Image Retrieval using Fractional Coefficients of Transformed Image using DCT and Walsh Transform

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Abstract

The paper presents innovative content based image retrieval (CBIR) techniques based on feature vectors as fractional coefficients of transformed images using DCT and Walsh transforms. Here the feature vector size per image is greatly reduced by taking fractional coefficients of transformed image. The feature vectors are extracted in fourteen different ways from the transformed image. Along with the first being all the coefficients of transformed image, seven reduced coefficients sets (as 50%, 25%, 12.5%, 6.25%, 3.125%, 1.5625% ,0.7813%, 0.39%, 0.195%, 0.097%, 0.048%, 0.024%, 0.012% and 0.06% of complete transformed image) are considered as feature vectors. The two transforms are applied on gray image equivalents and the colour components of images to extract Gray and RGB feature sets respectively. Instead of using all coefficients of transformed images as feature vector for image retrieval, these fourteen reduced coefficients sets for gray as well as RGB feature vectors are used, resulting into better performance and lower computations.

The proposed CBIR techniques are implemented on a database having 1000 images spread across 11 categories. For each proposed CBIR technique 55 queries (5 per category) are fired on the database and net average precision and recall are computed for all feature sets per transform. The results have shown the performance improvement (higher precision and recall values) with fractional coefficients compared to complete transform of image at reduced computations resulting in faster retrieval. Finally Walsh transform surpasses DCT transforms in performance with highest precision and recall values for fractional coefficients and minimum number of computations up to 0.097% and then DCT takes over.

Keywords: CBIR, DCT, Walsh Transform, Fractional Coefficients.

1. Introduction

The large numbers of images are being generated from a variety of sources (digital camera, digital video, scanner, the internet etc.) which have posed technical challenges to computer systems to store/transmit and index/manage image data effectively to make such collections easily accessible. Image compression deals with the challenge of storage and transmission, where significant advancements have been made [1,4,5]. The challenge to image indexing is studied in the context of image database [2,6,7,10,11], which has become one of the promising and important research area for researchers from a wide range of disciplines like computer vision, image processing and database areas.

The thirst of better and faster image retrieval techniques is increasing day by day. Some of important applications for CBIR technology could be identified as art galleries [12,14], museums, archaeology [3], architecture design [8,13], geographic information systems [5], weather forecast [5,22], medical imaging [5,18], trademark databases [21,23], criminal investigations [24,25], image search on the Internet [9,19,20].

A. Content Based Image Retrieval

In literature the term content based image retrieval (CBIR) has been used for the first time by Kato et.al. [4], to describe his experiments into automatic retrieval of images from a database by color and shape feature. The typical CBIR system performs two major tasks [16,17]. 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 [16,17,26].

For feature extraction in CBIR there are mainly two approaches [5] feature extraction in spatial domain and feature extraction in transform domain. The feature extraction in spatial domain includes the CBIR techniques based on histograms [5], BTC [1,2,16], VQ [21,25,26]. The transform domain methods are widely used in image compression, as they give high energy compaction in transformed image [17,24]. So it is obvious to use images in transformed domain for feature extraction in CBIR. Transform domain results in energy compaction in few elements, so large number of the coefficients of transformed image can be neglected to reduce the size of feature vector [23]. Reducing the size feature vector using fractional coefficients of transformed image and till getting the improvement in performance of image retrieval is the theme of the work presented here. Many current CBIR systems use Euclidean distance [1-3,8-14] on the extracted feature set as a similarity measure. The Direct Euclidian Distance between image P and query image Q can be given as equation 1, where Vpi and Vqi are the feature vectors of image P and Query image Q respectively with size 'n'.

$$ED = \sqrt{\sum_{i=1}^{n} (Vpi - Vqi)^2} \qquad (1)$$

2. DISCRETE COSINE TRANSFORM

The discrete cosine transform (DCT) [10,21-24] is closely related to the discrete Fourier transform. It is a separable linear transformation; that is, the two-dimensional transform is equivalent to a one-dimensional DCT performed along a single dimension followed by a one-dimensional DCT in the other dimension. The definition of the two-dimensional DCT for an input image A and output image B is

$$B_{pq} = \alpha_p \alpha_q \sum \sum A_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2n+1)q}{2N}, \begin{matrix} 0 \le p \le M-1 \\ 0 \le q \le N-1 \end{matrix} \qquad (2)$$

$$\alpha_p = \begin{cases} 1/\sqrt{M} & , p = 0 \\ \sqrt{2/M} & , 1 \le p \le M-1 \end{cases} \qquad (3)$$

$$\alpha_q = \begin{cases} 1/\sqrt{N} & , q = 0 \\ \sqrt{2/N} & , 1 \le q \le N-1 \end{cases} \qquad (4)$$

where M and N are the row and column size of A, respectively. If you apply the DCT to real data, the result is also real. The DCT tends to concentrate information, making it useful for image compression applications and also helping in minimizing feature vector size in CBIR [23]. For full 2-Dimensional DCT for an NxN image the number of multiplications required are $N^2(2N)$ and number of additions required are $N^2(2N-2)$.

3. WALSH TRANSFORM

Walsh transform matrix [18,19,23,26] is defined as a set of N rows, denoted Wj, for j = 0, 1, ... , N - 1, which have the following properties:

- Wj takes on the values +1 and -1.
- Wj[0] = 1 for all j.
- $W_j \, x W_k^T = 0$, for $j \neq k$ and $W_j \, x W_k^T = N$, for j=k.
- Wj has exactly j zero crossings, for j = 0, 1, ..., N-1.
- Each row Wj is even or odd with respect to its midpoint.

Walsh transform matrix is defined using a Hadamard matrix of order N. The Walsh transform matrix row is the row of the Hadamard matrix specified by the Walsh code index, which must be an integer in the range [0, ..., N - 1]. For the Walsh code index equal to an integer j, the respective Hadamard output code has exactly j zero crossings, for j = 0, 1,..., N - 1. For the full 2-Dimensional Walsh transform applied to image of size NxN, the number of additions required are $2N^2(N-1)$ and absolutely no multiplications are needed in Walsh transform [23].

Table 1. Computational Complexity for applying transforms to image of size NxN [23]

	DCT	Walsh
Number of Additions	$2N^2(N-1)$	$2N^2(N-1)$
Number of Multiplications	$N^2(2N)$	0
Total Additions for transform of 128x128 image	37715968	4161536

[Here one multiplication is considered as eight additions for last row computations]

4. PROPOSED CBIR-GRAY TECHNIQUES

Figure 1 explains the feature sets extraction used to extract feature sets for proposed CBIR techniques using fractional coefficients of transformed images.

A. Feature Extraction for feature vector ‘T-Gray’

Here the feature vector space of the image of size NxN has NxN number of elements. This is obtained using following steps of T-Gray

1. Extract Red, Green and Blue components of the colour image.
2. Take average of Red, Green and Blue components of respective pixels to get gray image.
3. Apply the Transform ‘T’ on gray image to extract feature vector.
4. The result is stored as the complete feature vector ‘T-Gray’ for the respective image.

Thus the feature vector database for DCT and Walsh transform are generated as DCT-Gray and Walsh-Gray respectively. Here the size of feature database is NxN for every transform.

B. Feature Vector Database ‘Fractional T-Gray’

The fractional coefficients of transformed image as shown in figure 1, are considered to form ‘fractional T-Gray’ feature vector databases. Here first 50% of coefficients from upper triangular part of feature vector ‘T-Gray’ are considered to prepare the feature vector database ‘50%-T-Gray’ for every image as shown in figure 1. Thus DCT-Gray and Walsh-Gray feature databases are used to obtain new feature vector databases as 50%-DCT-Gray and 50%-Walsh-Gray respectively. Then per image first 25% number of coefficients (as shown in figure 1) from feature vectors database DCT-Gray and Walsh-Gray are stored separately as feature databases 25%-DCT-Gray and 25%-Walsh-Gray respectively. Then for every image as shown in figure 1, fractional feature vector database for DCT-Gray and Walsh-Gray using 25%, 12.5%, 6.25%, 3.125%, 1.5625% ,0.7813%, 0.39%, 0.195%, 0.097%, 0.048%, 0.024%, 0.012% and 0.06% of total coefficients are formed.

C. Query Execution for ’T-Gray’ CBIR

Here the feature set of NxN for the query image is extracted using transform ‘T’. This feature set is compared with each entry of the same transform based feature sets from the feature database using Euclidian distance as similarity measure.

Thus DCT and Walsh transform based feature sets are extracted from query image and are compared respectively with DCT-Gray and Walsh-Gray feature sets to find Euclidian distances.

D. Query Execution for ‘Fractional T-Gray’ CBIR

For 50%-T-Gray query execution, only 50% number of coefficients of upper triangular part of ‘T’ transformed query image (with NxN coefficients) are considered for the CBIR and are compared ‘50%-T-Gray’ database feature set for Euclidian distance computations. Thus DCT and Walsh transform based feature sets are extracted from query image and are compared respectively with 50%-DCT-Gray and 50%-Walsh-Gray feature sets to find Euclidian distances.

For 25%, 12.5%, 6.25%, 3.125%, 1.5625% ,0.7813%, 0.39%, 0.195%, 0.097%, 0.048%, 0.024%, 0.012% and 0.06% T-Gray based query execution, the feature set of the respective percentages are considered from the ‘T’ transformed NxN image as shown in figure 1, to be compared with the respective percentage T-Gray feature set database to find Euclidian distances.

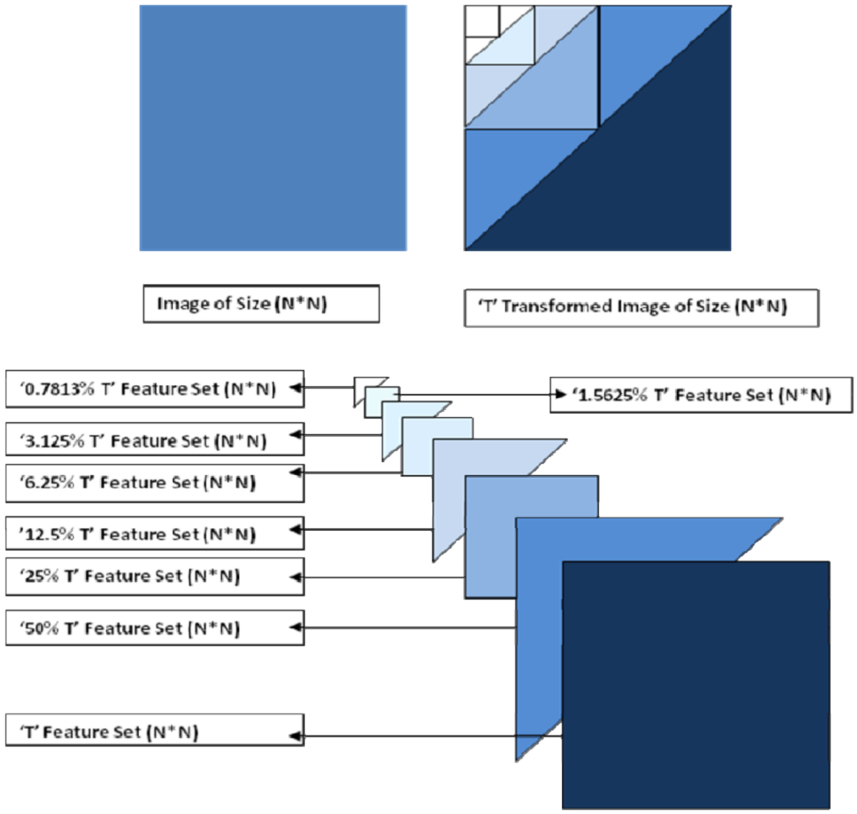


Fig 1. Feature Extraction for Proposed CBIR Techniques

5. PROPOSED CBIR-RGB TECHNIQUES

A. Feature Extraction for feature vector 'T-RGB'

Here the feature vector space of the image of size NxNx3 has NxNx3 number of elements. This is obtained using following steps of T-RGB

1. Extract Red, Green and Blue components of the color image.
2. Apply the Transform 'T' on individual color planes of image to extract feature vector.
3. The result is stored as the complete feature vector 'T-RGB' for the respective image.

Thus the feature vector database for DCT and Walsh transform are generated as DCT-RGB and Walsh-RGB respectively. Here the size of feature database is NxNx3.

B. Query Execution for 'T-RGB' CBIR

Here the feature set of NxNx3 for the query image is extracted using transform 'T' applied on the red, green and blue planes of query image. This feature set is compared with other feature sets in feature database using Euclidian distance as similarity measure. Thus DCT and Walsh transform based feature sets are extracted from query image and are compared respectively with DCT-RGB and Walsh-RGB feature sets to find Euclidian distances.

C. CBIR using 'Fractional-T-RGB'

As explained in section IV-B,C,D and section V-B the 'T-RGB' feature extraction and query execution are extended to get 50%, 25%, 12.5%, 6.25%, 3.125%, 1.5625% ,0.7813%, 0.39%, 0.195%, 0.097%, 0.048%, 0.024%, 0.012% and 0.006% of T-RGB image retrieval techniques.

6. IMPLEMENTATION

The implementation of the three CBIR techniques is done in MATLAB 7.0 using a computer with Intel Core 2 Duo Processor T8100 (2.1GHz) and 2 GB RAM. The CBIR techniques are tested on the image database [15] of 1000 variable size images spread across 11 categories of human being, animals, natural scenery and manmade things. The categories and distribution of the images is shown in table 2.

Table 2. Image Database: Category-wise Distribution

Category	Tribes	Buses	Beaches
No.of Images	85	99	99
Category	Horses	Mountains	Airplanes
No.of Images	99	61	100
Category	Dinosaurs	Elephants	Roses
No.of Images	99	99	99
Category	Monuments	Sunrise	
No.of Images	99	61	

Figure 2 gives the sample database images from all categories of images including scenery, flowers, buses, animals, aeroplanes, monuments, tribal people.

To assess the retrieval effectiveness, we have used the precision and recall as statistical comparison parameters [1,2] for the proposed CBIR techniques. The standard definitions of these two measures are given by following equations.

$$\Pr ecision = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_images\_retrieved} \quad (5)$$

$$\text{Re}\,call = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_relevent\_images\_in\_database} \quad (6)$$

Fig 2.Sample Database Images
[Image database contains total 1000 images with 11 categories]

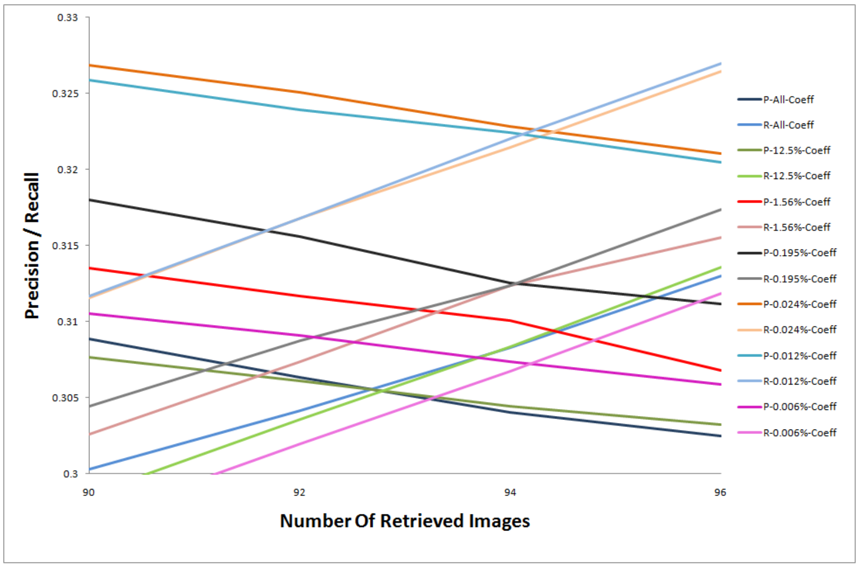
7. RESULTS AND DISCUSSION

For testing the performance of each proposed CBIR technique, per technique 55 queries (5 from each category) are fired on the database of 1000 variable size generic images spread across 11 categories. The query and database image matching is done using Euclidian distance. The average precision and average recall are computed by grouping the number of retrieved images sorted according to ascending Euclidian distances with the query image.

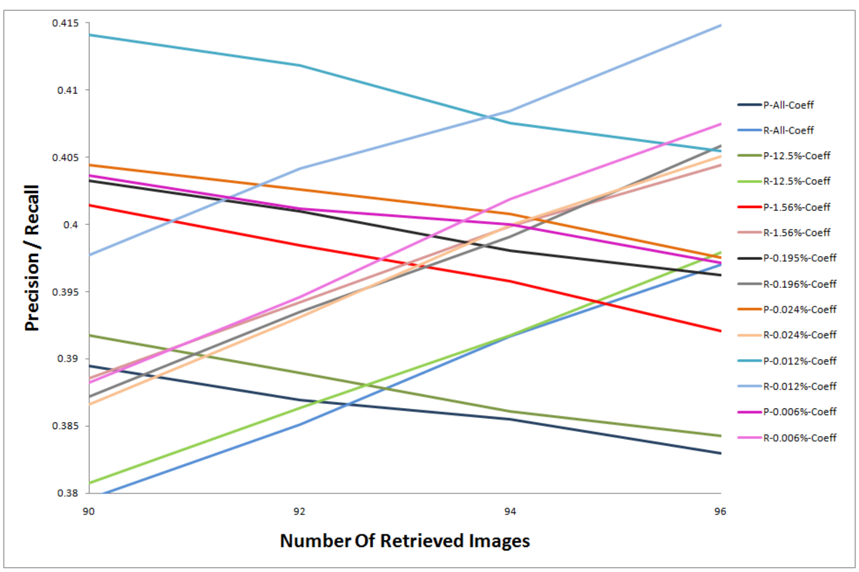
In DCT and Walsh transform, the average precision and average recall values for CBIR using fractional coefficients are higher than CBIR using full set of coefficients. The CBIR-RGB techniques are giving higher values than CBIR-Gray techniques. Even at the 0.024% fractional coefficients feature set the higher precision and recall values are obtained than considering 100% coefficients in DCT and Walsh transform based image retrieval. The crossover point of precision and recall of the CBIR techniques acts as one of the important parameters to judge their performance [1,2,19,20].

Figure 3 and figure 4 shows the precision-recall crossover points plotted against number of retrieved images for proposed image retrieval techniques using DCT. Overall in all proposed techniques considering partial coefficients improves the performance as signified by higher crossover point values for respective transforms. Uniformly in all image retrieval techniques based on gray DCT and colour DCT features 0.012% fractional feature set ($1/8192^{th}$ of total coefficients) based image retrieval gives highest precision and recall values.

Figure 3.a gives average precision/recall values plotted against number of retrieved images for all DCT-Gray image retrieval techniques. Precision/recall values for DCT-RGB image retrieval techniques are plotted in figure 3.b.



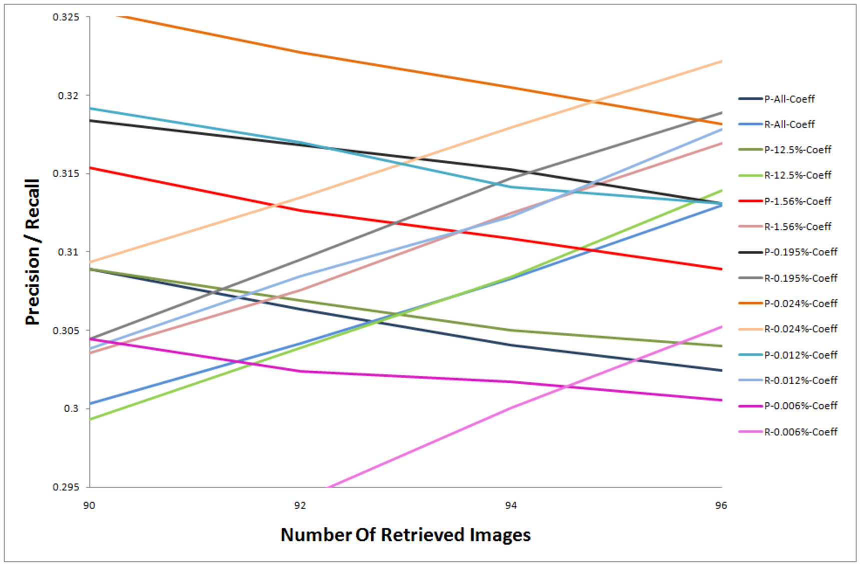
3.a. DCT-Gray based CBIR



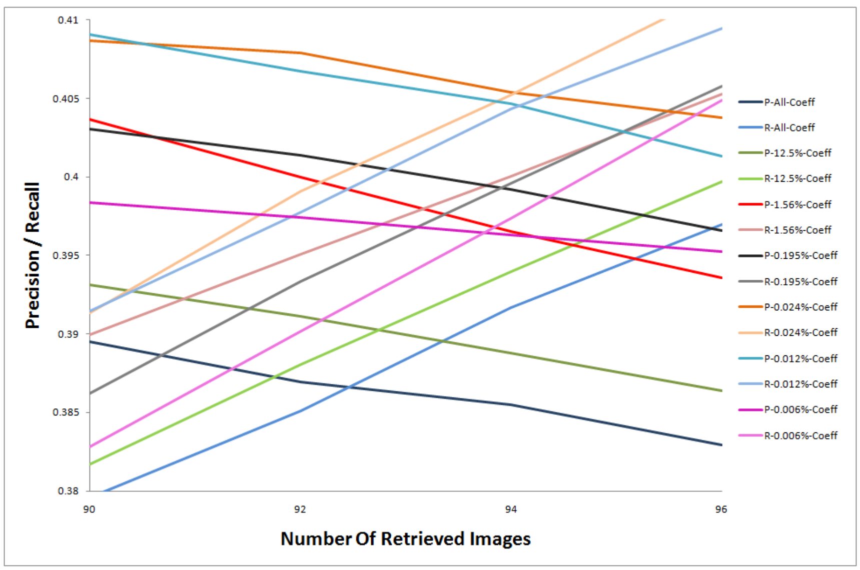
3.b. DCT-RGB based CBIR

Figure 3: Crossover Point of Precision and Recall Vs Number of Retrieved Images for DCT based CBIR.

Figures 4.a and 4.b respectively shows the graphs of precision/recall values plotted against number of retrieved images for Walsh-Gray and Walsh-RGB based image retrieval techniques. Here $1/4096^{th}$ fractional coefficients (0.024% of total Walsh transformed coefficients) based image retrieval gives the highest precision/recall crossover values specifying the best performance.



4.a. Walsh-Gray based CBIR

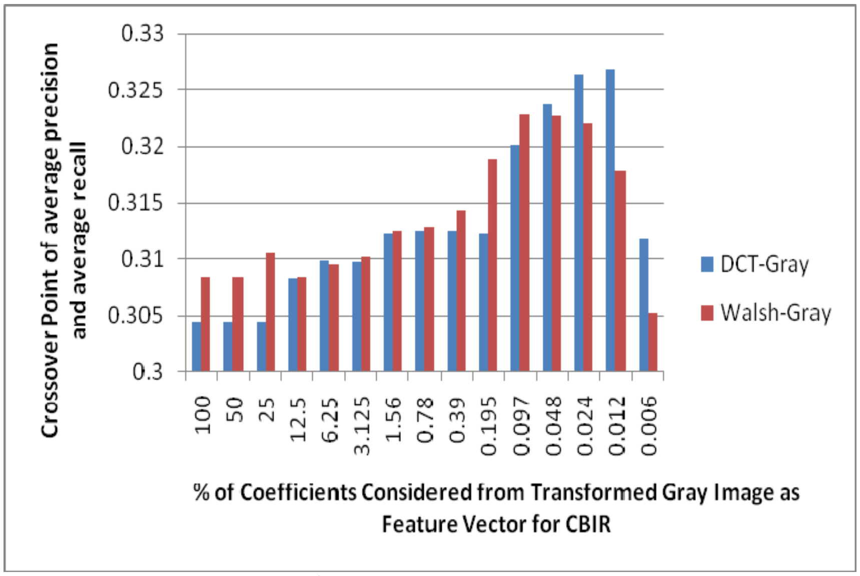


4.b. Walsh-RGB based CBIR

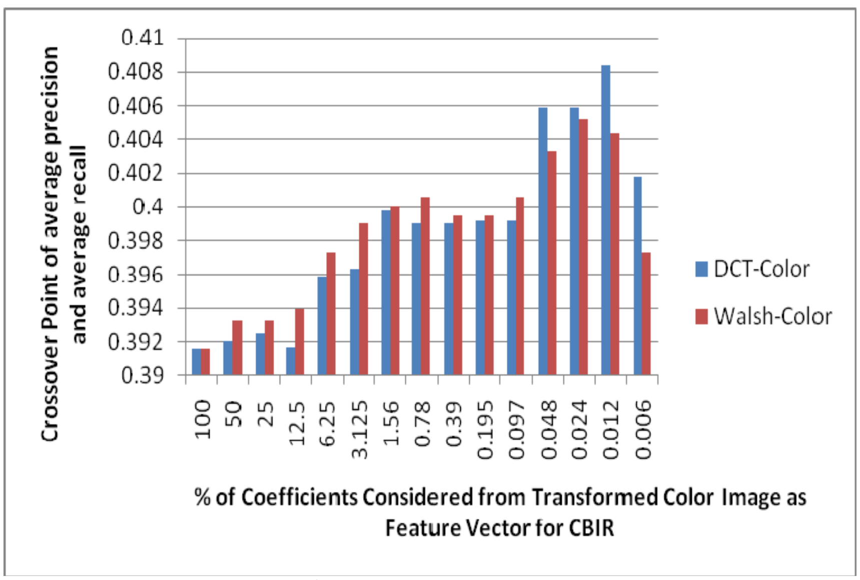
Figure 4: Crossover Point of Precision and Recall Vs Number of Retrieved Images for Walsh T. based CBIR

Figure 5 shows the performance comparison of both transforms for proposed CBIR techniques. Figure 5.a is indicating the crossover points of DCT-Gray CBIR and Walsh-Gray CBIR for all considered feature vectors (percentage of coefficients of transformed gray images). Here up to 0.097 % of coefficients Walsh transform performs better than DCT after which DCT outperforms Walsh, as the energy compaction in DCT is better than in Walsh transform. For Walsh-Gray CBIR the performance improves with decreasing feature vector size from 100% to 0.097% and then drops indicating 0.097% as best fractional coefficients. In DCT-Gray CBIR the performance is improved till 0.012% and then drops. Better performance at lower computational complexity can be achieved.

Figure 5.b indicates the performance comparison of Walsh-RGB CBIR and DCT-RGB CBIR with different percentage of fractional coefficients. Here Walsh-RGB CBIR outperforms DCT-RGB CBIR till 0.097% of coefficients as feature vector then DCT-RGB CBIR takes over. In Walsh-RGB CBIR the feature vector with 0.024% of coefficients gives best performance and in DCT-RGB CBIR 0.012% of coefficients shows highest crossover value of average precision and average recall.



5.a. Transform Comparison in Gray based CBIR



5.b. Transform Comparison in Color based CBIR

Figure 5: Performance Comparison of Fractional Walsh-CBIR and Fractional DCT-CBIR

8. CONCLUSION

Today because of advent of the technology there is a situation like information explosion. Images have giant share in this information. More precised retrieval techniques are needed to access the large image achieves being generated, for finding relatively similar images. Computational complexity and retrieval efficiency are the key objectives in the image retrieval system. Nevertheless it is very difficult to reduce the computations and improve the performance of image retrieval technique.

Here the performance of image retrieval is improved using fractional coefficients of transformed images at reduced computational complexity. For DCT and Walsh transform the average precision/recall values of CBIR using fractional coefficients are better than using all coefficients of transformed images as feature vectors. In Walsh transform based CBIR techniques the feature set with 0.024% of total transformed coefficients gives the best performance. In DCT based CBIR methods 0.012% of total coefficients gives highest crossover point value of average precision and average recall showing the best performance. In both transforms RGB based features are superior than Gray based feature sets. Finally the conclusion that the fractional coefficients gives better discrimination capability in CBIR than the complete set of transformed coefficients at much faster rate can be drawn from the proposed techniques and experimentation done.

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