Performance Comparison of DFT and Hartley Plane Sectorization with its Wavelets across RGB, LUV and YCbCr Colour Planes in CBIR

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ABSTRACT

This paper uses the sectorization method on DFT and Hartley transforms along with sectorization of the DFT and Hartley wavelets over 3 different color spaces namely RGB, LUV and YCbCr. A comparison and evaluation of these methods is carried out and the results are drawn based on the retrieval rates of each class of images from the database. Three different similarity measures such as Precision, Recall, Precision- Recall Crossover are used for the matching the feature vectors of the query image with that of the images in the database. Euclidean distance and sum of Absolute difference are used for measuring the distances between the images. The average precision-recall cross-over point plot (PRCP) and the overall average PRCP performances have been compared for all the methods.

Keywords— CBIR, Wavelet, DFT, Hartley, RGB, LUV, YCbCr, Euclidean Distance, Absolute Difference, Precision Recall Cross Over Point

1. INTRODUCTION

Image Processing and its related fields are today a lively discipline and the research and work in this field is ever expanding. Content Based Image Retrieval (CBIR) is one of the fields associated with Image Processing. And when research is concerned, after early successes, it becomes desirable to peer into the deeper problems as well as improving results iteratively [1].

CBIR is the method of applying image processing techniques to the image retrieval problem for digital images in significantly large databases. Here, the challenge is to integrate the strengths of content- and keyword-based image indexing and retrieval algorithms while alleviating their respective difficulties[2].

One of the important techniques associated with CBIR is applying powerful transforms to a given image. This technique is also applicable for various image processing fields such as compression, feature extraction etc. Various linear transforms like DFT [7], DCT [4], DST [6], Haar [5] etc are commonly used in CBIR and each of these transforms proves to provide varied results

Hence, we can understand the process of CBIR as following. Firstly we have a user who wants a desired image from a large database. To retrieve that image, the user provides a query image. This query image undergoes some algorithm by which features are extracted from the image. Similarly, each image of the database undergoes the same steps. Here the feature vectors are representations of the content of the images. Then we use a Similarity Measurement technique to find the distance between the query image and the images in the database and retrieve the most similar images from the database [10] [3].

This paper compares the retrieval performance of the CBIR system developed using wavelets of DFT and Hartley transforms along with DFT and Hartley plane sectorization[13-16]. But what we are really trying to achieve in this paper is the difference is results when we use not only the RGB colour space of images but also LUV and YCbCr colour spaces and comparing these results.

2. LITERATURE REVIEW

A. Content Based Image Retrieval (CBIR)

The typical CBIR system performs two major tasks. The first one is feature extraction (FE), where a set of features, called feature vector, is generated to accurately represent the content of each image in the database. The second task is similarity measurement (SM), where a distance between the query image and each image in the database using their feature vectors is used to retrieve the top "closest" images. Many approaches have been proposed for feature extraction in CBIR. [9].

The various methods related to feature extraction have been discussed below:

1. CBIR using Full Haar Sectorization [8]:

This paper uses a new innovative method of sectorization of Full Haar wavelet transform for extracting features of images into the 4,8,12 and 16 sectors. The paper proposes the use of two planes, forward and backward planes. The paper compares the performance of the methods with respect to type of planes, number of sectors, types of similarity measures and values of LIRS and LSRR.

2. CBIR feature vector dimension reduction [11]

Dimension reduction of CBIR feature vectors has gained momentum for swift image retrieval. The paper presents few novel techniques for image retrieval based on principal component analysis (PCA). Here feature vectors are eigenvectors of covariance matrix obtained using the row mean, column mean, forward diagonal mean, backward diagonal mean and mean combinations of database images. Instead of taking all pixels of database images for PCA, proposed CBIR methods use mean vectors.

3. CBIR using Kekre Transform [12]

In this paper novel image retrieval techniques based on features extracted from Kekre transform applied on row mean, column mean and combination are presented. Further the concept of image tiling is added to these to get total of 26 novel CBIR techniques. Proposed image retrieval techniques are applied to image database of 1000 images spread across 11 categories. Experimentation shows that taking row mean, column mean and combination improves the performance of image retrieval as compared to taking Kekre Transform of full image.

B. Colour Spaces

The following two sections discuss the colour spaces we are using in this paper along with the RGB colour space.

1. YCbCr Colour Space [13]

The YCbCr model defines a color space in terms of one luminance (brightness) and two chrominance (color) components. In the YCbCr color space, the Y component gives luminance and the Cb and Cr components give the chromaticity values of the color image. To get the YCbCr components, the conversion of the RGB components to YCbCr components must be known. The RGB to YCbCr conversion matrix is given below.

$$\begin{bmatrix} y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2989 & 0.5866 & 0.1145 \\ -0.1688 & -0.3312 & 0.5 \\ 0.5 & -0.4184 & -0.0816 \end{bmatrix} . \begin{bmatrix} R \\ G \\ B \end{bmatrix} (1)$$

To get the RGB values from the YCbCr components:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & -0.001 & 1.402 \\ 1 & -0.3441 & -0.714 \\ 1 & 1.7718 & 0.001 \end{bmatrix} . \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} \qquad (2)$$

2. Kekre's LUV color space[13,17]

In the Kekre's LUV colour space, the L component provides the luminance, while the U and V components contain the colour information. The RGB to Kekre's LUV conversion matrix is given below.

$$\begin{bmatrix} L \\ U \\ V \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ -2 & 1 & 1 \\ 0 & -1 & 1 \end{bmatrix} . \begin{bmatrix} R \\ G \\ B \end{bmatrix} (3)$$

To get the RGB values from the Kekre's LUV components, the following conversion matrix can be used.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & -2 & 0 \\ 1 & 1 & -1 \\ 1 & 1 & 1 \end{bmatrix} . \begin{bmatrix} L/3 \\ U/6 \\ V/2 \end{bmatrix} (4)$$

A negative value for the U component in the Kekre's LUV colour space indicates prominence of the red component in the colour image. Similarly, a negative value for the V component indicates prominence of the green component over the blue component in the colour image.

3. DFT TRANSFORM

Discrete Fourier Transform (DFT) basically transforms a finite list of equally-spaced samples of a function to coefficients that are ordered by frequency or basically converting functions from the original domain to the frequency domain. DFT can be defined as:

$$Fn = \sum_{k=0}^{N-1} \left(f_k e^{-2\pi ink/N} \right), \text{ where } i=\sqrt{-1} \qquad (5)$$

4. HARTLEY TRANSFORM

The Hartley Transform is a spectral transform closely related to the Fourier Transform [13]. Some advantage that the Hartley Transform enjoys over the Fourier Transform is that the Hartley Transform is a real function. Therefore it can result in quicker digital algorithms for calculating discrete versions of the transform in signal processing or Image processing [13]. It can be defined as a function of f:

$$H_x(f) = \int_{-\infty}^{\infty} x(t)cas(2\pi ft)dt (6)$$

$$X(t) = \int_{-\infty}^{\infty} Hx(f)cas(2\pi ft)dt (7)$$

5. FEATURE EXTRACTION USING WAVELETS

III. DFT Wavelet

Discrete Fourier Transform is used to generate feature vectors of an image in both real and imaginary parts of a complex number which are used for searching and retrieving images from the database. Steps involved in this algorithm are given below.

Step 1: Obtain the Discrete Fourier Transform wavelet, Dw

Step 2: Apply Dw on each of the three components i.e. Red, Green and Blue of an RGB image separately.

Step 3: Each of these R,G and B frequency domain planes are divided into

1. 4 equal sectors of 45 degrees each
2. 8 equal sectors of 22.5 degrees each.
3. 12 equal sectors of 15 degrees each.
4. 16 equal sectors of 11.25 degrees each.

Step 4: The real and imaginary parts of the Fourier complex number is calculated. The tangent of the real and imaginary part is used to determine in which plane the value lies. We do not consider the bottom half of the polar coordinate system as complex conjugates are equal.

Step 5: Thus an entire table of feature vectors of all the images in the database is created. Now we take a query image and find its feature vectors.

Step 6: To find out if the query image and the image from database matches, we calculate the euclidian and absolute distances between the feature vectors of query image and the feature vectors of images in the database.

IV. Hartley Wavelet

Step 1: Obtain the Hartley Transform wavelet, Hw.

Step 2: Apply Hw on each of the three components i.e. Red, Green and Blue components of the image.

Step 3: For each of the three components, excluding the first and last row and starting from the second row, create "a" and "b" vectors of alternating rows.

Step 4: After creating the "a" and "b" vectors, distribute the values of "a" and "b" according to the conditions of sectorizations for 4,8,12 and 16 sectors as shown in figures 2,3,4 and 5 respectively.

Step 5: We thus obtain new values for “a” and “b” vectors for each sector.

Step 6: Find the mean of these vectors in each sector.

6. THE DATABASE

1. Image Database

The database that is used by us is an augmented Wang [13-16, 26] image database of 1056 images. The images are classified into 12 different classes namely (in order they have been classified from class 1 to class 12 accordingly). Cartoons, Barbies, Sunsets, Mountains, Horses, Flowers, Elephants, Dinosaurs, Buses, Monuments, Beaches and Human images have been used for the different classes.

7. EXPERIMENTAL RESULTS

A. Overall Comparison between all methods over RGB, LUV and YCbCr color spaces

We have deployed the methods described above for generating the DFT, Hartley plane sectorization as well as their wavelets across 3 color spaces and ran the algorithm for the various Classes in the augmented database. On running the algorithm, the results of all these methods have been obtained and have been overall compared in the below table 1. Table 1 contains the performances of every method differentiated by the 3 color spaces and the retrieval rates of each method for 4,8,12 and 16 sectors with respect to the ED and the AD values.

The values that are there in the cells of the table are the Precision-Recall Crossover point (PRCP) values obtained and are the average performance of each sector. These values are directly proportional to the retrieval performance of each of the 4,8,12 and 16 sectors and the values differ according to the ED and the AD values.

Table 1: Overall Comparison of the Overall Average values for DFT, Hartley and DFT wavelet, Hartley Wavelet across RGB, YCbCr and LUV for 4,8,12 and 16 sectors (The highlighted boxes are the highest values in each colour plane

		4 Sectors		8 Sectors		12 Sectors		16 Sectors	
		ED	AD	ED	AD	ED	AD	ED	AD
	DFT	35.70%	34.26%	36.01%	34.02%	36.06%	34.11%	36.18%	34.10%
	Hartley	35.97%	36.67%	35.39%	34.48%	35.38%	34.55%	35.40%	33.89%
RGB	Wavelet of DFT	34.32%	33.79%	34.14%	33.07%	34.22%	32.88%	33.21%	33.09%
	Wavelet of Hartley	35.68%	38.26%	35.40%	34.34%	35.36%	34.42%	35.41%	34.37%
	DFT	35.98%	36.38%	36.04%	36.47%	35.99%	36.47%	36.02%	36.47%
	Hartley	37.00%	39.83%	35.99%	37.16%	36.06%	37.47%	36.09%	37.33%
YCbCr	Wavelet of DFT	34.79%	35.46%	34.60%	35.35%	34.95%	35.95%	31.86%	35.78%
	Wavelet of Hartley	36.26%	39.76%	35.98%	36.55%	35.91%	36.75%	35.91%	36.33%
	DFT	31.88%	31.59%	31.75%	31.53%	31.89%	31.52%	31.95%	31.56%
	Hartley	31.09%	32.85%	29.87%	30.35%	29.97%	30.88%	29.85%	29.89%
LUV	Wavelet of DFT	30.04%	30.09%	23.49%	23.08%	24.14%	25.18%	23.49%	23.08%
	Wavelet of Hartley	32.69%	35.26%	32.42%	32.45%	32.41%	32.60%	32.37%	32.52%

As we can see from Table 1, the overall performance of the YCbCr color space is marginally better than the performance of the RGB color space and significantly better than the performance of the LUV color space.

Since, higher the average PRCP values indicate higher retrieval rate, we can observe that YCbCr proves to have the best retrieval performance, followed by the RGB color space.

Table 2 below summarizes the top performances for each color plane according to the method implemented and the distance measure (ED or AD).

Table 2: Top 3 performances method-wise for each colour plane

Color Plane	Transform	Distance Measure	Sector	
RGB	Wavelet of Hartley	AD	4	38.26%
RGB	Hartley	AD	4	36.67%
RGB	DFT	ED	16	36.18%
YCbCr	Hartley	AD	4	39.83%
YCbCr	Wavelet of Hartley	AD	4	39.76%
YCbCr	Hartley	AD	12	37.47%
LUV	Wavelet of Hartley	AD	4	35.26%
LUV	Hartley	AD	4	32.85%
LUV	Wavelet of Hartley	ED	4	32.69%

Now we can take each color space individually, and compare the performances of each of the methods i.e. DFT, Hartley, DFT wavelet and Hartley wavelet.

1. RGB color space

Using the above approach for our methods, we have run the algorithm for the various Classes in the augmented database. The 12 classes are used for comparison and retrieval study by using the ED and AD measures.

1.1 DFT

Class 8 shows the best results of Average Precision Recall Crossover points of 83% and 79% for ED and AD respectively.

When we use DFT plane sectorization, the 16 Sectors give the highest retrieval rate using ED similarity measure.

1.2 Hartley

Class 8 shows the best results of 79% and 78% for the Average Precision Recall Crossover Points using ED and AD respectively.

When we use Hartley Transform, the 4 sectors give the highest retrieval rate using both ED and AD similarity measures

1.3 DFT Wavelet

Class 8 shows the best results of Average Precision Recall Crossover points of 85% and 88% for ED and AD respectively.

When we use DFT Transform wavelet, the 4 Sectorization method gives the highest retrieval rate using ED similarity measure.

1.4 Hartley Wavelet

Class 8 shows the best results of Average Precision Recall Crossover points of 79.55% and 83.20% for ED and AD respectively

When we use Wavelet Hartley Transform, the 4 Sectorization method gives the highest retrieval rate using AD similarity measure.

2. YCbCr color space

2.1 DFT

Class 8 shows the best results of Average Precision Recall Crossover points of 81% and 81% for ED and AD respectively

When we use DFT Transform, the 4 and 16 Sectorization method gives the highest retrieval rate using AD similarity measure.

2.2 Hartley

Class 8 shows the best results of Average Precision Recall Crossover points of 80% and 81% for ED and AD respectively

When we use Hartley Transform, the 4 Sectorization method gives the highest retrieval rate using AD similarity measure.

2.3 DFT Wavelet

Class 8 shows the best results of Average Precision Recall Crossover points of 83% and 89% for ED and AD respectively

When we use Wavelet of DFT Transform, the 12 Sectorization method gives the highest retrieval rate using AD similarity measure.

2.4 Hartley Wavelet

Class 8 shows the best results of Average Precision Recall Crossover points of 81% and 83% for ED and AD respectively

When we use Wavelet Hartley Transform, the 4 Sectorization method gives the highest retrieval rate using AD similarity measure.

3. LUV color space

3.1 DFT

Class 8 shows the best results of Average Precision Recall Crossover points of 86% and 85% for ED and AD respectively

When we use DFT transform, the 4 and 12 Sectorization methods gives the highest retrieval rate using AD similarity measure.

3.2 Hartley

Class 8 shows the best results of Average Precision Recall Crossover points of 78% and 76% for ED and AD respectively

When we use Hartley Transform, the 4 Sectorization method gives the highest retrieval rate using AD similarity measure.

3.3 DFT Wavelet

Class 8 shows the best results of Average Precision Recall Crossover points of 48% and 50% for ED and AD respectively

When we use Wavelet of DFT Transform, the 4 Sectorization method gives the highest retrieval rate using AD similarity measure.

3.4 Hartley Wavelet

Class 8 shows the best results of Average Precision Recall Crossover points of 80% and 82% for ED and AD respectively

When we use Wavelet Hartley Transform, the 4 Sectorization method gives the highest retrieval rate using AD similarity measure.

8. CONCLUSIONS

As the amount of digital content increases day by day, there is a need to be able to retrieve this data (images in our case) efficiently. Efficiently implies faster and more accurate results. CBIR techniques keep improving over time, with newer algorithms and methods. In this paper, we saw four approaches for feature extraction i.e. DFT, Hartley, DFT wavelet and Hartley wavelet. These 4 approaches were carried out on 3 different color spaces, namely, RGB, YCbCr and LUV.

What we observe is that DFT wavelet has really high retrieval rates if you consider individual class rates (Class 8 being the highest) for RGB and YCbCr color spaces. However for LUV, the performance of the DFT wavelet for class 8 isn't that good.

Hartley wavelet, when you consider class-wise performance, has consistent results in all the color spaces with class 8 providing the best retrieval rates of around 80-82%. Same can be said about DFT and Hartley transforms. They both have consistent and similar results for all the color spaces with class 8 having the highest retrieval rate of 80% and higher.

When we look at the overall average rates as shown in Table 1, we can infer that both RGB and YCbCr have better performance than LUV with YCbCr having slightly better results than RGB color space. Also, if we look in the table, the highest value is that of Hartley wavelet running in the YCbCr color space for the 4 sectors approach (for AD). This value is almost 40%.

Having seen the various results, we can safely comment that CBIR methods need not necessarily work well in any particular color space like the RGB. This paper shows that even in the YCbCr color space, the results are as good or even better. These results only show that CBIR as a field can never be limited to any particular technique and is an ever-increasing and ever-improving field.

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