An Improved Technique of CBIR using Gabor Filter and Genetic Algorithm

Satish Tunga, D Jayadevappa & C. Gururaj

Abstract— Content Based Image Retrieval (CBIR) system attains interest in image processing domain from past years due to its optimized applications. In order to retrieve images efficiently from a large database, an improved approach of integrating color and texture features using Gabor filter and genetic algorithm has been proposed. In this paper the image data is pre-processed and then we extract Gabor and shape based features. Genetic Algorithm has been used to investigate to refine the results such that, they are similar to query image features given by users. The implemented results shows that the proposed method gives higher retrieval accuracy compared to the traditional methods of image retrieval that use color, texture and shape features only for retrieving images.

Index Terms— *Image retrieval*, *Genetic algorithm*, *Gabor filter*, Morphological operation, image features, similarity measures, texture.

1 Introduction

THE Content based Image retrieval (CBIR) is the processing of searching and retrieving images from a huge dataset. CBIR [1] deals with retrieval of similar images from a large database for a given input query image. A large number of diverse methods have been proposed for CBIR using low level image content like edge, color and texture. For combination of different types of content, there is a need to train these features with different weights to achieve good results. In the past most of the images retrieval is text based which means searching is based on that keyword [2]. The text-based image retrieval systems only concern about the text described by humans, instead of looking into the content of images. Images become a replica of what human has seen since birth, and this limits the images retrieval. To overcome the limitations of text-based image retrieval, CBIR was introduced [2]. With extracting the images features, CBIR perform well than other methods in searching, browsing and content mining etc. The need to extract useful information from the raw data becomes important and widely discussed. Although many research improvements and discussions about those issues, still many difficulties haven't been solved.

Gabor filter proves to be very useful texture analysis and is widely used in the literature. Texture features are found by calculating the mean and variation of the Gabor filtered image. Gabor filter or Gabor wavelet is widely used to extract texture features from the images for image retrieval [3], [4], and has been shown to be very efficient. Gabor filter have shown that image retrieval using Gabor features outperforms that using pyramid-structured wavelet transform features. Basically, Gabor filters are a group of wavelets, with each wavelet capturing energy at a specific frequency and a specific direction. Expanding a signal using this basis provides a localized frequency description, therefore capturing local features/energy of the signal. Texture features can then be extracted from this group of energy distributions. The flexibility of scaling and orientation property of Gabor filter makes it especially useful for texture analysis.

Genetic algorithm (GA) frequently used as an optimization method, based on an analogy to the process of natural selection in biology. The biological basis for the adaptation process is evolution from one generation to the next, based on elimination of weak elements and retention of optimal and near-optimal elements. In a genetic algorithm approach, a solution is called a chromosome or string. A genetic algorithm approach requires a population of chromosomes representing a combination of features from the solution set, and requires an evaluation or fitness function. Genetic algorithm is an effective feature selection approach [5] and was used for finding the optimization weight in order to obtain better image retrieval results. An optimum weighted Manhattan distance function [6] was designed using GA to select a set of suitable regions for the feature extraction. Before applying genetic algorithm to a particular problem, certain decision has to be made to find a suitable gene for solving the problem, i.e., chromosome representation. Chromosome is a collection of genes. In this proposed work, chromosomes are mentioned as two types of image features i.e., color and texture.

2 Related Work

Currently, most techniques make an explicit or implicit assumption that all the images are captured under the same orientations.

In many practical applications such as image retrieval, objects recognition etc, such an assumption is unrealistic. Some other techniques carry out rotation normalization, but they are computationally demanding. A genetic programming framework and user oriented mechanism based on interactive genetic algorithm has been applied for image retrieval [7], [8].

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Color attributes like mean, standard deviation and image bitmap of color image are used as features for retrieval. In addition, Entropy based on Grey level co-occurrence matrix and edge histograms are considered as texture features. Using IGA improvement in retrieval performance can be obtained. The content based Kannada document image retrieval [9] has been proposed. Initially pre-processed an image to remove the noise present in the input image followed by segmentation.

Morphological operation is considered as repeated dilations of an image, called marker image, until the contour of the marker image fits under a second image, called the mask image. Gabor and shape based features are extracted from the training images to match features of query image. A technique to combine image similarity measures [10] were introduced which takes into account a particular query image. They introduced mixed-metrics obtained from colour and texture metrics by using their weighted linear combination. In Gabor filters [11] each wavelet captures energy at a specific frequency and at a specific orientation. Gabor filter is used for texture analysis due to its scale and orientation tunable property. The problem with color moment is that it does not encode any spatial information. To solve this, we divide the image horizontally into three equal sub images. Then from each sub image, the first two moments (mean, standard deviation) of each color channel is extracted. Texture refers to the visual patterns that have properties of homogeneity [12] and it is a natural property of virtually all surfaces. It contains important information about the structural arrangement of surfaces and their relationship to their surrounding environment.

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 work because of its separable property and texture in- variation to obtain texture features out of the database for image retrieval. An offline devnagari handwritten numeral recognition system was presented using Gabor filter [13]. Feature extraction by applying genetic algorithm and scale invariant feature transformation [14] has been proposed. The automatic recognition of deviation in the patient's magnetic response image [15] has been proposed by making use of Gabor filter. In this work, a four channel optimized Gabor filter [16], [17] is utilized to extract the texture feature. Gabor parameters in the specified range are tuned to get minimum energy. In this 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.

3 Materials and Methods

3.1 Gabor Filter

Gabor filter is a linear filter that acts as band pass spatial filter with the ability to tune to certain orientation and spatial frequency. A 2-D Gabor filter is an oriented complex sinusoidal defined by a 2-D Gaussian function, which is given by

$$G_{\sigma,\phi,\theta}(x,y) = g_{\sigma}(x,y).\exp[2\pi j\phi(x\cos\theta + y\sin\theta)] \quad (1)$$

Where

$$G_{\sigma,\phi,\theta}(x,y) = \frac{1}{2\pi\sigma^2}\exp[-(x^2+y^2/2\sigma^2] = \frac{1}{2\pi}\sigma^2]$$

and $j = \sqrt{-1}$

The frequency and orientation of the span-limited sinusoidal grating are given by ϕ and θ respectively. $G_{\sigma,\phi,\theta}(x,y)$ is the Gaussian function with scale parameter σ. For more complicated texture patterns, asymmetric Gaussian function may be needed. The parameters of a Gabor filter are, therefore, given by the frequency ϕ, the orientation θ and the scale σ.

The Gabor filter $G_{\sigma,\phi,\theta}(x,y)$ forms a complex valued function. Decomposing $G_{\sigma,\phi,\theta}(x,y)$ into real and imaginary parts gives

$$G_{\sigma,\phi,\theta}(x,y) = R_{\sigma,\phi,\theta}(x,y) + jI_{\sigma,\phi,\theta}(x,y) \quad (2)$$

where

$$R_{\sigma,\phi,\theta}(x,y) = g_{\sigma}(x,y).\cos[2\pi\phi(x\cos\theta + y\sin\theta)$$

$$I_{\sigma,\phi,\theta}(x,y) = g_{\sigma}(x,y).\sin[2\pi\phi(x\cos\theta + y\sin\theta)$$

The Gabor filter output of a gray level image $f(x,y)$ is obtained by the convolution of the image with the Gabor filter $G_{\sigma,\phi,\theta}(u,v)$ i.e.

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x+u,y+v).G_{\sigma,\phi,\theta}(u,v) \quad (3)$$

Apply Gabor filters on the image with different orientation at different scale to obtain an array of magnitudes. Given a neighborhood window of size WXW with $W = 2k+1$ the discrete convolutions of $f(x,y)$ with respective real and imaginary components of $G_{\sigma,\phi,\theta}(x,y)$ are

$$G_R(x,y\mathrm{I}\sigma,\phi,\theta) = \sum_{l=-k}^{k}\sum_{m=-k}^{k} f(x+l,y+m).R_{\sigma,\phi,\theta}(l,m) \quad (4)$$

and

$$G_I(x,y\mathrm{I}\sigma,\phi,\theta) = \sum_{l=-k}^{k}\sum_{m=-k}^{k} f(x+l,y+m).I_{\sigma,\phi,\theta}(l,m) \quad (5)$$

Define the energy $E(x,y)\mathrm{I}\sigma,\phi,\theta)$ at (x,y) within the window WXW as

$$E(x,y\mathrm{I}\sigma,\phi,\theta) = G_R^2(x,y\mathrm{I}\sigma,\phi,\theta) + G_I^2(x,y\mathrm{I}\sigma,\phi,\theta) \quad (6)$$

These magnitudes are the energy content at different scale and orientation of the image. Then the following mean and standard deviation of the magnitude of the transformed coefficients are used to represent the texture feature. The proposed Gabor filtering scheme is extended from gray-level texture images to colored texture images so that both chromatic and structural patterns of a texture can be simultaneously evaluated. Gabor based image retrieval technique gives the highest precision/recall crossover values specifying the best performance. The height of crossover point of precision and recall curves plays very important role in performance comparison of CBIR methods The following figure 1 illustrates the four channel optimized Gabor filter [16].

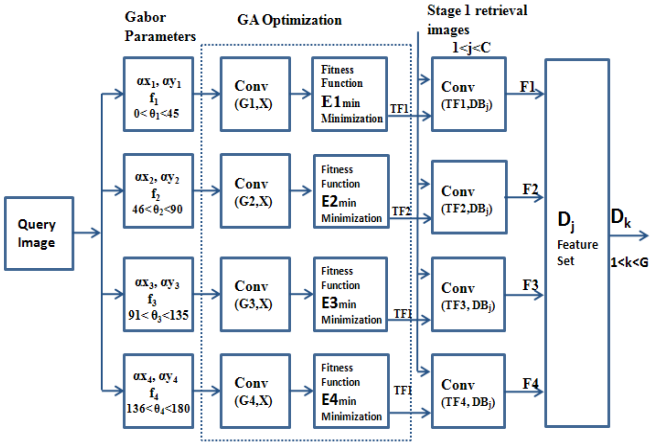

Fig. 1. Block diagram of a four channel optimized Gabor filter [16].

3.2 Genetic Algorithm

Genetic algorithm has been a great part of current automatic machine learning algorithms. The task of the GA consists of finding the weight that maximizes the retrieval accuracy to the context defined by the query image.In the design of automatic pattern classifiers, feature selection and extraction are significant in optimizing performance. It uses reasonably less computational effects to resolve many difficult problems using biological evolution. The retrieval model proposed in this paper can be treated as a multi variable parameters are concurrently varied thereby maintaining the solution with in a feasible search area.

Algorithm is starts with an initial population. Initial population is represented by chromosome, the chromosome of which is randomly generated. At start, the fitness function of each individual is evaluated. Two individuals having highest fitness value among all are selected from the population. These two individuals are called as parents and using crossover and mutation operators on parents' new individuals called children are formed. Figure 2 demonstrates the genetic algorithm.

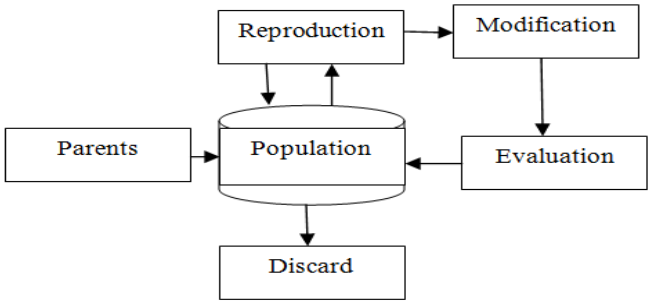

Fig. 2. Block diagram of the Genetic algorithm.

The following steps illustrate the simple steps of the genetic algorithm.

- **Begin** $(i = 0)$

INITIALIZE $(i = 0)$ population with arbitrary candidate solutions;

EVALUATE $S(i); i = i + 1$ each candidate;

Repeat

SELECT $S(i)$ from $S(i-1)$ parents;

CROSSOVER pairs of parents & MUTATE the resulting children using crossover probability and mutation probability.

EVALUATE children;

SELECT $S(i)$ individuals for the next generation until TERMINATION-CONDITION is satisfied.

End ▪

Using genetic algorithm the weights of colour feature similarity score and texture feature similarity score are assigned optimally. In genetic algorithm, the number of individuals in population and the initial values of the individuals will influence the solution greatly.

3.3 Proposed methodology

An improved technique of CBIR is developed by combining color, texture and shape features of an image. The main objective of this work is to combine low level features with high level concepts by unsupervised learning of genetic algorithm thus reducing the semantic gap between user's perception and the query. The frame work of the proposed is illustrated in the following figure 3.

In this system, retrieval is done in three phases as shown in figure 3. Considering database of 'N' images, 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 Gabor filter and the best matched 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 genetic algorithm. Irrelevant images at each stage are removed in this manner which makes the retrieval system fast and simple. Commonly in most of the retrieval systems, the Gabor parameters such as orientation, scale and frequency are selected to be constant and the features are extracted in different scale and orientations.

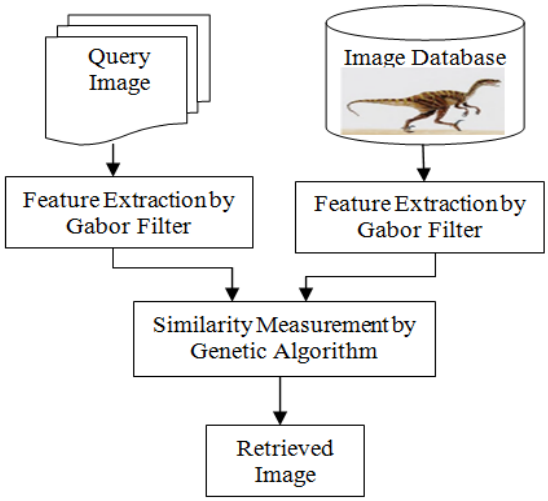

Fig. 3. Block diagram of the proposed framework.

Let us say there are 100 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. 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.

Genetic algorithm approach requires a population of chromosomes (strings) representing a combination of features from the solution set, and requires an evaluation or fitness function. This function computes the fitness of each chromosome. The algorithm manipulates a finite set of chromosomes (the population), based on the mechanism of evolution. The retrieved results are given to a genetic algorithm block and the original population is iteratively processed using the three operators namely selection, crossover and mutation until the termination condition is met.

Practically, user inputs a query image and initially feature extraction of all the database images of is performed. Feature extraction of query image is performed and similarity measurement using genetic algorithm is done and result is displayed. If user satisfied then result displayed is final result and searching get finished. Otherwise, user's feedback (explicit) is taken on retrieved result and similarity function is again calculated using genetic algorithm.

4 Experimental Results and Discussion

The proposed CBIR approach was implemented using Matlab. To show the effectiveness of the proposed system, extensive experiments were performed on image dataset. Results were compared against several existing approaches for CBIR. In this technique, dataset having 1000 images divided into 10 categories was used. These 1000 images are categorized into 10 classes where each class contains 100 images. The performance of the model is evaluated based on average precision and average recall. By making use of the retrieval outcomes of each of these images, the performance of the model is evaluated for each group.

The retrieval effectiveness can be defined in terms of average precision and average recall rates. Precision is the percentage of the number of retrieved similar images to the number of retrieved images, while recall is the ratio of the number of retrieved similar images to the entire number of similar images. The standard definitions of these two measures are given by following equations.

$$\Pr ecision = \frac{\text{Number of relevant images retrieved}}{\text{Total number of images retrieved}}$$

and

$$\text{Re}call = \frac{\text{Number of relevant images retrieved}}{\text{Total number of relevant images retrieved in database}}$$

The following figure 4 shows the Four query images that belong to four different classes of image data set.

Fig.4. Query images used for the proposed method.

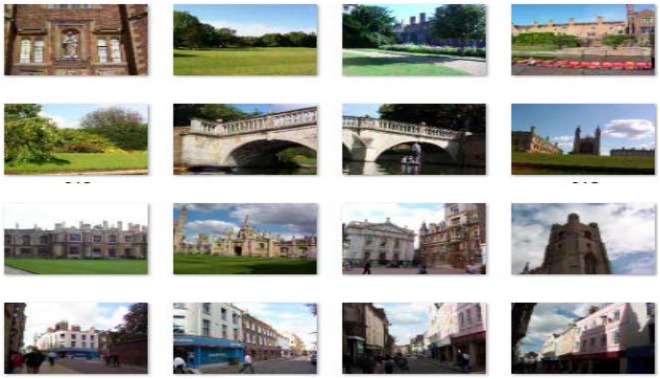
Fig. 5. Retrieval results for query image 1 using proposed method for Cambridge data set.


Fig. 6. Retrieval results for query image 2 using proposed method for Australia data set.


Fig. 7. Retrieval results for query image 3 using proposed method for Yellow stone data set.

Fig.8. Retrieval results for query image 4 using proposed method for Swish Mountains data set.

Precision and recall values plotted against number of retrieved images are shown in table I. It can be seen from the precision-recall values that, the proposed approach is comparable with existing techniques [16] and [17] and by combining Gabor filter scheme and genetic algorithm improves the effectiveness of the system. This improved retrieval rate greatly helps in large image collections. The proposed retrieval system is assessed by considering every single image in each group as To evaluate the effectiveness of the proposed system, we examined how many relevant images to the query images were retrieved by taking the values of N=20, 30, 40 and 50 respectively.

TABLE 1
COMPARISON OF PRECISION AND RECALL VALUES FOR THE PROPOSED APPROCH FOR VARIOUS NUMBER OF RETRIVED IMAGES

Query Images	Precision (%)				Recall (%)
	20	30	40	50	
Image 1	95	100	100	92	73
Image 2	95	100	95	100	94
Image 3	90	85	75	75	61
Image 4	95	95	95	97	85

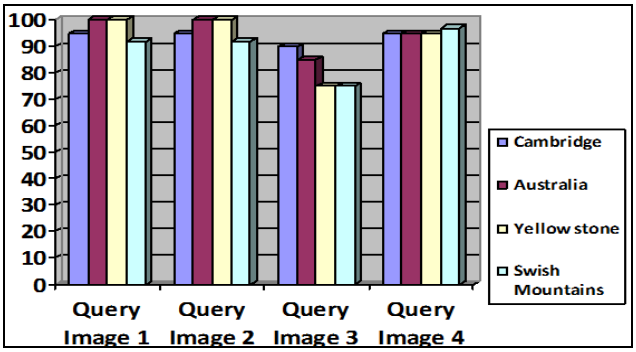

Fig. 9. Comparison of Precision (%) values for four query images.

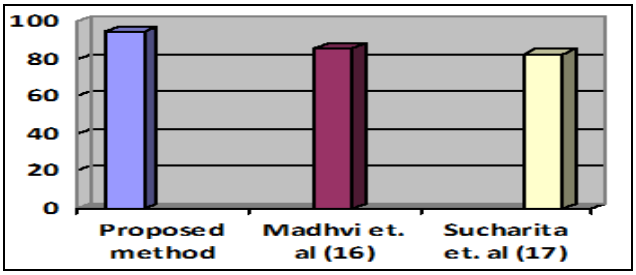

Fig. 10. Comparison of Precision (%) values of the proposed method with existing techniques.

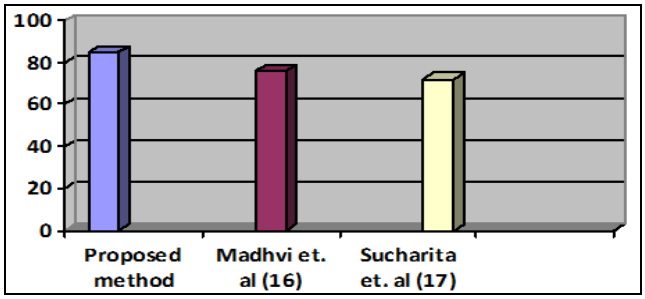

Fig. 11. Comparison of Recall (%) values of the proposed method with existing techniques.

The experimental results obtained using proposed retrieval approach and the other two existing methods. Figures 9 displays comparison of precision values for four query images. Figures 10 and 11demonstrates the comparison values of precision and recall values with the existing techniques. This comparison reveals that the proposed retrieval model shows the improved average precision and recall than existing models.

5 CONCLUSION

In the proposed approach, Content Based Image Retrieval System (CBIR) using Gabor filter and Genetic algorithm is giving higher Precision and Recall as compared to the CBIR technique using only Gabor magnitude features. The superiority of the system is because of the Gabor feature gives good response to texture of the image and makes it very clear and simple for genetic algorithm to retrieve the required image. In the paper, global texture features are extracted from the entire image, the extracted texture features are then used to measure the similarity between images. The retrieved results are further refined by using Genetic algorithm where images relevant to query are retrieved. Experiments demonstrate that the proposed system retrieves images which are from the same class to which the query belongs. For a query image, multiple similarity score lists based on different features are obtained. Then using genetic algorithm, better image retrieval results are gained. This approach needs to be validated by employing more visual features such as shape, spatial location etc., to provide the CBIR more robust and also the further reduction of computational complexity. These draw backs can be considered as future work.

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