Combined Application of Color Histogram and Wavelet Techniques for Content based Image Retrieval

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ABSTRACT
In this paper, we have proposed a novel method of content based image retrieval using combination of color histogram and wavelet techniques. We have used RGB color space to exploit the color features of image both for color histogram and wavelet decomposition of images. F-norm theory is used to extract features from wavelet transformed image. For histogram technique Euclidean distance is used and for wavelet technique F-norm theory based criteria is used to calculate similarity. We have shown that how individual techniques perform and have given approach to use both techniques in combination. Using recall rate it is shown that results have improved when both techniques are used together. We have also implemented the system in parallel and using speedup parameter it is shown that it has reduced the processing time making it practically useful in real world applications.

General Terms
CBIR, Content Based Image Retrieval

Keywords
CBIR, RGB, Histogram, Wavelets, Haar Wavelet, Parallel, Threads, Recall Rate etc

1. INTRODUCTION
CBIR or content based image retrieval is allowing the system to automatically extract out the features from the image and compare it with other images in database and retrieving results based on the similarity of the extracted features of query image with other images in database rather than the metadata associated with the image [1]. Now-a-days the image data is growing at a very rapid rate and manual annotation for all images is becoming more difficult. Moreover there are many limitations of manual annotation such as different names for same object, different emphasis laid by different persons for different objects in same image etc [2]. It makes CBIR demand more relevant and pragmatic. Many related works are already done in this field (e.g.: QBIC, Virage, Pichunter, visual SEEK, Chabot, Excalibur, photobook, Jacob) [3]. Content based image retrieval, which is allowing to automatically extract targets according to objective visual contents of image itself(e.g. color, texture and shape) has become increasingly attractive, in Multimedia Information Service System (MISS) [4]. With appealing time frequency localization and multi-scale properties, wavelet transform proved to be effective in visual feature extraction and representation [4]. The color feature is one of the most appealing feature of an image to human eyes [5]. Color feature is exploited by extracting out red, green and blue color information from the image by making their respective histograms. The images are compared using Euclidean distance between RGB histograms of the image and that of database images. The wavelet transform is a tool that cuts up data or functions or operators into different frequency components and then studies each component with a resolution matched to its scale [6]. In this paper, we used Haar wavelet transforms to decompose color images into multilevel scale and wavelet coefficients, with which we perform image feature extraction and similarity match by means of F-norm theory [7]. The efficiency in terms of recall rate and retrieval speed is tested with five types of images and the results reflect the importance of combination of coarse feature color and wavelets which divides the image into approximate and detail parts in CBIR. Both the techniques are also implemented in parallel to efficiently utilize the multicore processors.

The rest of this paper is organized as follows. In section 2, we introduced the general structure of the proposed CBIR system, and it provides the image decomposition using wavelets and color histograms. Section 3 describes feature extraction, similarity criteria and proposed combined retrieval strategy. Section 4 presents CBIR results using color histograms, wavelets and combined retrieval strategy. Finally conclusions are offered in section 5.

2. GENERAL STRUCTURE OF PROPOSED CBIR
The proposed CBIR algorithm is based on decomposition of database images using Haar wavelets and color histograms in the offline mode and same for the query image in online mode. With resulting Haar coefficients which serve as image features using F-norm theory similarity is computed of query image with database images and best matching results are produced [7]. With color histogram of images computation of Euclidean distance between query image and database images histogram is done. The database images which have smallest Euclidean distance with the query image are produced as results. Then using the results of both the methods and the proposed weighted retrieval strategy the final results are produced. The system is also implemented using 2 threads making the computation time less and leading to better utilization of multicore processor. The database has five kind of color images namely Roses, Horses, Dinosaurs, Buses, Landscape.

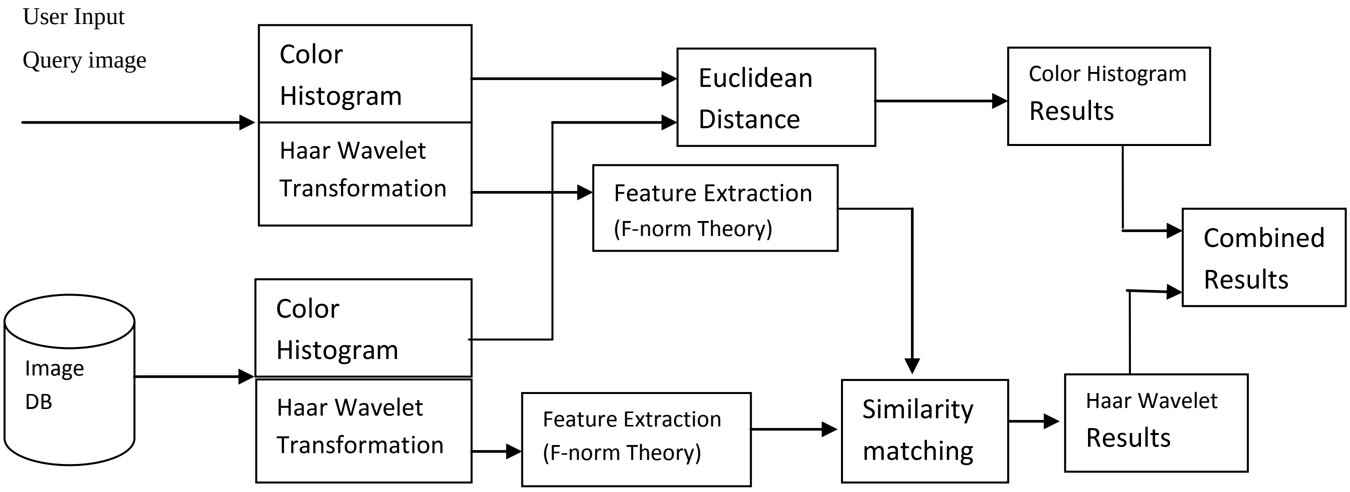
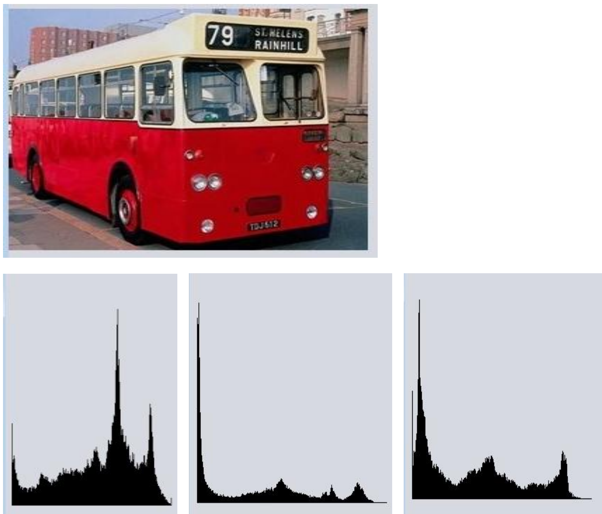


Fig. 1 General Structure of Proposed CBIR System

2.1 Color Histogram

Color histograms are frequently used to compare images [5]. Color histograms are popular because they are trivial to compute, and tend to be robust against small changes in camera viewpoint. For example, Swain and Ballard [8] describe the use of color histograms for identifying objects. Stricker and Swain [9] analyze the information capacity of color histograms. It is assumed that all images are scaled to contain the same number of pixels M (here in our case it is 256X256). We discretize the color space of the image such that there are n distinct (discretized) (256) colors. A color histogram H is a vector < $h_1, h_2, \ldots, h_n$ >, in which each bucket h_j contains the number of pixels of color j in the image. For a given image I, the color histogram HI is a compact summary of the image.



Red Green Blue

Fig. 2 RGB histograms of an image

A database of images can be queried with an example image I and the images with minimum Euclidean distances with the query image can be returned. The following is an outline of the method which is proposed by Jain and Vailaya [10] with some modifications:

1. Read images in database and extract RGB format pixel information from images.

(In Java getRGB method is used to get RGB information of image).

2. Create 256 bin normalized histograms for each of the RGB components of each image of database. Thus, each image will have 3 histograms associated with each image, one each for RGB (Where R=>Red, G=>Green, B=>Blue).

3. Read in a query image and extract RGB format pixel information.

4. Create histograms for query image for each of the RGB.

5. Compute Euclidean distance by comparing the query image histograms to that of each image in the database. Add the Euclidean distances of RGB histograms to get the final Euclidean distance of that image with query image.

6. Sort images in database in order of ascending Euclidean distance to query image and return as result.

256 bins were used in the proposed approach. Generally to increase the speed the number of bins is decreased to 64 or 32 but it leads to loss of information. Therefore it is a tradeoff of speed and accuracy. To increase speed system is implemented in parallel therefore speed and accuracy both have improved.

2.2 Image decomposition with Haar wavelet

We have used Haar wavelet approach for color image decomposition. The wavelet transformation produces average and fine detail coefficients [4]. These resulting decomposition coefficients are used to perform image feature extraction and similarity match by virtue of F-norm theory [7].

Wavelet analysis consists of decomposing a signal or an image into a hierarchical set of approximations and details. For images analysis two-dimensional wavelets are used. The discreet wavelet transform (DWT) of a signal is calculated by passing it through a series of filters (high and low pass filters) and then down-sampled [11], as we can see from Figure 3.

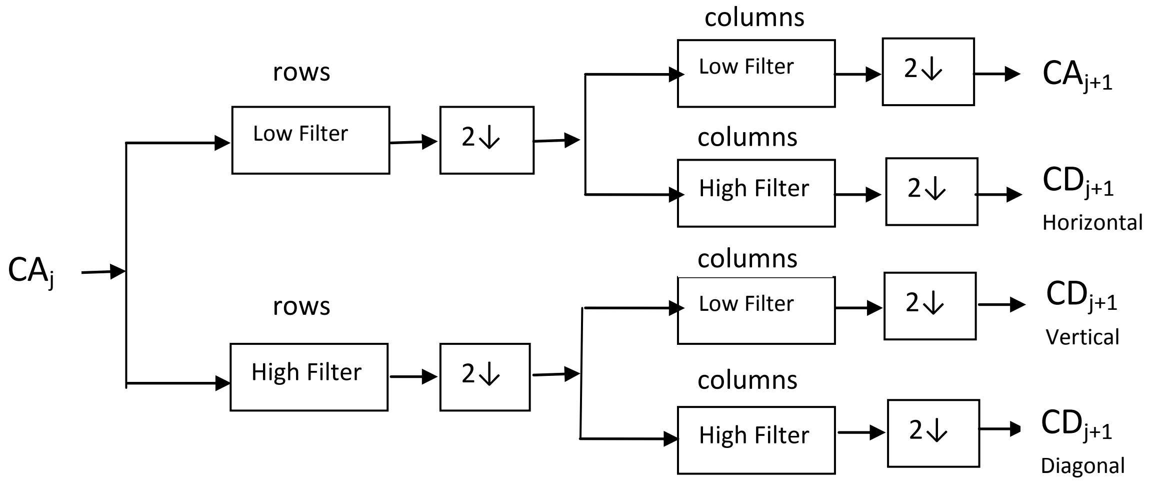


Fig 3 Multilevel 2-D Wavelet Decomposition

At each level, the signal is decomposed into low and high frequencies, and this decomposition halves the resolution since only half the number of samples are retained to characterize the entire signal. The algorithm retains the even indexed columns respectively rows. Based on this scheme, two-dimensional DWT leads to a decomposition of approximation coefficients at level j in four components: the approximation (CA) at level j+1 and the details (CD) in three orientations (horizontal, vertical, and diagonal) [11].

2.3 Haar Wavelet Transform

If a data set S_0, S_1 ….S_{N-1} contains N elements, after transformation there will be N/2 averages and N/2 wavelet coefficient values. The averages are stored in the upper half of the N element array and the coefficients are stored in the lower half as shown in the Fig.4. The averages become the input for the next step in the wavelet calculation, where for iteration i+1, Ni+1 = Ni/2. The recursive iterations are executed as many times as much as we want continue until a single average and a single coefficient are calculated. This replaces the original data set of N elements with an average, followed by a set of coefficients whose size is an increasing power of two. The Haar equations [4] to calculate an average a_i and a wavelet coefficient c_i from an odd and even element in the data set are:

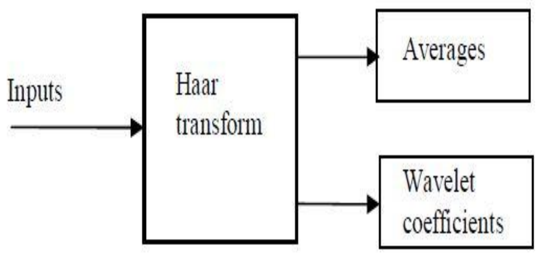


Fig. 4 Haar Transform

$$a_i = \frac{s_i + s_{i+1}}{2}$$

$$c_i = \frac{s_i - s_{i+1}}{2}$$

3. FEATURE EXTRACTION AND SIMILARITY CRITERIA

Our CBIR algorithm is based on direct wavelet decomposition of image in RGB color space and utilizes the "query by example" method. With approaches mentioned above, database images are decomposed offline into multi-level coefficients from -1 to -J levels, with which, we can generate color feature database and can perform similarity match between images. After decomposition, each resulting sub image is in fact a coefficient matrix, where, by special processing, large coefficients with more energy can be distributed in the upleft area, therefore, with F-norm theory, we can well decrease the dimension of image feature and perform highly efficient image matching.

3.1 Feature Vector

Suppose A is a square matrix and Ai is its ith order sub matrix where

$$A = \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \dots & \dots & \dots \\ a_{n1} & \dots & a_{nn} \end{bmatrix}, \quad A_i = \begin{bmatrix} a_{11} & \dots & a_{1i} \\ \dots & \dots & \dots \\ a_{i1} & \dots & a_{ii} \end{bmatrix} \quad (i = 1 \sim n)$$

The F-norm of Ai is given as

$$\|A_i\|_F = \left(\sum_{k=1}^{i} \sum_{l=1}^{i} |a_{kl}|^2 \right)^{1/2}$$

Let $\Delta A_i = \|A_i\|_F - \|A_{i-1}\|_F$ and $\|A_0\|_F = 0$, we can define the feature vector of A as [4]:

$VAF = \{\Delta A_1, \Delta A_2 \ldots\ldots \Delta A_n\}$

3.2 Similarity criteria

Define the Similarity α_i of ΔA_i and ΔB_i as [4]:

$$\alpha_i = \begin{cases} \min(\Delta A_i, \Delta B_i) / \max(\Delta A_i, \Delta B_i) --- \Delta A_i \neq 0 \, or \, \Delta B_i \neq 0 \\ 1 ----------------- \Delta A_i = 0 \, or \, \Delta B_i = 0 \end{cases}$$

and we can thus give the similarity α of the matrices A and B as:

$$a = \sum_{i=1}^{n} c_i a_i$$

Where $c_i = \frac{2i-1}{n^2}$ i=(1,2,3,…..n)

$$\sum_{i=1}^{n} c_i = 1$$

Higher the similarity values higher the similarity between the images.

3.3 Retrieval Strategy

In our setup we have used two different strategies to fetch results. First the color histogram based technique which is based on the Euclidean distance between query image and database image's histograms. The comparison is made between Red, Green and Blue components separately. The total distance is the sum of all the 3 components distance. The top 10 results are shown.

For wavelet transformation we have used haar transformation. We have decomposed the images upto 4 levels. Based on F-norm theory we match images with query image.

The top 10 images with highest similarity factor are shown in results. With results obtained from both the strategies the combined result is shown in order of increasing rank which is assigned as follows:

If the image is present in top 30 results of both color histogram and wavelet transformation method then its rank is (i+j) where i is its rank in color histogram method and j is in wavelet method.

If it is present only in one of the top 30 results of anyone of the two methods then its rank is (i+30) where i is the rank in the list.

4. RESULTS AND ANALYSIS

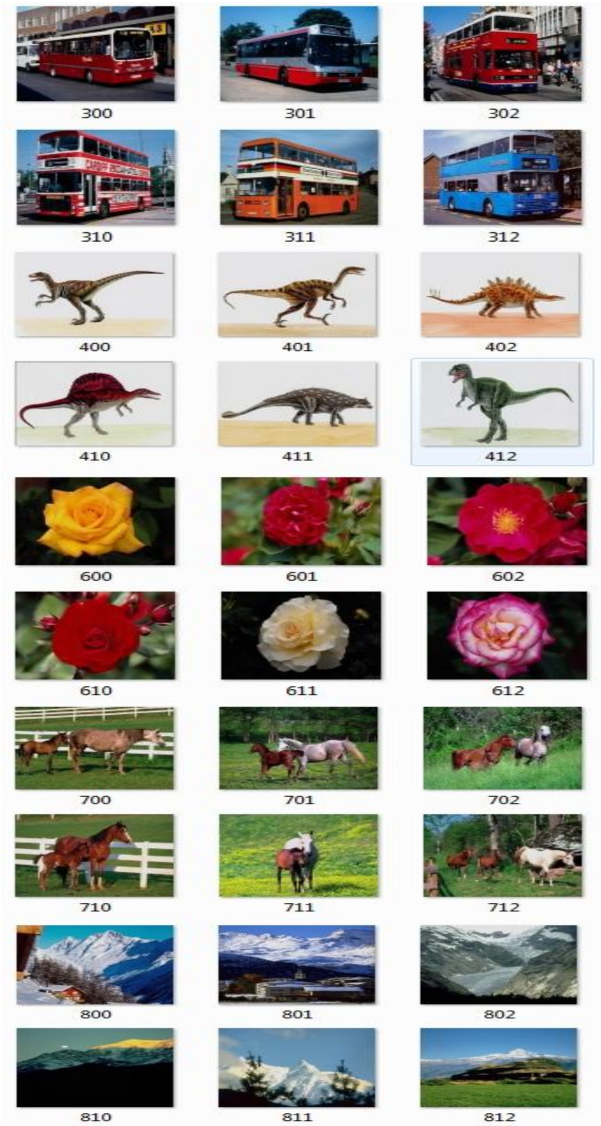
We have used a database of 500 images of 256X256 dimensions. It has 5 types of images in it; Horses, Buses, Landscapes, Dinosaurs and Roses. We have used the parameter of Recall rate to assess the effectiveness of the system. The Recall rate is defined as the ratio of the number of relevant (same category) retrieved images to the number of relevant items in collection [12].

$$Recall\ Rate = \frac{No.of\ relevant\ items\ retrieved}{Total\ No.of\ items\ in\ collection}$$

The time taken in returning results is a crucial factor in CBIR. We have used the speedup [13] parameter to assess the speed factor as we have implemented the system both in parallel and sequential manner.

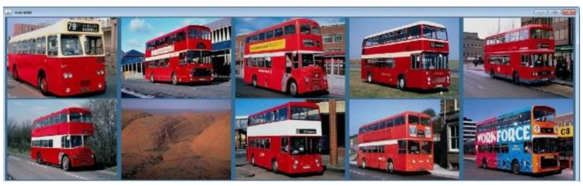
$$Speedup = \frac{Time\ taken\ in\ sequential}{Time\ taken\ in\ parallel}$$

Database sample images:



Some terms used in results representation:
Time taken in serial = Ts
Time taken in parallel= Tp
Here in our results the first image (in the top left corner of every result) is the query image.

Results Using wavelets transformation and F-norm Theory



Ts= 495 Tp= 421 RR=9/10

Ts= 331 Tp= 288 RR=10/10

Ts= 398 Tp= 277 RR=10/10

Ts= 430 Tp= 392 RR=9/10

Ts= 490 Tp= 309 RR=9/10

Results using Color Histograms and Euclidean Distance

Ts= 236 Tp= 219 RR=10/10

Ts= 193 Tp=200 RR=10/10

Ts= 179 Tp= 139 RR=10/10

Ts= 230 Tp= 230 RR=10/10

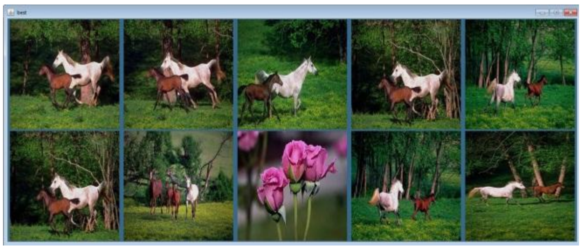
Ts= 275 Tp= 228 RR=7/10

Results using proposed retrieval strategy

Ts= 785 Tp= 784 RR=10/10

Ts= 701 Tp= 639 RR=10/10

Ts= 722 Tp= 672 RR=10/10

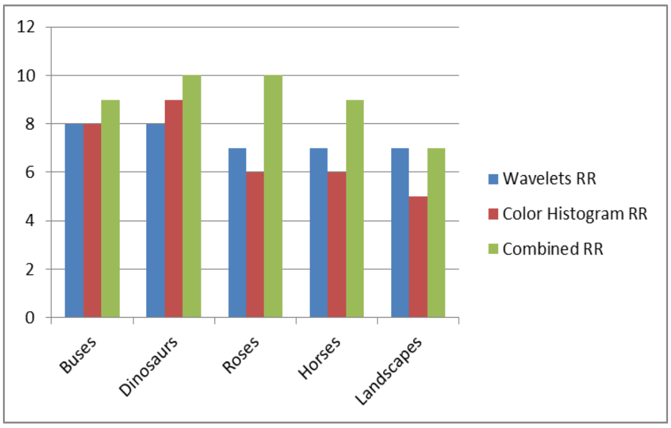


Ts= 613 Tp= 608 RR=9/10

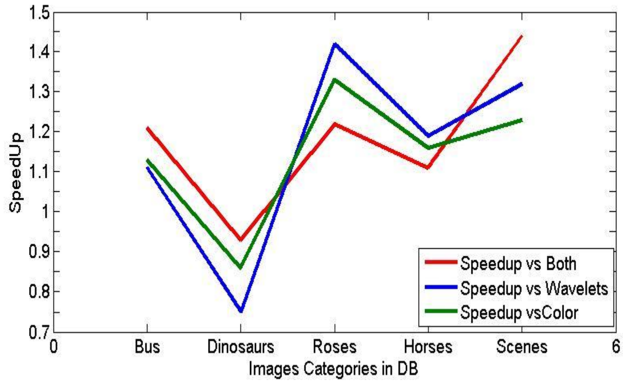
Ts= 699 Tp= 632 RR= 7/10

Recall Rate for Different categories of images

Category	Bus	Dinosaurs	Rose	Horses	Scene
Wavelets	**8/10**	**8/10**	**7/10**	**7/10**	**7/10**
Color Histogram	**8/10**	**9/10**	**6/10**	**6/10**	**5/10**
Both	**9/10**	**10/10**	**9/10**	**8/10**	**7/10**



Recall Rate Graph



Speedup Graph

5. CONCLUSIONS

The results show that the system is effective in bringing out visually similar images from the database. It is also observed that combining both color histogram technique and wavelet technique the results have improved and recall rate has increased. The parallel implementation of the system has helped in reducing the processing time and better utilization of processor. According to requirement the user can select to search on basis of color , on basis of wavelet transformation or the combined approach. The future work includes the clustering of database images in groups and taking the relevance feedback from user so that the system can learn.

6. REFERENCES

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