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Image Retrieval using GA Optimized Gabor Filter

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Abstract

Objective: A Hybrid content based image retrieval method is proposed in this paper. This method extracts color, tuned texture and shape features of the images in three successive phases. **Methodology:** In proposed system, color features are extracted using color histogram method in the first phase. The tuned texture features are extracted by employing GA optimized Gabor filters in second phase. Finally, shape features are extracted using the polygonal fitting algorithm. The best match output images of each phase are given as input images to the next phase to obtain 'S' best match images out of 'N' database images. **Findings**: The novelty of proposed system is that it employs a tunable filter that is tuned with the query image dynamically. The tuning of Gabor filter is implemented using GA in second phase. The proposed method shows improved retrieval rate in terms of average recall and average precision compared to the existing systems. The computation complexity is also found to be less than other existing methods. **Applications**: It can be employed in numerous fields such as medical, satellite, multimedia, and surveillance imaging systems, etc. where the retrieval of related images from huge databases is critical task for analysis.

Keywords: Gabor Filter, Genetic Algorithm (GA), Image Retrieval

1. Introduction

Research on image retrieval has turned to be much substantial throughout the previous decade. Enormous research on image retrieval has been done by many academicians, scientists and scholars to improve the efficiency of retrieval systems in terms of performance based on average precision and average recall. Content Based Image Retrieval (CBIR) system possibly will be able to derive perceptible features of images and retrieve desired image from the database of several images. An image retrieval scheme[1] has been proposed by the integration of color, texture and shape features and similarity between these three features are considered for retrieval. A programmed retrieval[2] of the images out of a database incorporating the features of color and shape has been presented. Derivation of digital images depending on the color feature from chosen database can be comprehended basing on the theory of color and the illustration of color is done using color histogram method. Multi model bio metric based authentication is used for human recognition using face, finger, palm print and iris[3]. An image retrieval method[4] with non-uniform quantized color histogram for representation and indexing the images utilizes perceptible features like texture, color, shape and spatial layout.

A retrieval system[5] elucidating the retrieving process of the images depending on two novel features has been presented. The retrieval method[6] that investigates the results of various Gabor filter parameters making use

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of texture feature has been proposed. A medical image retrieval system[7] using discrete sine transform and boosting classification techniques has been suggested.

In this paper a Hybrid Content Based Image Retrieval (HCBIR) system using optimized Gabor filter is proposed. It comprises three phases. After conducting numerous simulation experiments, the order for the retrieval at each phase is recommended to be color, texture and shape so as to improve efficiency of the method[8]. Henceforth, the order of feature extraction is maintained in the proposed method to retrieve the images at each phase. In the first phase, the color features are extracted out of the database of several images. In second phase, Gabor filter is presented for texture feature extraction. The Gabor filter parameters are tuned using Genetic Algorithm (GA) to get minimum energy in the given range of α_X, α_Y, f and γ for the query image. Instead of computing a large number of texture features using traditional Gabor filter, four Gabor filters are tuned simultaneously in the desired orientation and four features are extracted in each direction. In the third phase, shape features are extracted using the polygonal fitting algorithm. The proposed method not only improves maximum average recall and average precision rate but also reduces computation complexity involved in the retrieval system.

The organization of paper is as follows: The review of Gabor filter, Genetic algorithm and features of tuned Gabor filter for image retrieval are given in Section 2. The block diagram depicting the architecture of the proposed system and particulars of obtaining the feature extraction method is presented in Section 3. We present the experimental assessment and results in Section 4. We conclude the paper in Section 5.

2. Gabor Filter

Gabor defined 1D Gabor function and Daugman extended it to 2D. A 2D Gabor filter is obtained by successive multiplication of two 1D Gabor filters. The 1D Gabor is a complex sinusoidal function and is expressed as

$$G(x,y) = g(x,y).\ [\cos(2\pi f(x\cos\emptyset + y\sin\emptyset)) + j\sin(2\pi f(x\cos\emptyset + y\sin\emptyset))] \quad (1)$$

Where $G(x,y)$ is a complex function with real (Re) and imaginary (Im) parts with variable parameters as signal frequency f and its orientation $\emptyset$.

The 2D Gaussian function $g(x,y)$ is given by

$$g(x,y) = \left(\frac{1}{\sqrt{2\pi}\sigma_x} e^{\frac{-x^2}{2\sigma_x^2}}\right)\left(\frac{1}{\sqrt{2\pi}\sigma_y} e^{\frac{-y^2}{2\sigma_y^2}}\right) \quad (2)$$

Where σ_x and σ_y are scale parameters.

Now, the 2D gray image 'Ig' is convolved with the real and imaginary parts of the 2D Gabor filter of the Equation (1). This can be mathematically characterized by the following equations.

$$G_{Re}(x,y) = \sum_{p=-k}^{k}\sum_{q=-k}^{k} Ig(x+p, y+q).\ Re(p,q) \quad (3)$$

$$G_{Im}(x,y) = \sum_{p=-k}^{k}\sum_{q=-k}^{k} Ig(x+p, y+q).\ Im(p,q) \quad (4)$$

The energy of the filtered output can be obtained by the following equation

$$E(x,y) = G_{Re}^2(x,y) + G_{Im}^2(x,y) \quad (5)$$

2.1 Genetic Algorithm

Genetic algorithm has been a great part of current automatic machine learning algorithms. It uses reasonably less computational affects to resolve many difficult problems using biological evolution. The retrieval model proposed in this paper can be treated as a multi variable

unconstraint optimization problem in which all the four parameters are concurrently varied thereby maintaining the solution with in a feasible search area and ultimately search for the optimal solution[9]. The original population is iteratively processed using the three operators namely selection, crossover and mutation until the termination condition is met. One iteration of these three operators is known as a generation.

Selection: This operator selects good strings from existing population in a probabilistic way to form a mating pool with maximum good strings.

Crossover: Single point crossover is used in this model where a new child string is formed by selecting two parent strings from the mating pool and exchanging some portion of the bits between them.

Mutation: The mutation operator is used to perform local search of solution around the selected string.

Termination: This is done by making a bit one to zero or zero to one probabilistically. The termination can be based on number of iterations or when specified threshold energy is met. This retrieval model termination is done basing on number of iterations.

2.2 Gabor Optimized Filter using Genetic Algorithm

Commonly in most of the retrieval systems, the Gabor parameters (orientation, scale and frequency) are selected to be constant and the features are extracted in different scale and orientations. Assume there are 1000 images in a database. If Gabor filter feature is extracted in a scale of 5 and orientation of 6, it gives a total of 30 features after convolving Gabor filter with query image 30 times. Then in the retrieval stage, the Gabor filter features are extracted again with respect to all the database images. This involves convolving Gabor filter 30 times with all the thousand images in the database. Accordingly, a total of 30000 convolutions are required to extract the features which encompasses more number of computations.

To solve this problem, a tuned Gabor filter is incorporated for the image retrieval. The Gabor filter parameters are selected using Genetic algorithm by optimizing fitness function as energy response obtained after convolving Gabor filter with the query image. Here four Gabor filters are tuned with a query image in four ranges of orientation ($0<\theta<45$, $46<\theta<90$, $91<\theta<135$, $136<\theta<180$). As a result, specific tuned Gabor filter parameters P_i are obtained in four ranges of orientation.

The four tuned filter thus obtained is tuned with the query image for extracting the features from each database image. Here a total of four features are extracted from each database image making it up to a sum of 4000 features that are being extracted from the database. Obviously, this shows a considerable reduction regarding the computational complexity and also it is evident that the result obtained with this model has improved average precision and average recall.

3. Proposed Work

A new Hybrid Content Based Image Retrieval (HCBIR) system is developed by combining color, texture and shape features of an image. In this system, retrieval is done in three phases as shown in Figure 1. Considering database of 'N' images, best matched 'C' images are retrieved by the color feature extraction using color histogram in the first phase. The retrieved images from the first phase are given as input database for the second phase. In this phase, texture feature extraction has been done using four channel tuned Gabor filter and the best matched 'G' images are retrieved. The set of output images retrieved in the second phase are selected as input database for the third phase, where shape features is extracted using the polygonal fitting algorithm. Irrelevant images at each stage are removed in this manner which makes the retrieval system fast and simple.

The relationship between the total database 'N' and images retrieved at each phase is given by

$$N > C > G > S \quad (6)$$

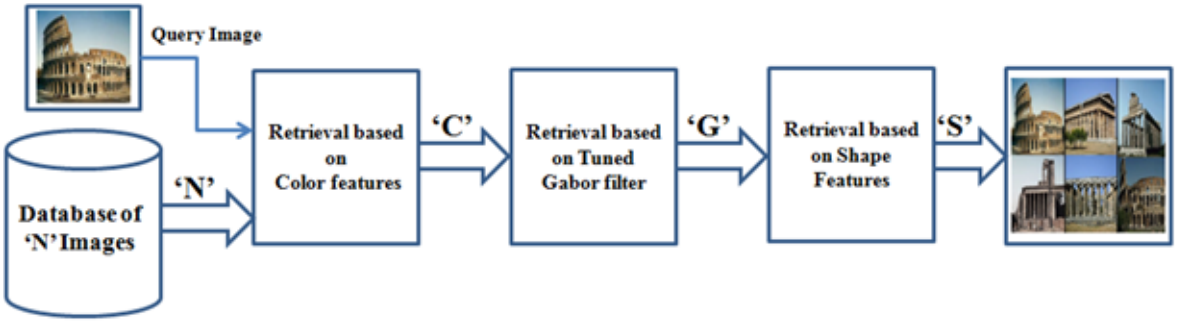

Figure 1. Block diagram of proposed retrieval system.

3.1 Color Feature Extraction(Phase-I)

This feature plays a very significant role in human perception mechanism. It is easy to analyze and widely used feature in HCBIR. Color is invariant to the size, orientation, rotation and other transformations of the image. Color can be retrieved by using many methods such as Conventional Color Histogram (CCH), Color Histogram (CH), Color Correlogram (CC) and Color shape based feature. In this paper, color histogram is used to retrieve color information from a huge dataset. This is simple and most frequently used method. HSV color space is used to extract the color component of the image. The obtained color components are more in number leading to processing overhead. This can be reduced by quantizing the HSV values.

For retrieving C images from a database of N images, we calculate the HSV histograms of query image and database images[10] for 32 bin and similarity between the query image and the database images is computed based on the distance measure (Db_i). These 'C' images are used as input images for Stage 2. The procedure for distance measure is

Step 1: Compute histograms of query image Q_h [0,..n-1] and each database image Db_h [0,...n-1].

Step 2:Q_h = hsvhist(query image) and Db_h =hsvhist(Db_{hi})

Where i=i^{th} image of the database.

Step 3: $$Db_i = \frac{Temp}{\min(hmod, gmod)} \quad (7)$$

Where hmod = $$\sqrt{\left(\mathbf{sum}(Q_h .* Q_h)\right)}$$

gmod = $$\sqrt{\left(\mathbf{sum}(Db_h .* Db_h)\right)}$$

Temp = sum (min([(Q_h ,Db]_h)))

Where Q_h and Db_h are quantized color histograms[11] and Db_i is sorted in ascending order to select the first 'C' images having highest distance metrics.

3.2 Texture Feature Extraction (Phase II)

Texture feature is one of the essential features in systems associated with image retrieval. It contributes the statistics regarding the relationship between the pixels in a specific region of the image or pixels in whole image. The design of Gabor filter bank[12] by applying genetic algorithms for maximum discrimination of texture features has already been done. Image features extraction depending on human emotion was presented by employing wavelet transform and an interactive genetic algorithm[13]. An evolutionary group

algorithm[14] was proposed to search optimum parameters to overcome complex time taking optimization problems. A genetic programming framework[15] has been applied for image retrieval and later frameworks based on relevance feedback[16] were presented to exploit the appropriate and non-relevant images.

The Gabor filter in which different orientation, scale and frequency are chosen to extract the feature of each image is adopted by most of the researchers because of its separable property and texture invariation to obtain texture features out of the database for image retrieval[17]. An offline devnagari handwritten numeral recognition system was presented using Gabor filter[18]. Feature extraction by applying genetic algorithm and scale invariant feature transformation[19] has been proposed. The automatic recognition of deviation in the patient's magnetic response image[20] has been proposed by making use of Gabor filter and wavelet transform.

In this paper, a four channel optimized Gabor filter shown in Figure 2, is utilized to extract the texture feature. Here Gabor parameters in the specified range are tuned to get minimum energy. In this four channel optimized Gabor filter, each channel is optimized in the specified orientation, frequency and scale. This leads to four different sets of parameters and these parameters are specific to the query image. These parameters are used for obtaining similar images out of the database by computing the energies for every database image. For each database image four energies are computed as E_{Dbij} a Feature set where j=1, 2, 3, 4 and i=1 to 1000. So a total of 'C' feature sets are computed. The energy expression is given in equation (5).So the total features extracted in this phase is C*4. Now the 'G' best match

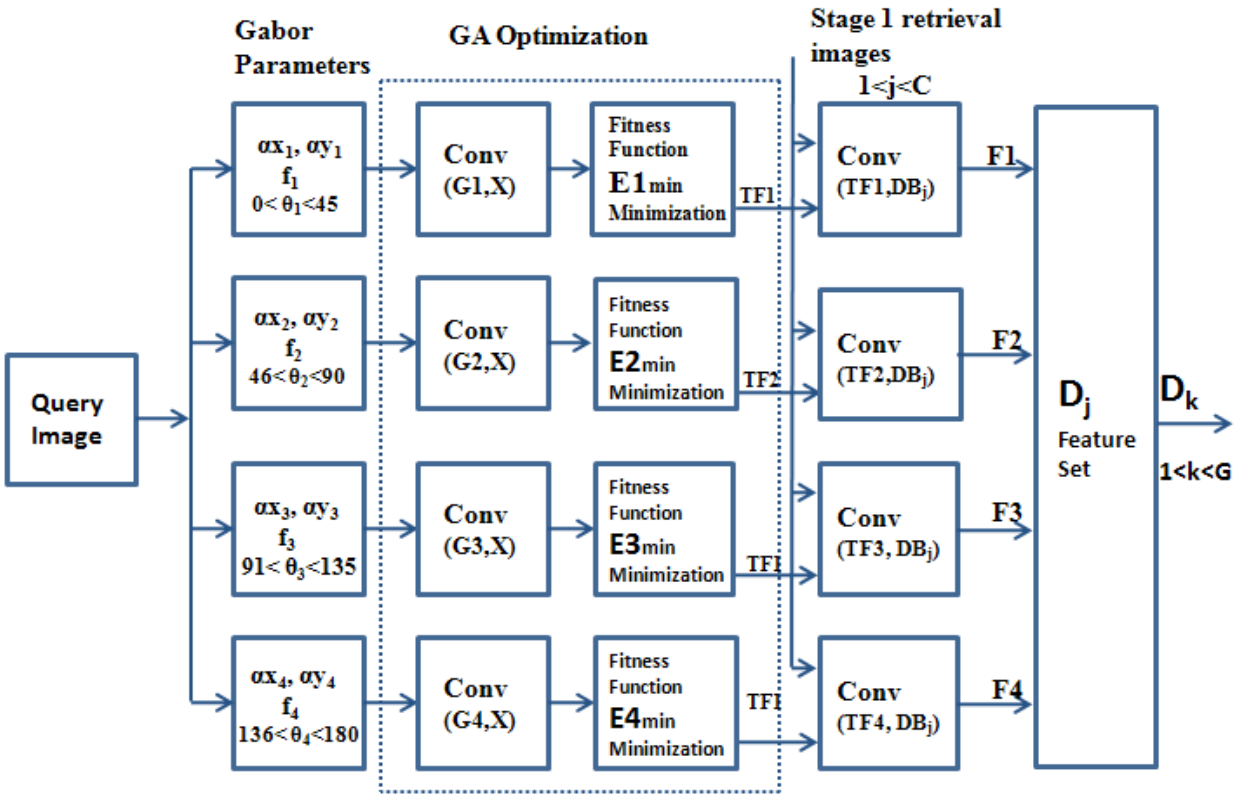

Figure 2. A four channel optimized Gabor filter.

images are retrieved by selecting the first 'G' minimum distances computed based on the distance metrics d_{min} which is given by the following equation

$$d_{min} = \sqrt{\sum_{i=1}^{4} (E_{Qi} - E_{Dbij})^2} \quad (8)$$

Where,

E_{Dbij} represent the i^{th} energy of the feature set of the j^{th} image

E_{Qi} represent the i^{th} energy of the query image feature set.

3.3 Shape Feature Extraction (Phase III)

Shape feature provides the most major semantic information regarding an image. Shape features are usually described using a part or region of an image. The accuracy of shape features mainly depends on the method used to divide an image into significant objects. The Shape features are extracted from the normalized coefficients of the shape signature r(t), where r(t) is 1D shape signature obtained from the extracted boundary coordinates of the maximum connected shape in the binarized image[21].

If the shape vector features of the query image is F_{sQi} and the shape vector feature of the each database image is F_{sDbi} then the distance metric used to select the best match image can be given by the following equation

$$d = \sqrt{\sum_{i=0}^{N-1} |F_{sQi} - F_{sDbi}|^2} \quad (9)$$

The distance vector is calculated for the query image and each 'G' database images obtained in the second phase, out of which the first minimum 'S' images are selected as the best matched images. In this manner, the three successive phases make the proposed system more efficient than the traditional retrieval methods which employ Gabor filter with blind convolution.

4. Experimental Results

This segment illustrates the investigational estimation of proposed model. The execution of the model is done using COREL database[22] in MATLAB.

The database comprises 100 natural images incorporated within each of the 10 groups making it a total of 1000 regular images. The different groups include Dinosaurs, African people, Buses, Beaches, Elephants, Buildings, Flowers, Foods, Mountains and Horses respectively. The depiction of each of these groups is done through sample images as displayed in Figure 3.The query image is portrayed in the Figure 4.

The exactitude of the proposed retrieval model is limited by values of C, G and S and hence suitable attention is ensured in choosing these parameters. The value of N is taken as the numerical value of total images taken in

Figure 3. Sample images depicting each category of COREL database.

Figure 4. Query image.

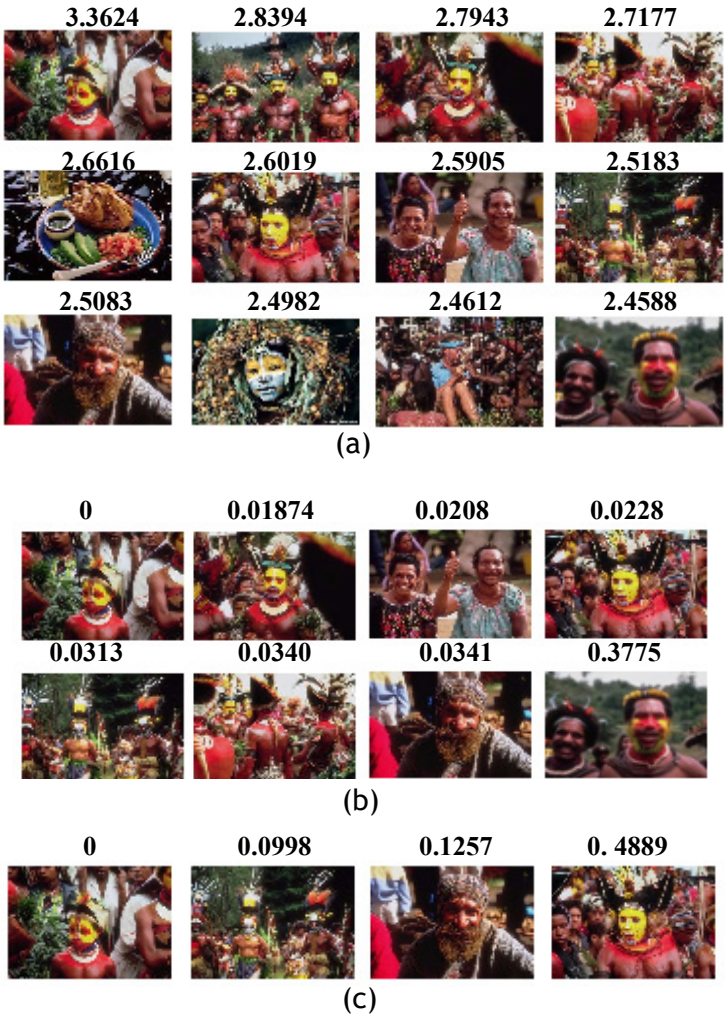

Figure 5. In-place computation results for each phase. (a) Result of first phase with C = 12. (b) Result of second phase with G = 8. (c) Final result of system with S = 4.

the database .The values of C, G and S are chosen to be 12, 8 and 4 respectively. The values of C and G are fixed manually by the user. The model can be further improved by selecting the values of C, G and S by varying values and taking results of average precision as well as average recall.

The retrieval results at every stage are depicted in Figure 5, by setting the value of C, G and S to 12, 8 and 4 correspondingly. At every single stage, the irrelevant images are filtered evidently thereby tapering down the search range. This results in making the basic level characteristics to depict the intention of the user.

The performance of the model is evaluated based on average precision and average recall. The ratio of the numerical value of relevant images retrieved to the numerical value of total images retrieved is defined as Precision, P.

$$P = \frac{Number\ of\ relevant\ images\ retrieved(r)}{Total\ number\ of\ images\ retrieved} \quad (10)$$

Table 1. Comparison of average precision of the proposed and other models

Category ID	Class	Proposed Method	Nishantet.al[8]	Huang et.al[5]
1	Dinosaurs	1.000	1.000	0.581
2	African people	0.753	0.736	0.424
3	Buses	0.813	0.789	0.846
4	Beaches	0.586	0.581	0.456
5	Elephants	0.756	0.726	0.429
6	Buildings	0.627	0.617	0.401
7	Flowers	0.875	0.903	0.895
8	Food	0.881	0.747	0.426
9	Mountains	0.681	0.538	0.267
10	Horses	0.898	0.813	0.585
Average		0.787	0.745	0.531

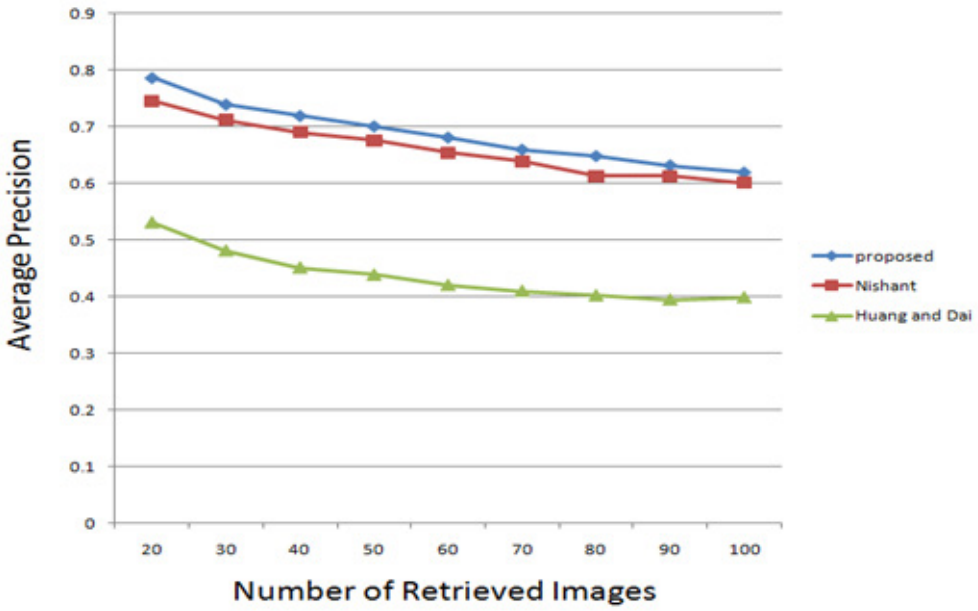

Figure 6. Comparison of average precision among different models.

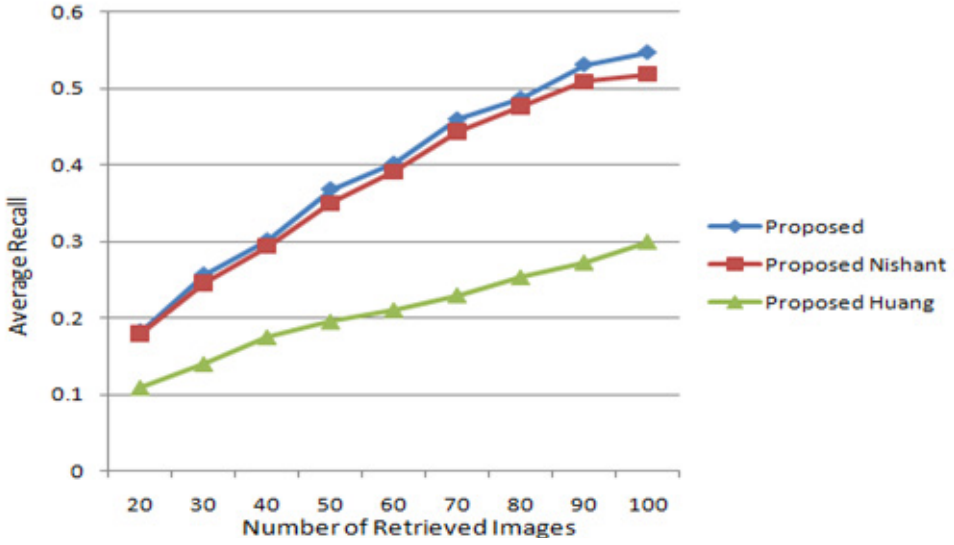

Figure 7. Comparison of average recall among different models.

The numerical value of relevant images retrieved divided by the numerical value of total relevant images in the whole database is defined as Recall, R.

$$R = \frac{Number\ of\ relevant\ images\ retrieved(r)}{Number\ of\ relevant\ images\ in\ the\ database(N)} \quad (11)$$

The proposed retrieval model is assessed by considering every single image in each group as the query image by taking the value of S=20. By making use of the retrieval outcomes of each of these images, the performance of the model is evaluated for each group.

Table 1 displays the experimental results obtained using proposed retrieval model and the other two models. It is revealed that the proposed retrieval model shows improved average precision than existing models in each group except for 'Flowers' group. Nevertheless by prudently choosing the values of C, G and S, the average precision can be enhanced for 'Flowers' group.

The average precision of the proposed retrieval model and existing models by varying the values of L from 20 to 100 is shown in Figure 6. Figure 7 demonstrates the average recall under the same conditions. The investigational results disclose that the proposed retrieval model is an enhanced model compared to the other existing models..

5. Conclusion

Image retrieval proved to be an active area of exploration in the past decade. In proposed work, a color histogram is used primarily for image retrieval depending on color. It has shown that the use of tuned Gabor filter for texture feature extraction has great impact on average precision and average recall when compared with the traditional Gabor filter methods. The tuned Gabor implemented in this paper is obtained using evolutionary Genetic algorithm. The results can be further improved by using particle swarm optimization and other optimization techniques. Fourier descriptor is used in the final stage of implementation for shape feature extraction which can be further replaced with wavelet descriptor. In this proposed method, it is shown that the average precision and average recall are improved at less computational complexity.

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