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Content Based Image Retrieval Using Heuristic Particle Swarm Optimization

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Abstract: In the last decades has witnessed the research interest in the field of Content Based Image Retrieval (CBIR). It inspects the visual content and detects images in the database. In this study, it is proposed a novel approach to improve the efficiency of the CBIR system based on heuristic Particle Swarm Optimization (PSO). The mean and standard deviation values of the color images are used as color features. Moreover, it is also contemplated an active contour as the region feature. PSO is used to reduce the semantic gap between retrieval results and user expectations. Experiments demonstrated that the proposed image retrieval system performed well.

Key words: Content based image retrieval, statistical feature, region feature, particle swarm optimization, witness

INTRODUCTION

In an incumbent national geographic imagery archive of the US has grown from Petabytes (PB) to Terabytes (TB) (Vassilieva, 2009). It elicits the demand of qualitative and quantitative image retrieval systems. An image retrieval system is a computer based system for searching and retrieves images from a large database of digital images. Searching and retrieving is neither bit by bit comparison nor a matching process on the raw data.

Image retrieval systems have been classified into two different types: Text based and content based. The snags of text based approaches are: massive amount of man power is required for manual image annotation and for a particular image, different user annotates different keywords. These snags of the text based image retrieval motivate the researcher to examine in the genre of CBIR. In CBIR, retrieval is based on the image contents. Many techniques have been developed for the primary purpose of CBIR systems (Liu *et al*., 2007; Veitkamp and Tanase, 2000; Singaravelan and Murugan 2013). Besides, some studies have shown the comparison results of the recent techniques in this genre (Antani *et al*., 2002; Zhou and Huang 2002). Despite, the survey of literatures in the domain of CBIR reveal exceptional endeavors have been carried out, still an elaborate analytical inquisition is demanded to frame a proficient system which would enhance the performance metric such as precision and minimize the semantic gap. In this study it is contemplated to design a simple heuristic along with evolutionary algorithm to have a competent CBIR system.

In a CBIR system, the retrieval of images has been done by assess the similarity between the query image and all the candidate images from the database. The simplest method for assess the similarity between two images is, to compute the distance between the feature vectors in lieu of the two images. Color, shape and texture are three low-level features widely used for image retrieval. Moreover, (Lu and Chang, 2007) have suggested the region features (shape) which provides surpassing results. Besides, region features, mean and standard deviation value (color) are used to implement the Heuristic Particle Swarm Optimization (PSO) algorithm to recognize the consistent images in CBIR system.

MATERIALS AND MEHTODS

System overview: Figure 1 shows the block diagram of the proposed CBIR system. In this research, there are two processes namely off-line and on-line. The functions carried out in off-line process are image collection from standard image databases such as 101 object categories and Wang 1000 (Chiang *et al*., 2009), extraction of features such as regions, mean and standard deviation value of Red (R), Green (G) and Blue (B) components of an image and Store the images and its features into the database. Table 1 depicts the name of the data set, semantic name of the image and the number of images stored in each data set. About 1300 images and its features have been measured for implementation. Figure 2 illustrates sample images for this proposed method.

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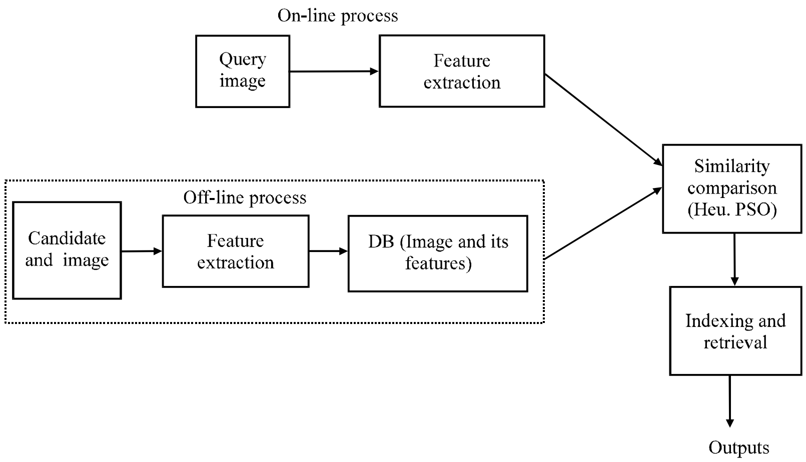

Fig. 1: Block diagram of the proposed system

Fig. 2: Sample images

Table 1: Details of the image database

Name of the dataset	Semantic name of the image	No. of images	Total number of images in each dataset
Caltech 101-object categories	Cougar	100	700
	Flamingo	100	-
	Bike	150	-
	Airplane	200	-
	Ketch	150	-
Wang 1000	Dinosaur	100	600
	Elephant	100	-
	Butterfly	100	-
	Rose	100	-
	Bus	100	-
	Car	100	-

With respect to online process, the user gives the query image for retrieval. Then the system identifies contour regions, computes the mean and standard deviation value of R, G and B components of the query image. A heuristics approach along with PSO is used to compute the similarity between the query and candidate images from the database and the resultant images are retrieved.

Proposed approach: One of the key issues in CBIR is the selection of features considered for image retrieval. In this study, the following features have been identified active contour selection (region identification) (Li *et al*., 2005), mean and standard deviation value of the color image (Red, Green and Blue).

Region identification: In region identification, active contours are dynamic curves that move towards the object boundaries. To accomplish this goal, it explicitly defines an external energy that can move the zero level curve towards the object boundaries. Let I be an image, and g be the edge indicator function which is described by Eq. 1:

$$g = \frac{1}{1+|\nabla G_\sigma \times I|} \quad (1)$$

where, G_σ is the Gaussian kernel with standard deviation σ. After identifying initial edges of an image, Dirac smoothening function, Time step and number of iterations are used to extract contour regions. Figure 3 shows the query image and contour regions after 100, 200, 300, 400- 500 iterations and an exact active contour will be obtained.

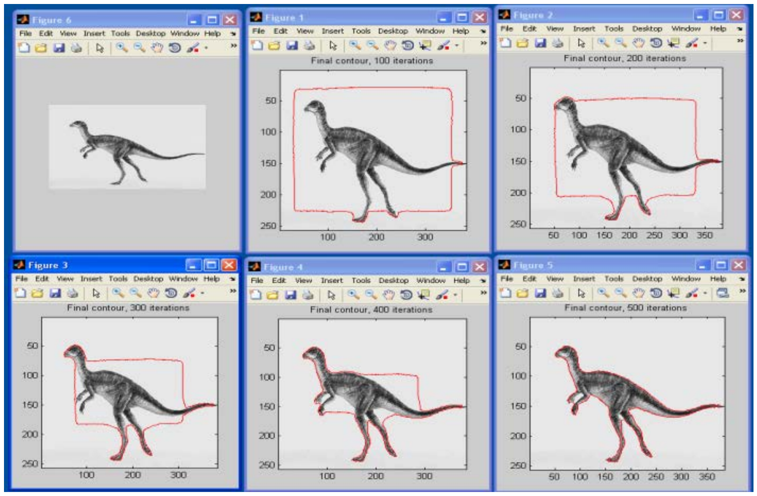

Fig. 3: Region identification using dirac function

Color feature: Color is an important dimension of human visual perception that allows discrimination and recognition of visual information. Color features are relatively easy to extract which is effectively used for searching and indexing of color images. Here, the mean and standard deviation values of the pixel colors will be considered as the color features.

Each image in the database can be represented by three primary color spaces. The most common color space is RGB. Thus, each pixel of a color image is represented by a vector in Eq. 2:

$$P_i = [\,R_i \quad G_i \quad B_i\,] \tag{2}$$

where, P_i is the ith pixel of the image, 1 = i = M and R_i, G_i and B_i are the components of primary colors red, green and blue, respectively. The M is the size of an image and the components of P_i depict the color information. The mean (μ) and standard deviation (σ) value of the color image are determined by the following Eq. 3 and 4.

$$\mu = \frac{1}{M}\sum_{i=1}^{M} P_i \tag{3}$$

$$\sigma = \left[\frac{1}{M-1}\sum_{i=1}^{M}(P_i - \mu)^2\right]^{1/2} \tag{4}$$

where, $\mu = [\mu_R\ \mu_G\ \mu_B]^T$ and $\sigma = [\sigma_R\ \sigma_G\ \sigma_B]^T$, each component of μ and σ indicates the RGB information, respectively.

Heuristic approach with particle swarm optimization algorithm: In previous, the development of optimization algorithms has been inspired by natural and biological behaviors. These optimization approaches affords an innovative techniques to realize nearly-optimal solutions in highly nonlinear, multidimensional solution spaces, with lower complexity and faster convergence than traditional algorithms. Kennedy and Eberhart have proposed PSO in the genre of computational intelligence in the year 1995. This is a population-based stochastic technique which solves complex optimization problems. It is successfully applied as an optimization tool in several practical problems as well as different domains such as image classification, ad-hoc sensor network, design of antennas array, medical images and neural networks (Jinsa Kuruvilla and Gunavathi, 2014; Ambika and Samath, 2013). In this study, its proposed heuristic particle swarm optimization to accomplish a proficient interactive CBIR algorithm. A heuristic view of PSO is shown in Fig. 4. The following variables are used in the algorithm:

- QI-Query Image
- PS-Particle Size
- DP1-3, Data base image properties, i.e., mean value of R, G and B, respectively
- WP1-3, Weightage of query image properties 1-3

The user has to give the query image for the retrieval of similar images. The system identifies contour regions using Dirac function and extracts statistical features such as mean and standard deviation of Red, Green and Blue components of the image. Query image properties, such as standard deviation values of Red (QP1), Green (QP2) and Blue (QP3) have been considered as inputs for this experiment. Allowed deviation/error rate for QP1, QP2 and QP3 is assumed to be ±5 and WP1, WP2 and WP3 have considered as 0.33, 0.33 and 0.33, respectively.

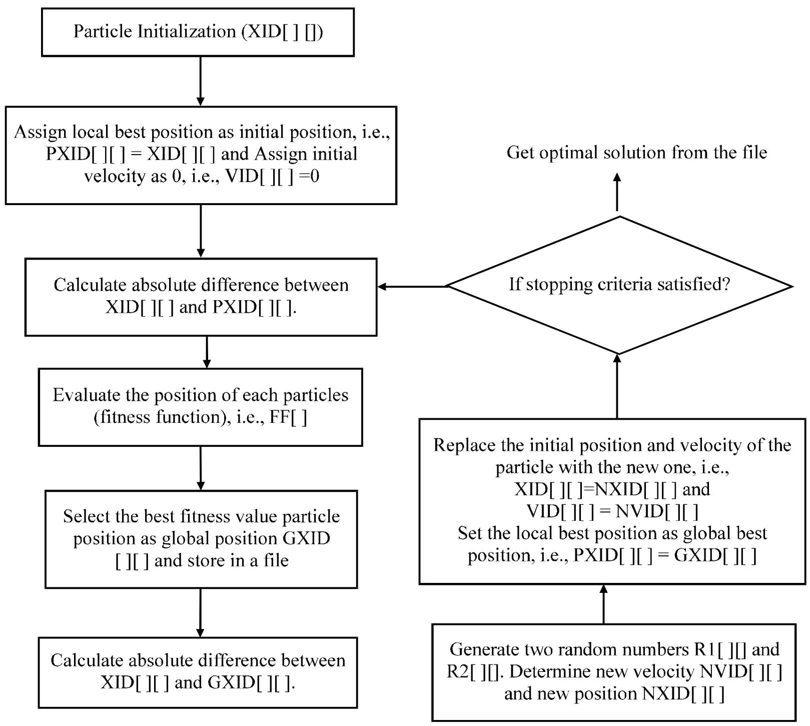

Fig. 4: Heuristic view of particle swarm optimization

Stage 1-particle initialization:

Step 1: Formulate three random numbers within ±5 for the standard deviation value of Red, Green and Blue component of an image such as QP1, QP2 and QP3. Assign these values to XID[PS][1], XID[PS][2] and XID[PS][3] respectively.

Step 2: Repeat the above step until reach the PS.

Stage 2-determination of local best position:

Step 1: Initially, assume the local best position (PXID [ ] [ ]) is similar to initial particle position (XID[ ][ ]). Assign the initial velocity of each particle (VID [] []) as 0.

Step 2: Determine the absolute difference between XID [ ] [ ] and PXID[][].

Stage 3-determination of global best position:

Step 1: Choose the first particle (XID[1][ ]).

Step 2: Compute DP1 as QP1 + XID[1][1]. With respect to DP1, choose data base image property values(R, G and B) and store in DP1RP, DP1GP and DP1BP. Compute DP2 as QP2 + XID[1][2]. With respect to DP2, choose data base image property values(R, G and B) and store in DP2RP, DP2GP and DP2BP. Compute DP3 as QP3 + XID[1][3]. With respect to DP3, select data base image property and store in DP3RP, DP3GP and DP3BP.

Step 3: Compute the position of a particle i.e. objective function in Eq. 5-7

$$PP1 = Abs\begin{pmatrix}(QP1\text{-}DP1RP)\times WP1+(QP2\text{-}DP1GP)\\ \times WP2+(QP3\text{-}DP1BP)\times WP3\end{pmatrix} \quad (5)$$

$$PP2 = Abs\begin{pmatrix}(QP1\text{-}DP2RP)\times WP1+(QP2\text{-}DP2GP)\\ \times WP2+(QP3\text{-}DP2BP)\times WP3\end{pmatrix} \quad (6)$$

$$PP3 = Abs\begin{pmatrix}(QP1\text{-}DP3RP)\times WP1+(QP2\text{-}DP3GP)\\ \times WP2+(QP3\text{-}DP3BP)\times WP3\end{pmatrix} \quad (7)$$

The following Eq. 8 reveals the minimum value of the objective functions to choose the fitness value of the first particle.

$$FF[1] = Min(PP1,PP2,PP3) \quad (8)$$

Step 4: Repeat Steps 1 to 3 until reaches the PS.

Step 5: The result of the first iteration is to choose a minimum value of a particle, which is assigned as a global best (gbest) position of particle (GXID[][]).

Stage4-determination of new position and velocity of particles:

Step 1: Determine the absolute difference between XID[ ][ ] and GXID[ ][ ] of each particle.

Step 2: Formulate two sets of random numbers (R1 and R2) within the allowable deviation. The size of R1 [ ] and R2 [ ] are same as the particle size (PS).

Step 3: The underneath Equations (9 and 10) are used to ascertain the values of T1 [][] and T2[][] for the individual parameters XID[ ][1] ….[] (Veitkamp and Tanase 2000).

For parameter QP1:

$$T1[][] = C1\times R1[][]\times Abs(XID[][]\text{-}GXID[][]) \quad (9)$$

$$T2[][] = C2\times R2[][]\times Abs(XID[][] - PXID[][]) \quad (10)$$

Set W(Weight factor) as (0.9-C)/ itr+1

where, C is assumed as 0.5 after sensitivity analysis and itr is the current iteration number.

The underneath equation(11) are used to determine the new velocity of the particle (NVID[ ][ ]) and new position of the particle (NXID[ ][ ]):

$$\begin{aligned}NVID[][] &= (VID[][]\times W) + T1[][] + T2[][]\\ NXID[][] &= XID[][] + NVID[][]\\ NVID[][] &= Remainder\left(NXID[][]/Deviation\right)\end{aligned} \quad (11)$$

Similarly, calculate for the parameters QP2 and QP3.

Stage 5-replacement: The NXID[][] and NVID[][] have been replaced by an existing XID[][] and VID[][] respectively. Let consider PXID [][] is GXID[ ][ ]. With the aforesaid stages, the result of the retrieval image is concluded. Repeat the above stages I to V upto 'ni' number of iterations. The assumed other PSO parameters tabulated in Table 2.

RESULTS AND DISCUSSION

To analyze the retrieval performance, the following feature combinations are used in the above proposed approach:

- Region and mean value
- Region and standard deviation
- Region, mean and standard deviation

For all the CBIR experiments, MATLAB programming environment is used. The average computation time (ACT) is defined as the time (seconds) taken for retrieval of each iteration. It is obtained on Windows 7 platform of Laptop with 2.30 GHz Intel(R) Core™ i5 Processor and 4 GB RAM. To depict the effectiveness of the proposed methods, the results of 11 sample images are reported in this present work. In the experiments, 1300 different sizes of images have chosen including 11 categories. The retrieval performance can be defined in terms of precision. It is defined as the ratio of the number of relevant images retrieved (N_r) to the number of total retrieved images (K) in Eq. 12.

$$\text{Precision} = N_r / K \tag{12}$$

Table 3 shows the performance measures of the proposed heuristic PSO for the above combination of features. Figure 5 and 6 represent image vs. precision chart and image vs. ACT chart for the same.

Table 4 shows performance measures of the proposed heuristic approach and existing genetic algorithm method developed by (Lai and Chen, 2009). From this table, it is observed that the precision value is high for some categories such as Dinosaur, Bike, Rose, Ketch, Car and Airplane. Since, the region can be identified easily. For other categories, background image dominates the foreground image. Figure 7 and 8 represent Image vs. precision graph and image vs ACT for existing and proposed heuristic approach, respectively.

Table 2: PSO Parameters value

Particulars	Value/method
Particle Size	20
Value of Constant C	0.5
Value of Constant C1, C2	2
Replacement strategy	Complete replacement
Stopping criteria	100 iterations or no change in 25 subsequent iteration fitness value

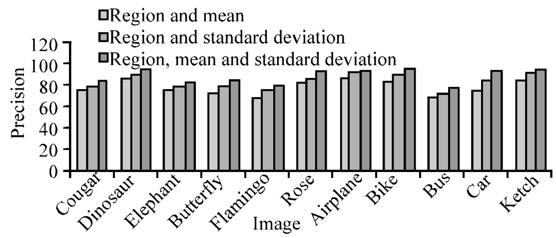

Fig. 5: Image vs. Precision comparison Graph for Heuristic PSO

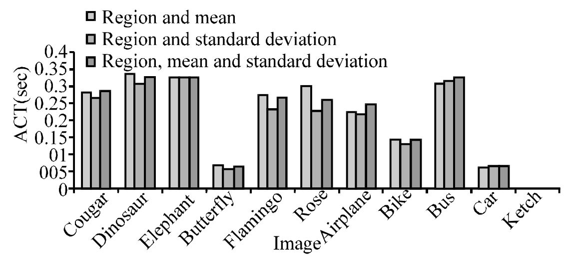

Fig. 6: Image vs. ACT comparison Graph for Heuristic PSO

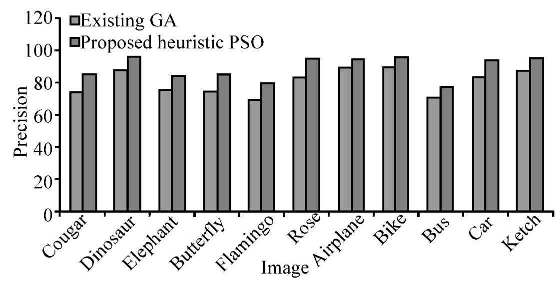

Fig. 7: Images vs. Precision Graph for Existing GA and Proposed Heuristic PSO

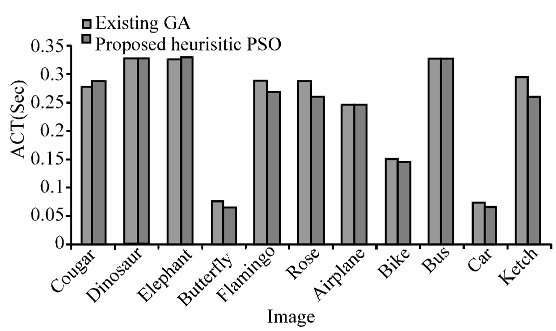

Fig. 8: Images vs. ACT Graph for Existing GA and Proposed HeuristicPSO

Table 3: Performance metrics of Heuristic PSO

	No. of iterations = 100, Population size = 20					
	Region and mean		Region and standard deviation		Region, mean and standard deviation	
Images	Pre	ACT (sec)	Pre	ACT (sec)	Pre	ACT (sec)
Cougar	75	0.2810	80	0.2663	85	0.2860
Dinosaur	86	0.3358	91	0.3070	96	0.3257
Elephant	75	0.3276	79	0.3271	84	0.3275
Butterfly	72	0.0714	79	0.0607	85	0.0643
Flamingo	69	0.2760	75	0.2364	79	0.2664
Rose	83	0.2970	87	0.2264	95	0.2594
Airplane	87	0.2222	93	0.2170	94	0.2430
Bike	83	0.1426	91	0.1344	96	0.1440
Bus	68	0.3059	72	0.3144	77	0.3274
Car	76	0.0638	85	0.0668	94	0.0648
Ketch	85	0.2539	92	0.2478	95	0.2576

Table 4: Performance metrics of existing and proposed heuristic

	No. of iterations = 100, Population size = 20			
	Existing GA method; Entropy, mean and standard deviation		Proposed heuristic PSO; Region, mean and standard deviation	
Image	Precision	ACT (sec)	Precision	ACT (sec)
Cougar	74	0.2760	85	0.2860
Dinosaur	88	0.3258	96	0.3257
Elephant	75	0.3288	84	0.3275
Butterfly	74	0.0730	85	0.0643
flamingo	69	0.2860	79	0.2664
Rose	83	0.2870	95	0.2594
Airplane	89	0.2422	94	0.2430
Bike	89	0.1496	96	0.1440
Bus	70	0.3259	77	0.3274
Car	83	0.0738	94	0.0648
Ketch	87	0.2939	95	0.2576

CONCLUSION

In this study, an approach for region identification and color image retrieval has been discussed. Regions are identified by Dirac function. The mean and standard deviation value of Red, Green and Blue are used as color information of an image. In particular, the heuristic approach along with PSO used to search interrelated images. Experimental results have exposed that the performance of the proposed approach is significant. precision and reduces computation complexity.

In this CBIR system, equal weightage of three attributes have chosen as a feature vector for image representation. Despite this, more low-level image descriptors (e.g. color, texture, shape etc.) may be considered as feature vector for image representation Based on the property of features, due weightage may be given. Other optimization techniques such as Tabu Search, Ants Colony Algorithm etc. may be considered to measure the similarity between query and database images for indexing and retrieval.

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