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COMBINING MULTIPLE COLOR AND SHAPE FEATURES FOR IMAGE RETRIEVAL

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ABSTRACT

Image retrieval has been getting importance and popularity in the field of information retrieval since the last decades. Systems have been developed to retrieve image on the basis of its contents for indexing, matching, searching and browsing the image databases. In this study, an effective CBIR system has been proposed by defining a shape feature extraction model named symmetry, area, direction angle and arc length features (SADAF) model. SADAF introduces a new shape features model which is generic in nature. In the proposed approach, objects are first located with image segmentation. SADAF model is then applied to extract visual shape contents of the image. After matching, searching and retrieval process, the retrieved results are arranged according to the distance of color from query image to those of retrieved images, calculated through color histogram. Qualitative analysis for proposed technique has been performed with widely accepted quantification measures precision and recall rates. Comparison of the method proposed with other existing descriptors of shape has also been done to prove its supremacy and reliability over the techniques already in literature.

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KEY WORDS

Boundary Extraction, CBIR, Feature Extraction, High Level Features, Image Segmentation, Image Information, Low Level Features, Matching, Searching, Shape Descriptor.

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INTRODUCTION

With the growing popularity and advancing technology in image acquisition, electronic archives of image have also increased considerably due to the emergence of devices with high speed processors and cheapest memories. For proper organization of these electronic archives, implementation of database is amongst strongly recommended approaches. Hence Content Based Image Retrieval (CBIR) has remained most popular database image manipulator for the indexation, matching, searching and retrieval of images [1-8].

With the emergence of CBIR, color features have gained greater popularity for image recognition visually but the semantic gap [9] has often resulted in compromised or poor performance of the system. This is due to the fact that color features only recognize the color of image and not its visual contents. This has created a difference between meanings of images. For example, in Figure 1 both images have same colors visually but their meaning is completely different.

To minimize the semantic gap, a state of the art technique has been presented in [10] which uses evolutionary programming to extract shape, texture and color features of image. Color features do not include spatial information of image and hence fail to completely describe the contents of image. But fuzziness can overcome the absence of color features as introduced in Fuzzy Color Histogram (FCH) [11], Self Organization Map (SOM) and Subtractive Fuzzy Clustering [12].

Within the context described above and keeping in view the fact that shape descriptors are more stronger in describing an image semantically in comparison with features of image like color and texture [13], a shape descriptor is required which can fully describe the contents of image i.e., what the image is comprised of. There are many descriptors of shape mentioned in existing literature which are divided as *shape descriptors based on region and shape descriptors based on contour*. Information about boundary is only considered in contour based

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shape descriptors whereas all image pixels are taken in region based shape descriptors [14]. Fourier descriptor (FD) is contour based shape descriptor and suitable for character recognition application. Fourier transform is applied on complex vector of image boundary to obtain FD [15]. The curvature scale space descriptor (CSS) performs analysis of image boundary as a 1D signal in scale space [16]. Adopted in MPEG-7, the ART is a 2D descriptor which is based on both moment and region [17]. Image moments (IM) are useful in recognition problems and also have the capability of coping with geometric transformations like scaling, translation and rotation as well as general affine transformations [18].

Fig: 1. Semantic Gap

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Image segmentation allows combination of same pixels due to their coherent visual characteristics; therefore, it is considered essential for various standard applications as it tends to semantic approach for image analysis [19]. A new shape descriptor has been demonstrated in this paper which follows a newly defined shape features model SADAF in combination with color features calculated through color histograms.

The sections of paper are arranged like this. Proposed work complete description is mentioned under Section 2 whereas Section 3 demonstrates the results along with discussion of proposed approach at length. Section 4 concludes the method described and Section 5 presents the references.

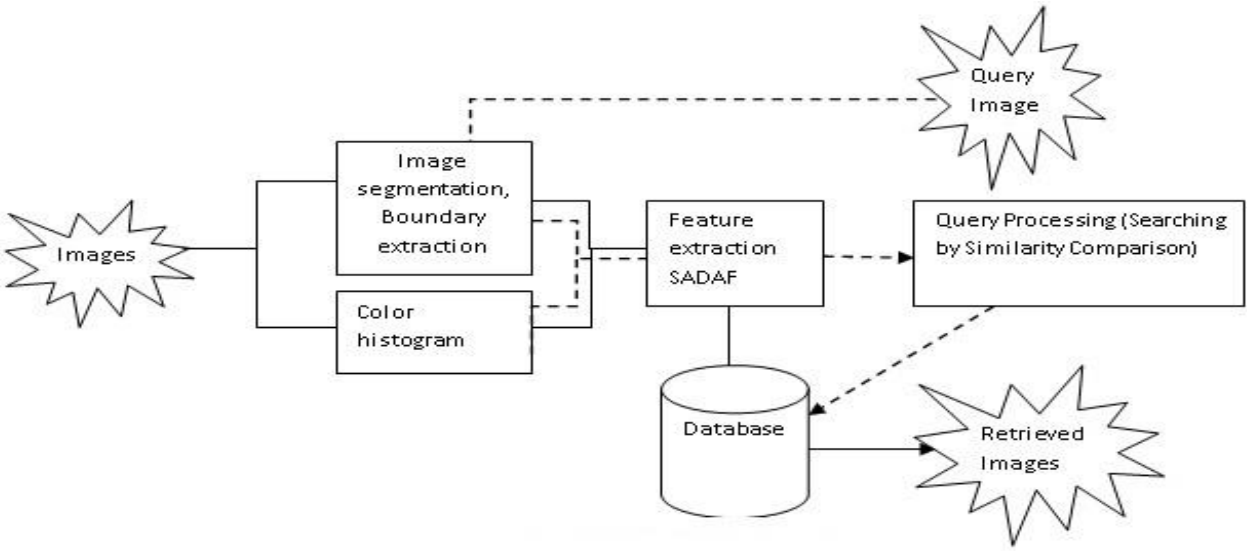

Fig: 2. Architecture of Proposed Method

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METHODS

Proposed CBIR System

A new CBIR system has been proposed in this paper based on the idea that similar images contain same features. Figure 2 presents general architecture of the system. First, color histogram is calculated for database population and image segmentation for boundary extraction is then performed. To these boundary images, the new proposed features extraction model SADAF is applied to extract the shape features. Numerical values of these features are saved in database. When query image is presented, the same process is performed for features calculation and distance of features for both images is calculated. As a result, images with less distance are selected as retrieved images and sorted according to distance in color from the query image. This process is further described in the succeeding sections.

Segmentation of Image

Segmentation of image based on edges is adopted for the proposed approach. For this purpose, canny edge descriptor [20] is used because strong edges are needed for boundary extraction and canny edge operator fully detects the strong edges. Figure 3 shows the input and gradient images.

Fig: 3. Input Image is on the Left, Gradient Images on the Right

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The operator performs convolution with original image and 3×3 kernels for horizontal and vertical derivatives approximation calculation. The horizontal gradient G_x and vertical gradient G_y can be computed as follows if I be the original image [21].

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$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * I \qquad (1)$$

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * I \qquad (2)$$

Here $*$ means the 2-dimensional convolution operation. Towards the right, the x-coordinate increases whereas towards down, the y-coordinate increases. The gradient magnitude can be calculated by combining both gradient approximations as follows:

$$G = \sqrt{|G_x|^2 + |G_y|^2} \qquad (3)$$

Boundary Extraction

In this section, boundary of objects contained in the image is extracted by tracing the continuous edges. For this eight connected neighbors, as specified in Figure 4, are used. The image at hand is a binary edge image in which a 0 is a non edge pixel and 1 is an edge pixel. By image scanning from top to bottom and from left to right, we look at its eight connected neighborhood pixels if a pixel is 1 and if a pixel is found to be 1 in the neighborhood then we trace its neighborhood recursively. In this manner, solid and continuous edges are traced out.

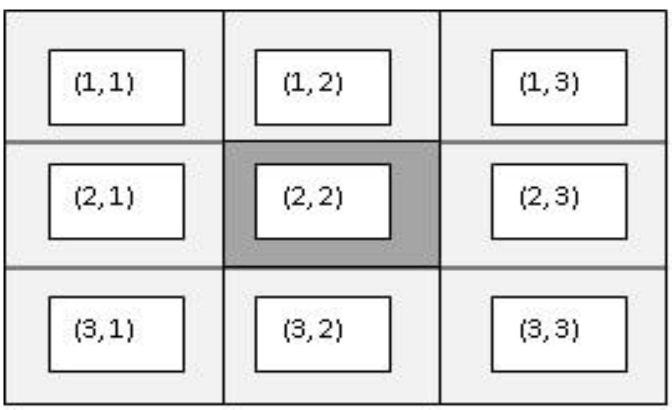

Fig: 4. Eight Connected Neighbors

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Features Extraction Model: SADAF

Features extraction has been performed by defining a new features extraction model SADAF in which four features namely symmetry, area, direction angle, and arc length have been specified by treating image as a function $f(x, y)$ in a plane surface. These features are discussed in detail one by one respectively in the following sections.

Symmetry

Following expression defines an image $I(m,n)$ with rows *m* and columns *n* as its dimensions in plane surface.

$$I(m,n) = f(x,y) \qquad (4)$$

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By setting up the central point of extracted boundary image at the origin of plane surface, very useful characteristics of an image are obtained, one of them being Symmetry. Symmetry is a property that specifies the spatial layout of an image i.e., in which quadrant that part of image lies. Figure 5 shows some examples of extracted boundary images in a plane surface.

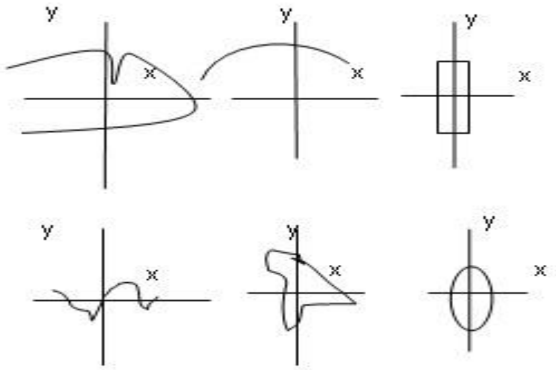

Fig: 5. Examples of Traced Boundaries in the Plane Surface

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Symmetry can be defined by the following expressions.

$$f(x,-y) = f(x,y) \quad (5)$$
$$f(-x,y) = f(x,y) \quad (6)$$
$$f(y,x) = f(x,y) \quad (7)$$
$$f(-x,-y) = f(x,y) \quad (8)$$

Expressions 5 to 8 specify that the image is in 1^{st}& 4^{th}, 1^{st}& 2^{nd}, 1^{st}, 1^{st}& 3^{rd} quadrants respectively.

Area

Assuming that $f(x,y) \geq 0$, area under the curve in Figure 6 has to be determined.

Let $x_o, x_1, x_2, \cdots, x_{k-1}, x_k$ be a partition of $[m,n]$ such that length of each subinterval $[x_{r-1}, x_r] = \dfrac{n-m}{k}$.

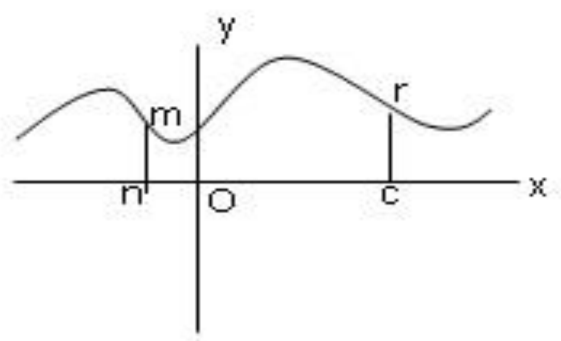

Fig: 6. Area under an Image

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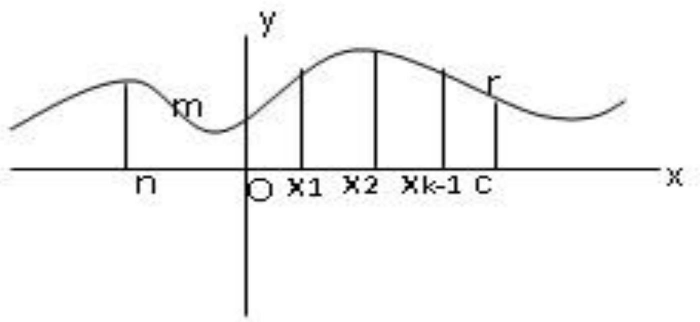

Fig: 7. Partitioning into K Rectangles

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Drawing vertical lines from each of the points $x_r, r = 1, 2, 3, \cdots, k$ to the graph of $y = f(x, y)$, partitions are made into n smaller areas. Let a_r be any point of $[x_{r-1}, x_r]$. Corresponding to a_r the ordinate of point on $y = f(x, y)$ graph is $f(a_r, b_c)$. On each sub interval $[x_{r-1}, x_r]$ we construct rectangle with the closed interval as its base and $f(a_r, b_c)$ as its height. The rectangle on $[x_{r-1}, x_r]$ is shown in greater detail in Figure 7. Its area is $f(a_r, b_c)$ and sum of all k rectangles $= \sum_{r=1}^{k}\sum_{c=1}^{k} f(a_r, b_c)\Delta x = S(p, f)$ (9)

Thus by putting the limit, area of an image $I(m,n) \backslash r \le m \le 1, c \le n \le 1$ in plane surface is defined by the expression.

$$A = \int_{m=1}^{r}\int_{n=1}^{c} f(x, y)dydx \qquad (10)$$

Direction Angle

If different points are taken on the image and vectors are drawn from those points to the origin of graph $y = f(x, y)$, the direction angle can easily be determined. From this the angle of orientation is calculated for any image under consideration as shown in Figure 8.

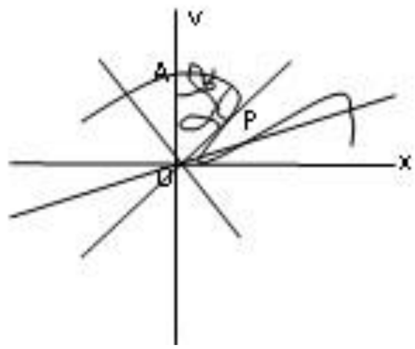

Fig: 8. Computing Direction Angle

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Let $v| = [x, y]$ be a vector, the direction angles α, β of v are defined as:

$$\alpha = \Theta(v, x) \quad (11)$$
$$\beta = \Theta(v, y) \quad (12)$$

By definition each of these angles lies between 0 and π from the right ΔOAP.

$$\cos\alpha = \frac{x}{OP} = \frac{x}{\sqrt{x^2 + y^2}} \quad (13)$$

$$\cos\beta = \frac{y}{OP} = \frac{y}{\sqrt{x^2 + y^2}} \quad (14)$$

From Eqs.13 and 14:

$$\alpha = \cos^{-1}\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad (15)$$

$$\beta = \cos^{-1}\left(\frac{y}{\sqrt{x^2 + y^2}}\right) \quad (16)$$

Arc Length

Let $x_0, x_1, x_2, \cdots, x_{n-1}, x_n$ are points such that $a = x_0 < x_1 < x_2, \cdots < x_{n-1} < x_n = b$ is a partition of [a, b]. Then the arc AB is divided into n smaller arcs by the points

$$P_o(x_o, f(x_o, y_o)), P_1(x_1, f(x_1, y_1)),$$
$$P_2(x_2, f(x_2, y_2)), \cdots, P_{r-1}(x_{r-1}, f(x_{r-1}, y_{c-1})),$$
$$P_r(x_r, f(x_r, y_c)),$$

By definition rth chord passes from the point P_{r-1} to P_r

$$|P_{r-1}P_r| = \sqrt{(x_r - x_{r-1})^2 + (y_c - y_{c-1})^2 + (f(x_r, y_c) - f(x_{r-1}, y_{c-1}))^2} \quad (17)$$

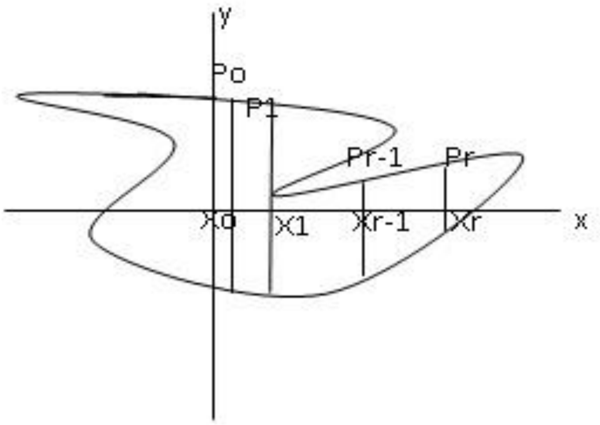

Fig: 9. Computing the Length of Arc

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From Figure 9, the total length for image can be calculated by summing up all the lengths as follows:

$$s = \int_{x=1}^{r} \int_{y=1}^{c} \sqrt{1+\left(\frac{dy}{dx}\right)^2 \left(\frac{dx}{dy}\right)^2}\, dydx \qquad (18)$$

Color Extraction

For color extraction, color histograms are computed and saved in database as color features because of the reason that color histogram is easy to compute and indexed in database. On the basis of above four features, images are selected and presented according to the distance of their histograms from the query image. In this way, sorting of retrieved images is done according to query image color i.e., image nearer to query image in color is presented first and so on.

RESULTS AND DISCUSSION

To provide quantification results, 9 images have been provided as query image one by one from 9 random categories. The database used is COREL database [22, 23] of 10,000 images from which a set of 60 images per category is constructed to form a 540 images testing database.

Belonging to the same category of query image, a retrieved image is considered as relevant.
Table 1 list nine categories from which query images have been provided. All categories contain images having the content as mentioned in category name. Widely accepted quantification measures precision rate and recall rate have been computed to demonstrate the strength of proposed solution. Precision and recall rates have been computed with the help of following expressions.

P = Relevant retrieved images/Total retrieved images
R = Relevant retrieved images/Total images in that category

Table1. Categories of Test Images

S. No.	Name of Category
1	Butterfly
2	Voyage
3	Sunset
4	Flowers
5	Building
6	Food
7	Vehicle
8	Horses
9	Beach

A tradeoff has always been observed between precision and recall as ratio of retrieved images to total images is defined as recall and ratio of accurate images to retrieved images of that category is defined as precision. A good balance can be maintained by retrieving a maximum number of accurate images according to the image provided as query image.

The proposed method is intended to retrieve 50 images per search but due to space limitations top 20 results of first 3 categories have been presented in Figure 10.

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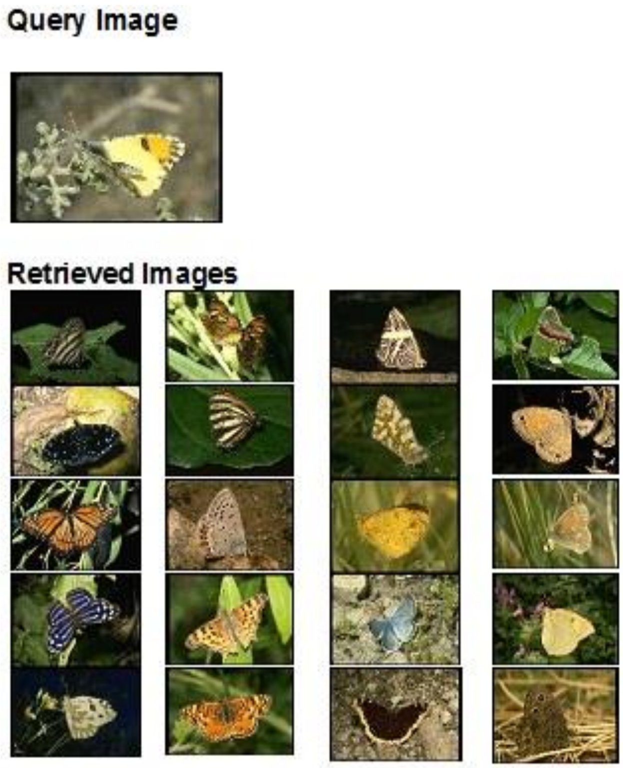

a) Results of first 20 Retrieved Images of Butterfly, On the top is Query image of Butterfly

b) Results of first 20 Retrieved Images of Voyage, On the top is Query image of Voyage

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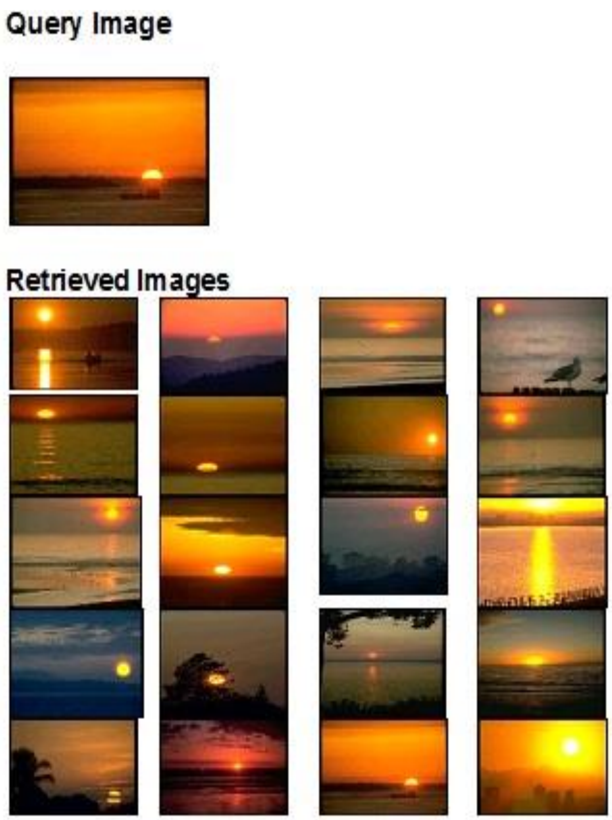

c) Results of first 20 Retrieved Images of Sunset, On the top is Query image of Sunset

Fig: 10. Top 20 Retrieved Results

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For comparison, contour based shape descriptors FD [7], CSS [8] and Smallest Rectangle Distance (SRD) [14] have been used. These three shape descriptors have been tested in the same environment as that of proposed method i.e., Intel Core i3 processor, 2.8 GHz processor speed, 2 GB RAM, Windows OS and Matlab 7.0 as a tool used with the same database. Average precision results have been shown in Table 2 and plotted in Figure 11.

Table 2. Comparison of Average Precision

No. of Retrieved Images	FD	CSS	SRD	SADAF
10	0.68	0.62	0.67	0.79
20	0.58	0.6	0.58	0.72
30	0.56	0.49	0.52	0.7
40	0.52	0.44	0.48	0.65
50	0.5	0.4	0.36	0.63

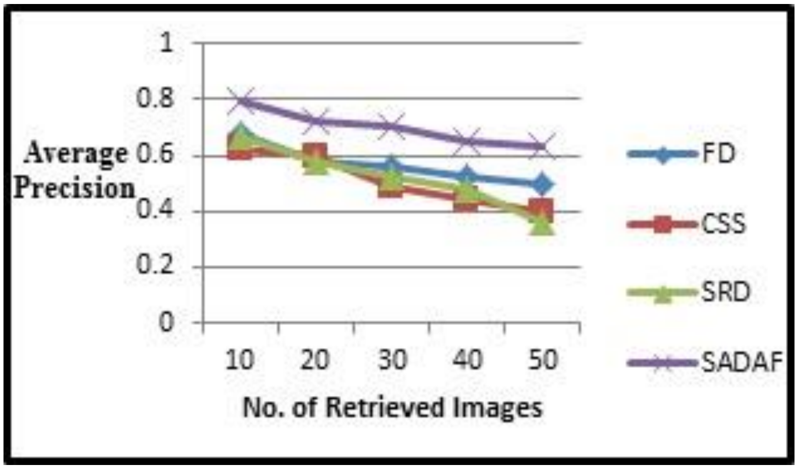

Fig: 11. Comparison Results of Average Precision Rates, Test Image Categories: Butterfly, Voyage, Sunset, Retrieved Images 10, 20, 30, 40 & 50

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It is clear from Table 2 and Figure 11 that the proposed solution presents best retrieval performance. As FD and CSS are contour based descriptors, the proposed descriptor is also contour based but it performs much better than both existing contour based descriptors. If features are properly extracted from the image, image matching becomes simpler. Moreover, the system is robust to image alterations like changes in size, scale and orientation. Rotation is controlled through feature direction angle; if the area is less distant from the area of query image and angle is different, in this case the images are same but rotated at the rate of direction angle. Similarly, arc length serves as an identification of change in size and symmetry in change of position. These changes can be observed in Figure 10; all changes are present in retrieved images. System successfully identifies these changes and accurately retrieves the relevant images. Image segmentation simplifies image matching because it narrows down the search space and decreases the processing overheads because in identifying a major or strong object, there is no need to take into account less information presented in the image and wasting the time. Processing speed of proposed solution is very high. It takes 1.5 seconds to calculate the query image features and get them matched with database images. Distance is calculated with Euclidean distance formula and images are sorted. From these sorted images, top 50 images are selected as retrieved images because proposed system is intended to retrieve 50 images per search.

Recall and precision for all nine categories is given in Table 3.

Table3. Proposed System Precision and Recall (%)

No. of Retrieved Images	Category	Precision	Recall
50	Butterfly	79.4	68.1
50	Voyage	78.9	68.8
50	Sunset	78.1	68.2
50	Flowers	78.4	69.9
50	Building	79.8	68.0
50	Food	78.3	69.5
50	Vehicle	79.6	69.6
50	Horses	79.0	69.7
50	Beach	79.9	68.1

From each of nine categories one by one, the system receives a query image to record recall and precision for performance evaluation of system proposed. Total images to be retrieved are selected as 50. Precision and recall of butterfly are 79.4 & 68.1, voyage-78.9 & 68.8, sunset-78.1 & 68.2, flowers-78.4 & 69.9, building-79.8 & 68.0, food-78.3 & 69.5, vehicle-79.6 & 69.6, horses-79.0 & 69.7 and beach-79.9 & 68.1 respectively. This is also plotted in Figure 12. The systems shows an overall mean precision of 79 and mean recall of 68. This shows that the system balances the tradeoff between precision and recall.

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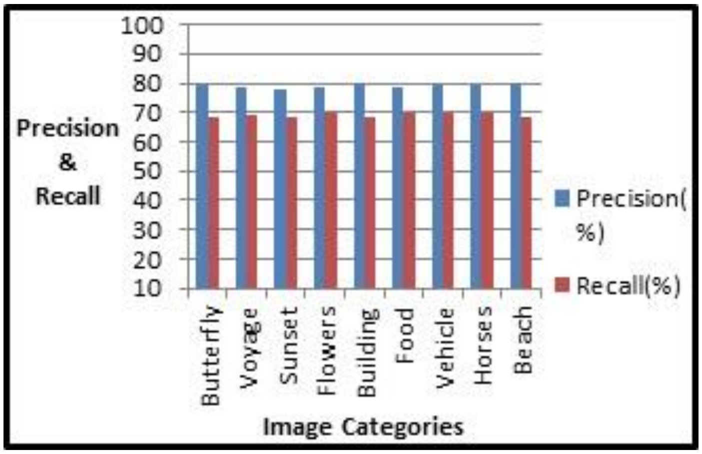

Fig: 12. Precision and Recall (%) of Proposed System

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Next, the system receives an image from all nine categories as query image. Desired images which are required to be retrieved are selected as 10, 20, 30, 40 and 50. Precision and recall are recorded which are given in Table 4 and Table 5 respectively.

Table4. Precision (%) for No. of Images to be retrieved 10, 20, 30, 40 & 50

Category	No. of Images to be Retrieved				
	10	20	30	40	50
Butterfly	83.7	83.7	80.1	79.9	79.4
Voyage	83.5	83.1	80.4	79.9	78.9
Sunset	84.6	83.0	80.2	79.6	78.1
Flowers	83.8	82.2	80.3	80.8	78.4
Building	84.8	83.7	80.4	79.7	79.8
Food	83.3	83.2	80.8	79.2	78.3
Vehicle	83.5	82.7	80.0	80.5	79.6
Horses	83.2	83.0	81.8	79.7	79.0
Beach	83.2	82.8	81.8	79.4	79.9

Table 5. Recall (%) for No. of Images to be retrieved 10, 20, 30, 40 & 50

Category	No. of Images to be Retrieved				
	10	20	30	40	50
Butterfly	55.8	57.5	62.6	65.8	68.1
Voyage	55.5	58.4	61.0	65.1	68.8
Sunset	54.9	57.3	61.0	65.2	68.2
Flowers	54.8	58.3	61.3	66.8	69.9
Building	54.8	57.3	62.2	66.9	68.0
Food	54.6	57.7	62.4	66.1	69.5
Vehicle	55.0	58.2	62.2	65.1	69.6
Horses	55.0	58.5	61.9	65.4	69.7
Beach	55.6	57.1	62.0	65.7	68.1

As could be observed from Table 4 and Table 5, when the number of images to be retrieved is low, precision increases and recall decreases. It is due to the fact that recall falls when low number of images is to be retrieved because the relevant retrieved images to total relevant images ration is on the higher side due to high number of relevant images in the database. Whereas the relevant retrieved images and total number of retrieved images ratio decreases in case the number of images to be retrieved is low hence the system retrieves most relevant images efficiently. So, relevant images retrieval needs to be in maximum number for balancing the system. In Figure 13(a) & (b) respectively, precision as well as recall of each category for 10, 20, 30, 40 and 50 images to be retrieved is plotted.

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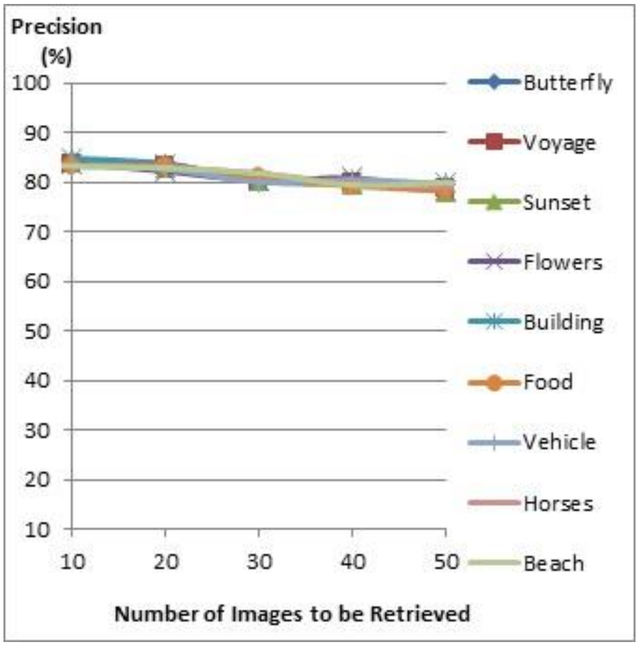
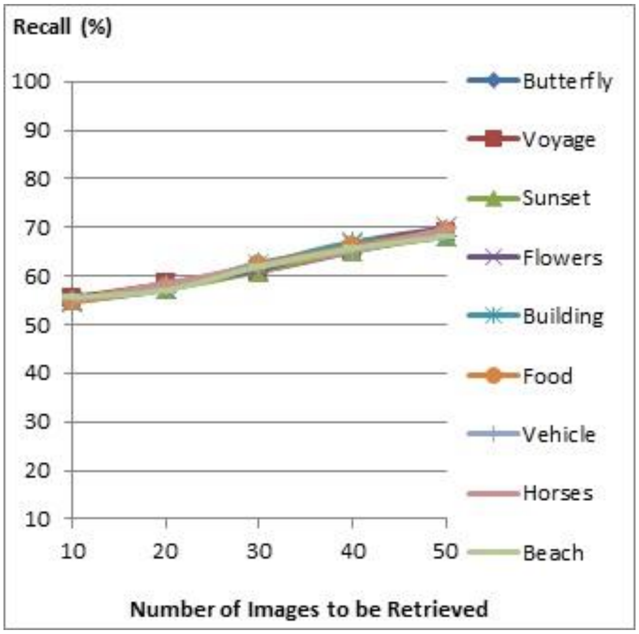


(a) Precision(%) for All Categories for Number of Images to be Retrieved 10, 20, 30, 40 & 50



(b) Recall (%) for All Categories for Number of Images to be Retrieved 10, 20, 30, 40 & 50

Fig: 13. Precision and Recall (%) of Proposed System

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CONCLUSION

A new scheme for features extraction has been presented in this study which ensures a fast and accurate retrieval of images on the basis of their shape and color contents. The system is based on the idea of presenting a query image to the system. On the basis of such query image, the system filters out images which are similar in shape and color. Like any other CBIR system, the proposed system also takes into consideration the fact that similar

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images have some common features. The features extraction model SADAF selects features in a way that it can recognize image well in case of any image alterations like scaling, translation and rotation. System speed is implementable i.e., it can be implemented in a real time system of CBIR. Image segmentation speeds up the process of features extraction and image matching. The descriptor proposed is a simple and small descriptor that outperforms the existing descriptors.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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None.

FINANCIAL DISCLOSURE

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