

Content Based Image Retrieval: Wavelets

Y. M. Latha, B.C. Jinaga, and V.S.K. Reddy

Abstract-- Content-Based Image Retrieval (*CBIR*) allows to automatically extracting target images according to objective visual contents of the image itself. Representation of visual features and similarity match are important issues in *CBIR*. In this paper a novel *CBIR* method is proposed by exploit the wavelets which represent the visual feature. We use Haar and D4 wavelet 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. We tested four categories of color images in the experiments. The retrieval performance of D4 wavelet is compared with Haar wavelet in terms of recall rate and retrieval speed, the results outperforms Haar wavelet. Experiment results reflect the importance of wavelets in *CBIR* for fast and efficient retrieval.

Index Terms-- Content- based image retrieval, Color feature vector, wavelets.

I. INTRODUCTION

CONTENT-Based Image Retrieval (*CBIR*) is considered as the process of retrieving desired images from huge databases based on extracted features from the image themselves (without resorting to a key word). Features are derived directly from the images and they are extracted and analyzed by means of computer processing[1].*CBIR* is a bottleneck of the access of multimedia databases that deal with text, audio, video and image data which could provide us with enormous amount of information . Many commercial and research *CBIR* systems have been built and developed (e.g.: *QBIC*, Virage, Pichunter, visual *SEEK*, Chabot, Excalibur, photobook, Jacob) [2]. Content based image retrieval [3]-[4], 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*). With appealing time frequency localization and multi-scale properties, wavelet transform proved to be effective in visual feature extraction and representation. It can be used to characterize textures using statistical properties of the gray levels of the points/pixels comprising a surface image.

In *CBIR*, wavelet approaches mainly include wavelet histogram and wavelet moment of image, etc. [12]. Wavelet transform can be used to characterize textures using statistical properties of the gray levels of the pixels comprising a surface image [13]. 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.

In this paper, we used D4 and 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. We also present a progressive retrieval strategy, which contributes to flexible compromise between the retrieval speed and the recall rate. The retrieval performances are compared for both the techniques. The efficiency in terms Recall rate and retrieval speed is tested with four types of images and the results reflect the importance of wavelets in *CBIR*.

The rest of this paper is organized as follows. In section 2, we introduced the general structure of the proposed *CBIR* system. Section 3 provides the image decomposition using wavelets. Section 4 describes Feature Extraction and Similarity criteria. Section 5 describes the implementation and experimental results. Finally conclusions are offered in section 6.

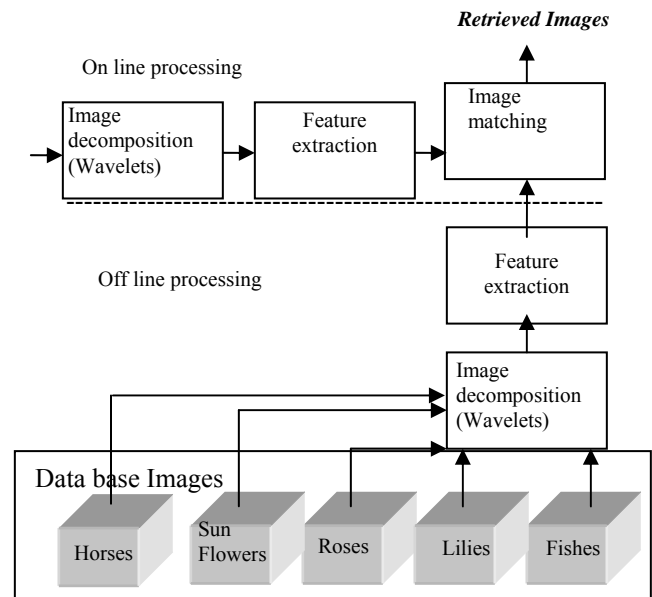


Fig.1. Structure of proposed *CBIR* system

Manuscript Received November 15, 2007.

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II. GENERAL STRUCTURE OF TEXTURE BASED CBIR SYSTEM

Our proposed *CBIR* algorithm is based on decomposition of the database images using Haar and D4 wavelets in the offline as well as in online for query image. With resulting coefficients using F-norm theory we extract the features and perform highly efficient image matching. In the database we used four typical groups of color images namely Sunflowers, Horses, Roses and Fishes as shown in the Fig. 1.

III. IMAGE DECOMPOSITION WITH WAVELETS

We used two wavelet approaches for color image decomposition, namely Haar, D4 wavelets. These resulting decomposition coefficients are employed to perform image feature extraction and similarity match by virtue of F-norm theory

A. Haar Wavelet Transform

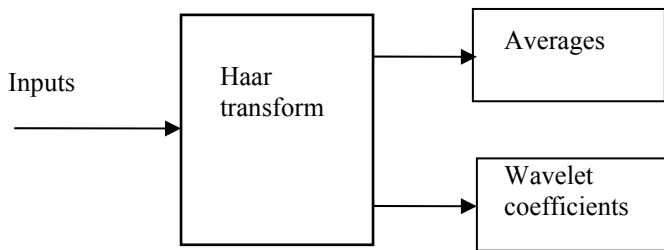


Fig. 2. Haar wavelet forward transform

If a data set $S_0, S_1 \dots S_{N-1}$ contains N elements, 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. The averages become the input for the next step in the wavelet calculation, where for iteration $i+1$, $N_{i+1} = N_i/2$. The recursive iterations 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 (Ex: $2^0, 2^1, 2^2 \dots N/2$).

The Haar equations to calculate an average a_i and a wavelet coefficient c_i from an odd and even element in the data set are:

$$a_i = \frac{s_i + s_{i+1}}{2} \quad c_i = \frac{s_i - s_{i+1}}{2} \quad (1)$$

Forward Haar transform for an eight element signal is shown below. Here signal is multiplied by the forward transform matrix.

The arrow represents a split operation that reorders the result so that the average values are in the first half of the vector and the coefficients are in the second half. To complete the forward Haar transform there are two more steps. The next step would multiple the average values a_i by a 4x4

$$\begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} \leftarrow \begin{bmatrix} a_0 \\ c_0 \\ a_1 \\ c_1 \\ a_2 \\ c_2 \\ a_3 \\ c_3 \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{2} & -\frac{1}{2} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{2} & -\frac{1}{2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2} & -\frac{1}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{2} & -\frac{1}{2} \end{bmatrix} \cdot \begin{bmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \\ s_7 \end{bmatrix}$$

transform matrix, generating two new averages and two new coefficients which would replace the averages in the first step. The last step would multiply these new averages by a 2x2 matrix generating the final average and the final coefficient.

B. The Daubechies D4 Wavelet Transform

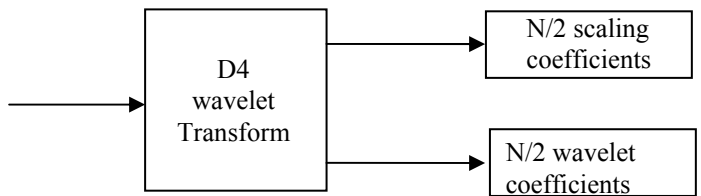


Fig. 3. D4 wavelet forward transform

The D4 transform has four wavelet and scaling function coefficients as shown in the Fig.3.

The scaling function coefficients are:

$$\begin{aligned} h_0 &= \frac{1 + \sqrt{3}}{4\sqrt{2}} & h_1 &= \frac{3 + \sqrt{3}}{4\sqrt{2}} \\ h_2 &= \frac{3 - \sqrt{3}}{4\sqrt{2}} & h_3 &= \frac{1 - \sqrt{3}}{4\sqrt{2}} \end{aligned} \quad (2)$$

Each step of the wavelet transform applies the scaling function to the data input. If the original data set has N values, the scaling function will be applied in the wavelet transform step to calculate $N/2$ smoothed values. In the ordered wavelet transform the smoothed values are stored in the lower half of the N element input vector.

The wavelet function coefficient values are:

$$g_0 = h_3; g_1 = -h_2; g_2 = h_1; g_3 = -h_0. \quad (3)$$

Each step of the wavelet transform applies the wavelet function to the input data. If the original data set has N values, the wavelet function will be applied to calculate $N/2$ differences (reflecting change in the data). In the ordered wavelet transform the wavelet values are stored in the upper half of the N element input vector.

The scaling and wavelet functions are calculated by taking the inner product of the coefficients and four data values. The equations are shown below.

Daubechies D4 scaling function

$$a_i = h_0 s_{2i} + h_1 s_{2i+1} + h_2 s_{2i+2} + h_3 s_{2i+3}$$

$$a[i] = h_0 s[2i] + h_1 s[2i+1] + h_2 s[2i+2] + h_3 s[2i+3] \quad (4)$$

Daubechies D4 wavelet function

$$c_i = g_0 s_{2i} + g_1 s_{2i+1} + g_2 s_{2i+2} + g_3 s_{2i+3}$$

$$c[i] = g_0 s[2i] + g_1 s[2i+1] + g_2 s[2i+2] + g_3 s[2i+3] \quad (5)$$

Each iteration in the wavelet transform step calculates a scaling function value and a wavelet function value. The index i is incremented by two with each iteration, and new scaling and wavelet function values are calculated. D4 forward transform matrix for 8 element signal is shown in the Fig.4..

$$\begin{bmatrix} h_0 & h_1 & h_2 & h_3 & 0 & 0 & 0 & 0 \\ g_0 & g_1 & g_2 & g_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & h_0 & h_1 & h_2 & h_3 & 0 & 0 \\ 0 & 0 & g_0 & g_1 & g_2 & g_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & h_0 & h_1 & h_2 & h_3 \\ 0 & 0 & 0 & 0 & g_1 & g_2 & g_3 & g_4 \\ 0 & 0 & 0 & 0 & 0 & 0 & h_0 & h_1 & h_2 & h_3 \\ 0 & 0 & 0 & 0 & 0 & 0 & g_0 & g_1 & g_2 & g_3 \end{bmatrix} \cdot \begin{bmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \\ s_7 \end{bmatrix}$$

IV. 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 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 up-left area, therefore, with F-norm theory[7], we can well decrease the dimension of image feature and perform highly efficient image matching.

A. Feature Vector

Suppos Suppose A is a square matrix and A_i is its i^{th} order sub matrix where

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

The F-norm of A_i is given as:

$$\|A_i\|_F = \left(\sum_{k=1}^i \sum_{l=1}^i |a_{kl}|^2 \right)^{1/2} \quad (6)$$

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:

$$V_{AF} = \{\Delta A_1, \Delta A_2 \dots \Delta A_n\} \quad (7)$$

B. Similarity criteria

C. Define the Similarity α_i of ΔA_i and ΔB_i as:

$$\alpha_i = \begin{cases} \min(\Delta A_i, \Delta B_i) / \max(\Delta A_i, \Delta B_i) & \text{--- } \Delta A_i \neq 0 \text{ or } \Delta B_i \neq 0 \\ 1 & \text{--- } \Delta A_i = 0 \text{ or } \Delta B_i = 0 \end{cases} \quad (8)$$

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

$$\alpha = \sum_{i=1}^n c_i \alpha_i \quad (9)$$

Where, $C_i = \frac{2i-1}{n^2} (i = 1, 2, \dots, n)$ and $\sum_{i=1}^n C_i = 1$.

Obviously, the similarity $0 \leq \alpha \leq 1$.

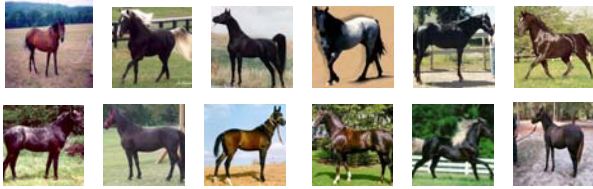
V. EXPERIMENTAL RESULTS

The general flow of the experiments starts with the decomposition of data base image using Haar and D4 wavelet in offline. The maximal decomposition level $J = 4$. We repeated the same decomposition in online for query image. With F-norm theory we extracted the image feature vector and performed highly efficient image matching. We used progressive retrieval strategy to balance between computational complexity and retrieval accuracy. We focus on the comparison of two important retrieval indices, namely retrieval accuracy and the speed. The test image database contains over 2400 images of 24 bits true color. They are divided into 4 groups each containing 600 images. The four groups are Horses, Fishes, Sunflowers, and Roses. For simplicity, all images are pre processed to be 256x256 sizes before decomposition. Sample data base images for each category are shown in the Fig.4.

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 [8].

$$\text{Recall rate} = \frac{\text{Number of relevant items retrieved}}{\text{Total number of relevant items in collection}}$$

SAMPLE DATA BASE IMAGES



Horses



Fishes



Sunflowers



Roses

Fig. 4. Sample data base images of four categories

RETRIEVED IMAGES BASED ON HAAR WAVELET

Query Image



Retrieved Images:



Query Image



Retrieved Images



Query Image



Retrieved Images



Query Image



Retrieved Images

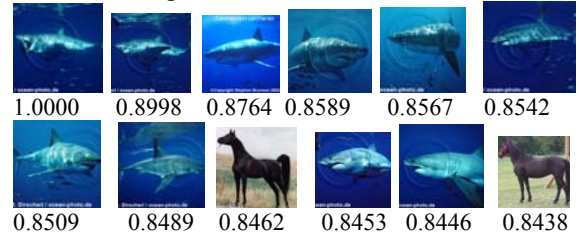


Fig.6.Retrieved Images based on D4wavelet

RETRIEVED IMAGES BASED ON D4 WAVELET

Query Image



Retrieved Images



Query Image



Retrieved Images:



1.0000 0.8415 0.8357 0.8256 0.8060 0.7954

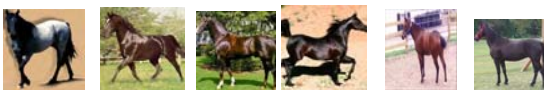


0.7934 0.7929 0.7922 0.7901 0.7761 0.7679

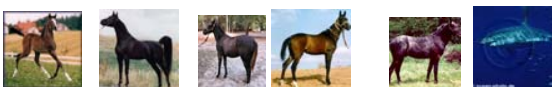
Query Image



Retrieved Images



1.0000 0.8863 0.8824 0.8676 0.8642 0.8550



0.8516 0.8476 0.8427 0.8423 0.8306 0.8241

Query Image



Retrieved Images



1.0000 0.8902 0.8769 0.86389 0.8569 0.8502



0.84989 0.8446 0.8414 0.8363 0.8246 0.8108

Fig.7.Retrieved Images based on D4 lifting scheme

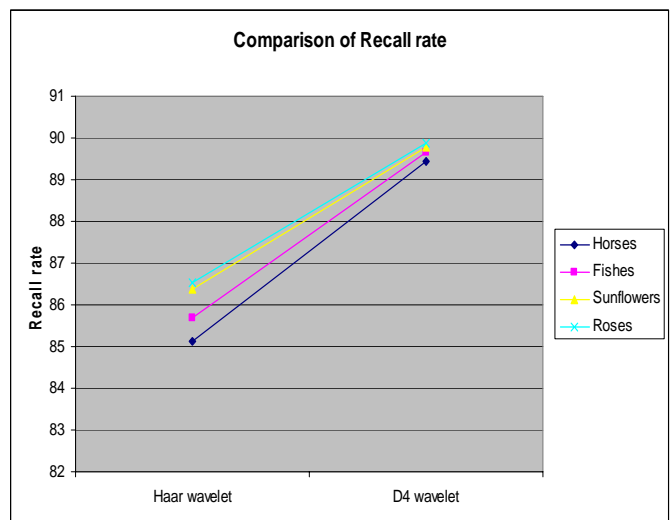
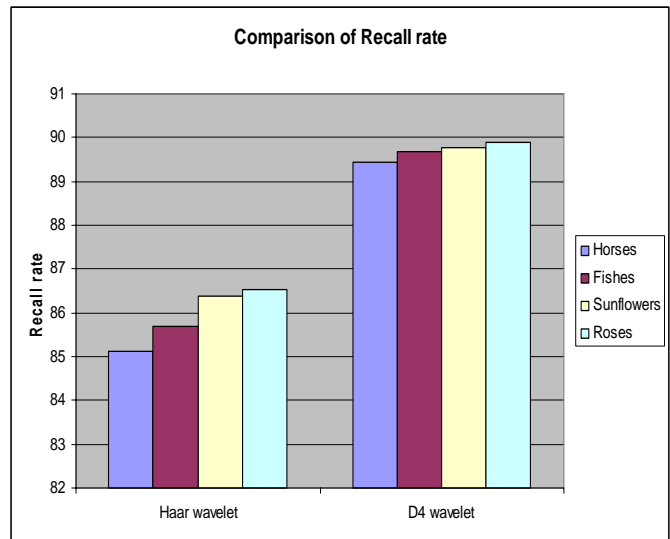


TABLE.1.COMPARISON OF RECALL RATE

	D4 wavelet	D4 lifting
Horses	85.12	89.45
Fishes	85.68	89.67
Sunflowers	86.39	89.78
Roses	86.52	89.89

The following graphs and Table.1 shows the Recall rate achieved by the two schemes namely D4 and Haar Wavelet Transform for each category of color images. As compared to Haar D4 lifting scheme achieves the best Recall rate.

According to the experimental results we obtain:

- In CBIR, representing image using Haar and D4 wavelets achieves efficient recall rate. This is also the most apparent advantage of the wavelets in real time applications.

VI. CONCLUSIONS

In this paper we introduced a novel *CBIR* approach via wavelet decomposition of images, followed by feature extraction and similarity match under F-norm theory. We compared the retrieval performance of D4 wavelet with that of the Haar wavelets. It turns out that D4 wavelet has greatly speeded retrieval as well as ensured enough recall rate comparable with its Haar wavelet. Finally we conclude from the results that wavelets achieve high retrieval performance in real time *CBIR* systems.

VII. REFERENCES

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VIII. BIOGRAPHIES



Y.Madhavelatha, born on January, 1972, completed her graduation and post graduation from JNT University, Hyderabad. She has been working at G.Narayanamma Institute of Science and Technology, JNT University, Hyderabad. Currently she pursuing Ph.D at JNT University under guidance of Dr.B.C.Jinaga . Her research interest includes Image and Video processing, Multimedia Systems Design. She is Life Member of Institute of Electronics and Telecommunication

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