NCICIT 2013: 1st National Conference on Intelligent Computing and Information Technology, November 21, CUET, Chittagong-4349, Bangladesh

Content-Based Image Retrieval using Haar Wavelet Transform

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***Abstract*—Content-Based Image Retrieval (CBIR) system, also known as Query by Image Content (QBIC), is an image search technique to retrieve relevant images based on their contents. Here contents refer to the color, texture and shape of the image. In this paper we propose a content-based image retrieval system, where we use Haar wavelet transform to extract the image feature. We use f-norm theory to reduce the dimension of the feature vector and finally we use Canberra distance to calculate the distance between query image and database images. Our experiment result reflects the importance of Haar wavelet transform in CBIR system.**

Keywords— CBIR, Haar wavelet transform, Canberra distance, F-norm theory

I. INTRODUCTION

Content-based image retrieval (CBIR) [1] has been an active research topic in the last few years. Comparing to the traditional systems, which represent image contents only by keyword annotations, the CBIR systems perform retrieval based on the similarity defined in terms of visual features with more objectiveness.

A typical CBIR system automatically extract visual attributes like color, shape, texture and spatial information of each image in the database based on its pixel values and stores them in to a dissimilar database within the system called feature database. The feature data for each of the visual attributes of each image is very much smaller in size compared to the image data. The feature database contains an abstraction of the images in the image database; each image is represented by compact illustration of its contents like color, texture, shape and spatial information in the form of a fixed length real-valued multi-component feature vectors or signature. The users generally prepare query image and present to the system. The system automatically extract the visual attributes of the query image in the same mode as it does for each database image and then identifies images in the database whose feature vectors match those of the query image, and sorts the best similar objects according to their similarity value. During operation the system processes less compact feature vectors rather than large size image data therefore giving CBIR its cheap, fast and efficient advantage over text-based retrieval. Most CBIR systems work in the same way. A feature vector is extracted from each image in the database and the set of all feature vectors is organized as a database index. When similar images are searched with a query image, a feature vector is extracted from the query image and it is matched against the feature vectors in the index. Difference between the various systems lies in the features that they extract and the algorithms that are used to extract that features. The block diagram of basic CBIR system is shown in Figure 1.

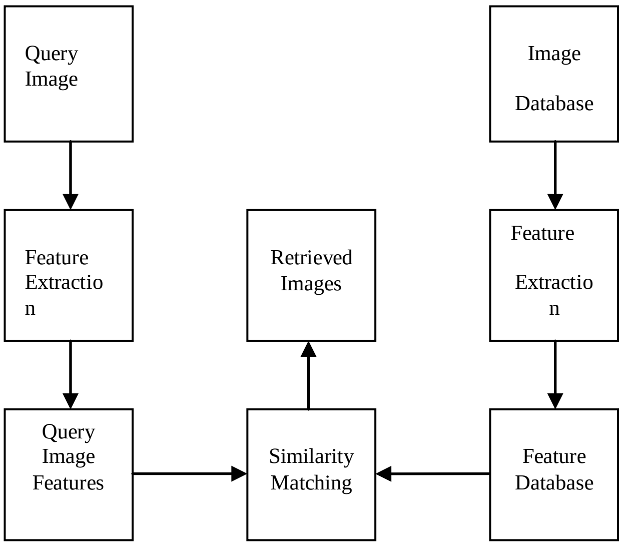

Figure 1. CBIR System

The significant applications for CBIR technology could be listed as art galleries [2], architecture design [3], medical imaging, criminal investigations, image search on the Internet [4, 5]. In this paper, we have proposed a content-based image retrieval system that extract image feature using Haar Wavelet transform, then we reduce the dimension of feature vector using f-norm theory, similarity between images is calculated by Canberra distance and efficiency of our proposed method is measured in terms of recall.

The rest of the paper is organized as follows. In section 2, we explain our proposed method. Section 3 describes the implementation and experimental results and finally conclusions are given in section 4.

II. PROPOSED METHOD

A. *Wavelet Transformation*

Wavelet transform provides a multi-resolution approach to texture analysis and classification [6]. The computation of the wavelet transforms of a two dimensional signal involves recursive filtering and sub-sampling. At each level, the signal is decomposed into four frequency sub-bands, LL, LH, HL, and HH, where L denotes low frequency and H denotes high frequency. Figure 2 shows the level 1 of 2D wavelet transform.

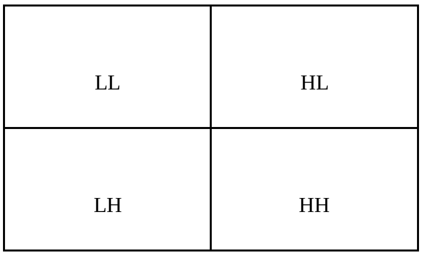

Figure 2. level 1 of 2D wavelet transform

We used Haar wavelet for image decomposition.

B. *Haar Wavelet Transform*

If a data set $X_0, X_1 \ldots. X_{N-1}$ contains N elements, there will be N/2 averages and N/2 wavelet coefficient values. The averages are stored in the first half of the N element array and the coefficients are stored in the second half of the N element array. The averages become the input for the next step in the wavelet calculation.

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:

$$a_i = \frac{X_i + X_{i+1}}{2} \tag{1}$$

$$c_i = \frac{X_i - X_{i+1}}{2} \tag{2}$$

Steps for 1D Haar transform of an array of N elements:

1. Find the average of each pair of elements using equation 1. (N/2 averages)
2. Find the difference between each pair of elements and divide it by 2. (N/2 coefficients)
3. Fill the first half of the array with averages.
4. Fill the second half of the array with coefficients.
5. Repeat the process on average part of the array until a single average and a single coefficient are calculated.

Steps for 2D Haar transform:

1. Compute 1D Haar wavelet decomposition of each row of the original pixel values.
2. Compute 1D Haar wavelet decomposition of each column of the row-transformed pixels.

Red, green and blue values are extracted from the images. Then we apply 2D Haar transform to each color matrix.

Figure 3 shows the level 1 of 2D Haar decomposition of the image:

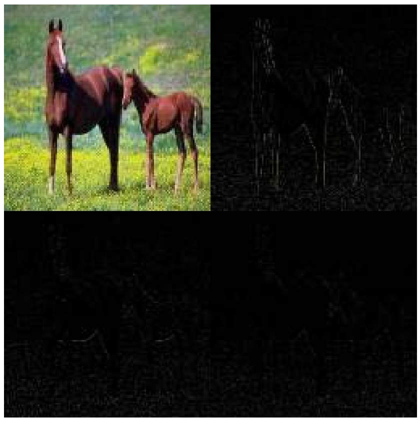

Figure 3. level 1 of 2D Haar wavelet transform

C. *Wavelet Feature Extraction*

We apply Haar wavelet decomposition of image in RGB color space. We continue decomposition up to level 4 and with F-norm theory [7] we decrease the dimension of image feature and perform highly efficient image matching.

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

$$A = \begin{bmatrix} a_{11} & \ldots & a_{1n} \\ \ldots & \ldots & \ldots \\ a_{n1} & \ldots & a_{nn} \end{bmatrix},$$

$$A_i = \begin{bmatrix} a_{11} & \ldots & a_{1i} \\ \ldots & \ldots & \ldots \\ a_{i1} & \ldots & a_{ii} \end{bmatrix} (i = 1 \sim n)$$

The F-norm of A_i is given as:

$$\left\| A_i \right\|_F = \left(\sum_{k=1}^{i} \sum_{l=1}^{i} \left| a_{kl} \right|^2 \right)^{1/2} \tag{3}$$

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

$$V_{AF} = \{\Delta A_1, \Delta A_2 \ldots \Delta A_n\} \tag{4}$$

D. Similarity Measure

The similarity between two images is computed by calculating the distance between feature representation of the query image and feature representation of the image in dataset. We use Canberra (eq.5) distance for distance calculation of the feature vectors.

$$dis(q,d) = \sum_{i=1}^{n} \frac{|q_i - d_i|}{|q_i| + |d_i|} \qquad (5)$$

Where:

$q = (q_1, q_2 ... q_n)$, feature vector of query image

$d = (d_1, d_2 ... d_n)$, feature vector of image in database

n = number of element of feature vector.

If the distance between feature representation of the query image and feature representation of the database image is small then it is considered as similar.

III. EXPERIMENTS AND RESULTS

In our experiment, we select four types of image, 50 images in each category and 200 images in total from Wang's [8] database. The images are resized into 256x256.

The performance of a CBIR system can be measured in terms of its precision and recall. Precision measures the retrieval accuracy; it is ratio between the number of relevant images retrieved and the total number of images retrieved. Recall measures the ability of retrieving all relevant images in the database. It is ratio between the number of relevant images retrieved and the whole relevant images in the database. They are defined as follows:

$$\text{Precision} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of images retrieved}} \qquad (6)$$

$$\text{Recall} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of relevant images}} \qquad (7)$$

We extracted image features using Haar wavelet transform. Table 1 shows the average recall result for our proposed method.

Table 1. Average recall result

Category	Haar Wavelet Transform
Buses	0.71
Dinosaurs	0.68
Roses	0.79
Horses	0.67
Average Recall (%)	71.25

Figure 4 shows the graphical representation of our proposed method.

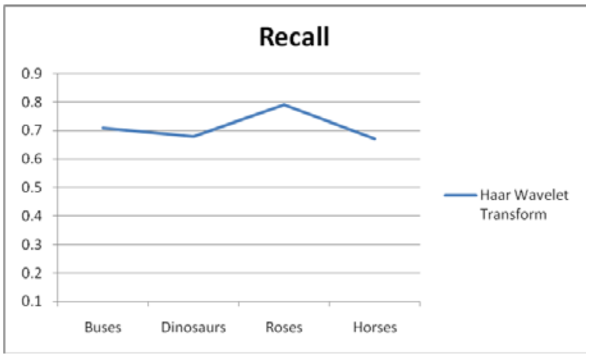

Figure 4. Average recall of proposed system

From Table 1 and Figure 3 it is seen that the average recall (%) based on our proposed method is 71.25. That means we can use Haar wavelet transform in CBIR system.

We implement our proposed method in Java. Some screenshot from our application for some sample query image is taken and they are shown below. Figure 5 shows retrieval result for the query image bus based on our proposed method. Figure 6, Figure 7, Figure 8 shows the retrieval result for the query images dinosaur, rose and horse respectively based on our proposed method.

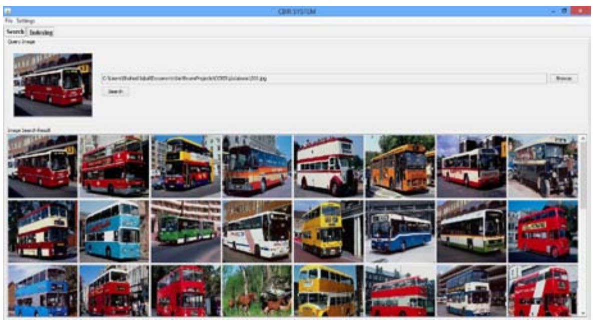

Figure 5. Retrieved images based on our proposed method for the bus as query image

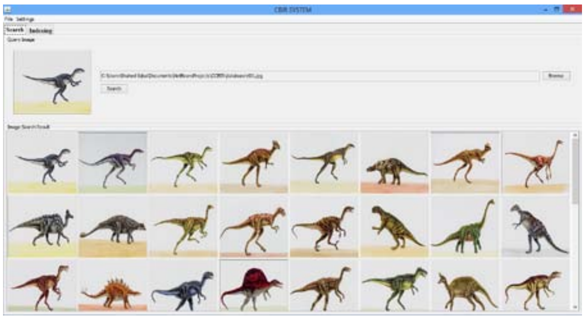

Figure 6. Retrieved images based on our proposed method for the dinosaur as query image

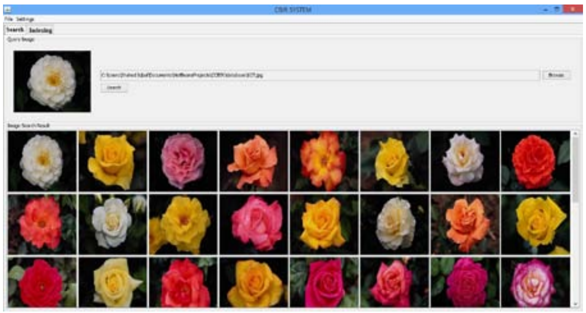

Figure 7. Retrieved images based on our proposed method for the rose as query image

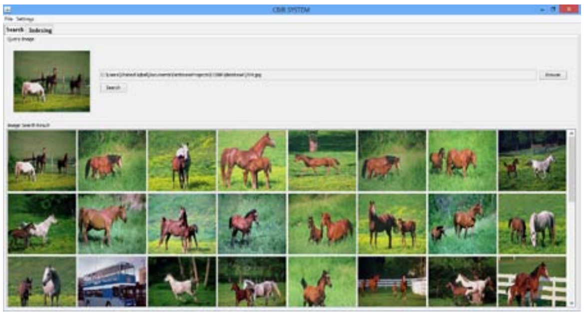

Figure 8. Retrieved images based on our proposed method for the horse as query image

IV. CONCLUSION

In this paper, we have proposed a CBIR method where we have successfully used the Haar wavelet transform. First we apply Haar wavelet transform to images in the database, then we apply F-norm theory to reduce the dimension of the feature vector and thus image feature is extracted using Haar wavelet transform. All the features for the database images are pre-calculated and stored in the database. Then when similar images are searched using a query image, we calculate the features for that image and the distance between the query image feature and database image features is computed using Canberra distance. Then we display the similar images according to their weight value. Our experiment result demonstrates that Haar wavelet transform can be used for image feature extraction in CBIR system.

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