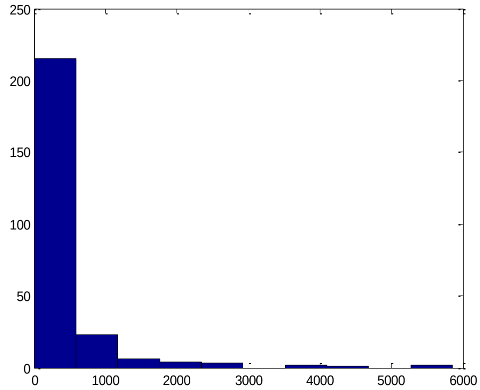

Figure 4: Histogram of shape feature

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D. Recovering Images using Colour, Texture and Shape

The result of a retrieval using more than one characteristic can be much more efficient, so this paper uses the combination of three colour, texture and shape characteristics.

The similarity between the reference image and one from the database is measured using three characteristics: colour, texture and shape. These characteristics represent different aspects so it is convenient to add a weight that differentiates its value. The distance between two images was taken from [27] and is measured as:

$$F1_{i..n} = [\text{shape} + \text{texture} + \text{colour}]; \qquad (19)$$

Where n is number of images in dataset.

$$Fq = [\text{shape} + \text{texture} + \text{colour}]; \qquad (20)$$

F_q is the feature set of query.

$$d(F_i, F_q) = \sqrt{\sum_{i=1}^{n} (F_i - F_q)^2} \qquad (21)$$

Where d is Euclidean distance.

V. Simulation And Results

A. Image Set

For the purpose of experimentation, an image dataset having established ground truth is used. A set of 500 Corel images assorted into 5 categories with 100 images in each category, forms the dataset. The images are of size either 384×256 or 256×384. The 5 image categories available are: (1) Africa, (2) Beach, (3) Transportation, (4) Architecture and (5) Dinosaur. The images in each category are numbered (Category 1: 0 to 99, Category 2: 100 to 199 etc…). This image database is known as Corel database in the literature and has been used for experimentation in the SIMPLIcity system proposed by Wang et al., 2001 [28].This database is publicly available for experimentation [29].

B. Results

Query Image

Figure 5: Retrieved image from database

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Table 1: Performance Evaluation

Class	Category	False Negative Rate	False Positive Rate	True Positive Rate	True Negative Rate
1	Africa	0.0176	0.0882	0.9118	0.9824
2	Beach	0.0175	0.0700	0.9300	0.9825
3	Transportation	0.0369	0.0957	0.9043	0.9631
4	Architecture	0.0025	0.0481	0.9519	0.9975
5	Dinosaur	0	0	1.0000	1.0000

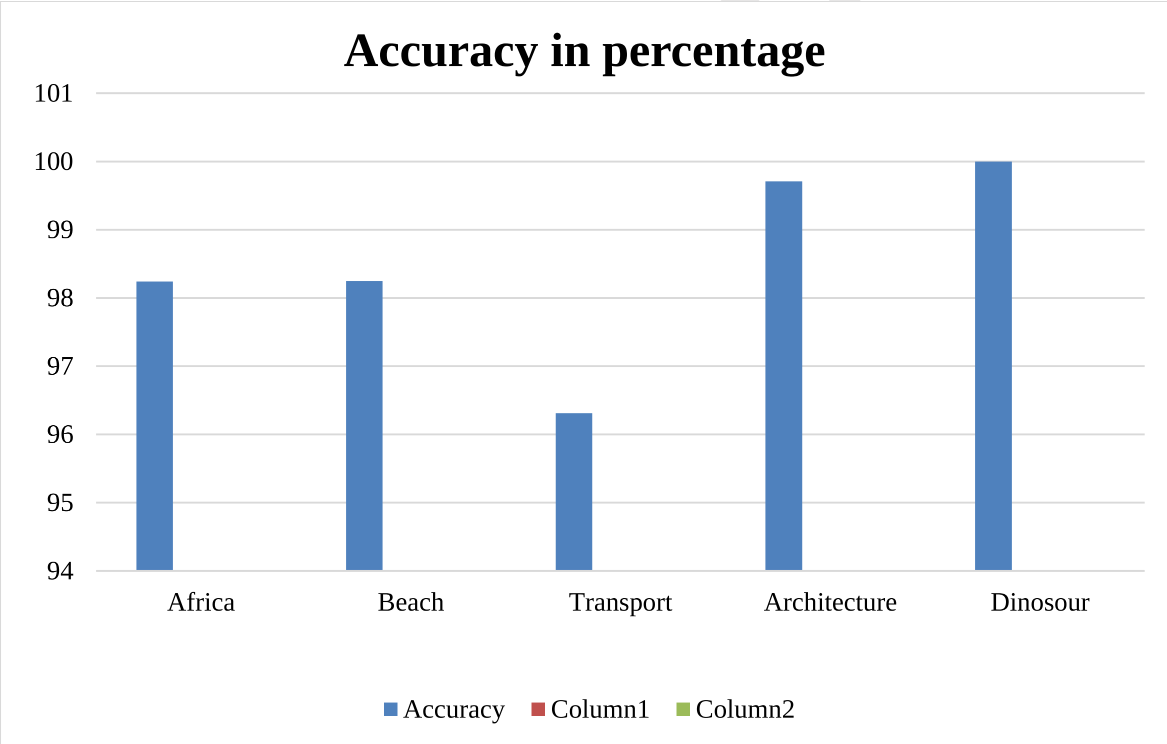

Figure 6: Accuracy in percentage of different category

VI. CONCLUSION

The proposed method uses colour, texture and shape to create an image retrieval system. Using the three characteristics the system provides better results. In addition, this proposal focuses on an area where there is not yet a similar tool available to experts in the field, which led us to make adaptation knowledge. The results obtained in the experiments show that on average the system performs a correct diagnosis of 90% providing good results. We will also consider placing it on the web and will be a Content Based Image Retrieval for any database provided that the database meets the required specifications; any user could upload their database and use the system, which means that this system could be applied to a variety of similar problems.

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