Image Retrieval using Fractional Coefficients of Orthogonal Wavelet Transformed Images with Seven Image Transforms

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ABSTRACT
The paper presents novel content based image retrieval (CBIR) methods using orthogonal wavelet transforms generated from 7 different transforms namely Walsh, Haar, Kekre, Slant, Hartley, DST and DCT. Here the feature vector size per image is greatly reduced by taking fractional coefficients of the transformed image. The feature vectors are extracted in fifteen different ways from the transformed image. Along with the first being all the coefficients of transformed image, fourteen 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 0.006% of complete transformed image) are considered as feature vectors. Instead of using all coefficients of transformed images as the feature vector for image retrieval, these fourteen reduced coefficients sets 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 (randomly selected 5 images per category) are fired on the database and average precision and recall values are plotted to get precision-recall crossover point. The results have shown the performance improvement (higher precision-recall crossover point) with fractional coefficients compared to complete transform of image at reduced computations resulting in faster retrieval. The wavelet transform generated using Kekre transform for 0.048% reduced coefficient set gives the best performance among the proposed CBIR techniques.

Keywords
CBIR; Fractional Coefficients, Wavelet Transforms, Walsh, Haar, Kekre, Slant, Hartley, Sine, Cosine.

1. INTRODUCTION
A 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 the 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] and image search on the Internet [9, 19, 20].

1.1 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] namely 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] and 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]. The theme of the work presented here is reducing the size of feature vector using fractional coefficients of transformed image until improvement in performance of image retrieval is achieved. 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. GENERATING WAVELET TRANSFORM FROM ANY ORTHOGONAL TRANSFORM

Wavelet transform matrix [27] of size P^2 x P^2 can be generated from any orthogonal transform M of size P x P. For example, if we have orthogonal transform matrix of size 9x9, then its corresponding wavelet transform matrix will have size 81x81 i.e. for orthogonal matrix of size P, wavelet transform matrix size will be Q, such that $Q = P^2$.

To generate the wavelet matrix, every column of the orthogonal transform matrix is repeated P times. Then the second row is translated P times to generate next P rows. Similarly all rows are translated to generate P rows corresponding to each row. Finally we get the wavelet matrix of the size Q x Q, where $Q = P^2$.

3. PROPOSED METHOD

In the proposed CBIR methods, wavelet transforms of size 256 x 256 are generated from 7 different 16 x 16 orthogonal transforms namely Walsh, Haar, Kekre, Slant, Hartley, DST and DCT. These wavelet transforms are then applied on the image to obtain transformed image content. Along with complete transformed image content, different fractional coefficients [28] of this transformed image are considered as feature vectors. For 50% reduced fractional coefficients upper triangular part of the transformed content is considered as feature vector. The first quadrant of the transformed image is considered as feature vector for 25% reduced fractional coefficients. The process is repeated till reduced fractional coefficient of 0.006%. The size of the feature vector is reduced considerably with the fractional coefficients as shown in Figure 1.

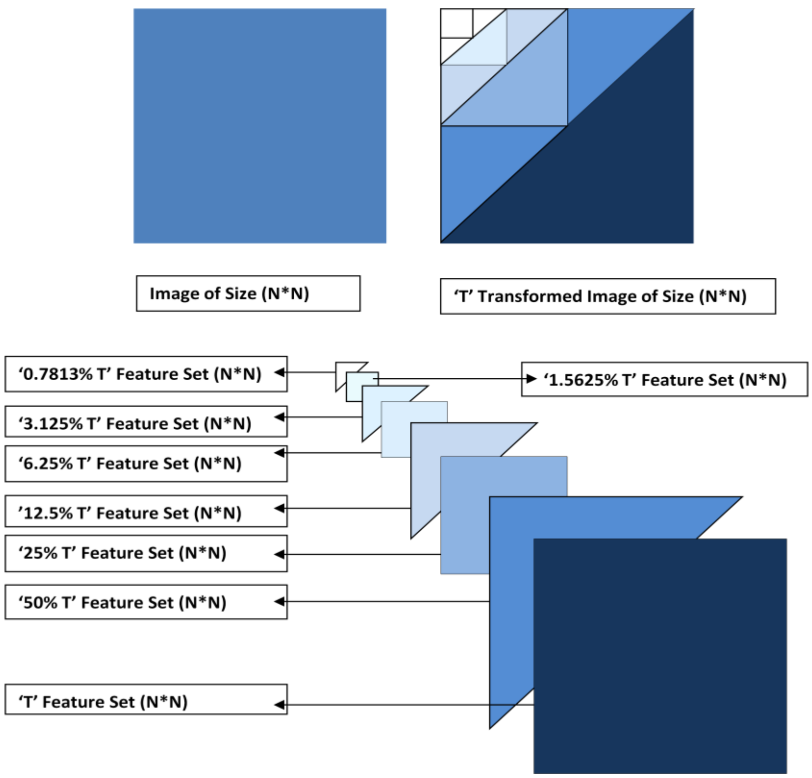

Figure 1. Feature Extraction for Proposed CBIR Techniques

Table 1. Feature Vector Size for different Levels of Fractional Coefficients

Fractional Coefficient	Feature Vector Size	Fractional Coefficient	Feature Vector Size	Fractional Coefficient	Feature Vector Size
100%	196608	**3.125%**	6144	**0.097%**	192
50%	98304	**1.5625%**	3072	**0.048%**	96
25%	49152	**0.7813%**	1536	**0.024%**	48
12.5%	24576	**0.39%**	768	**0.012%**	24
6.25%	12288	**0.195%**	384	**0.006%**	12

4. IMPLEMENTATION

The implementation of the proposed 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
Number of Images	85	99	99
Category	**Horses**	**Mountains**	**Airplanes**
Number of Images	99	61	100
Category	**Dinosaurs**	**Elephants**	**Roses**
Number of Images	99	99	99
Category	**Monuments**	**Sunrise**	
Number 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, etc.

Figure 2. Sample Database Images Spread across 11 Categories

To assess the retrieval effectiveness, we have used the crossover point of precision and recall as statistical comparison parameters [1,2] for the proposed CBIR techniques. The standard definitions of these two measures are given by equations 2 and 3.

$$Precision = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_images\_retrieved} \quad (2)$$

$$Recall = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_relevent\_images\_in\_database} \quad (3)$$

5. RESULTS AND DISCUSSION

The performance of the proposed CBIR methods is tested by firing 55 queries (randomly selected 5 images from each image category) on the image database. The feature vector set of the query image is extracted and compared with the respective feature set of the transform using Euclidian distance.

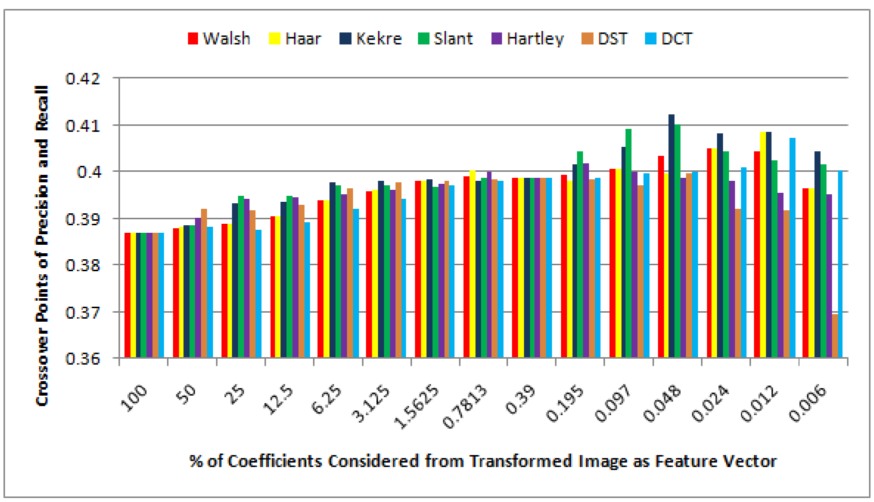

Figure 3. Performance comparison of the proposed CBIR methods for different percentages of fractional coefficients

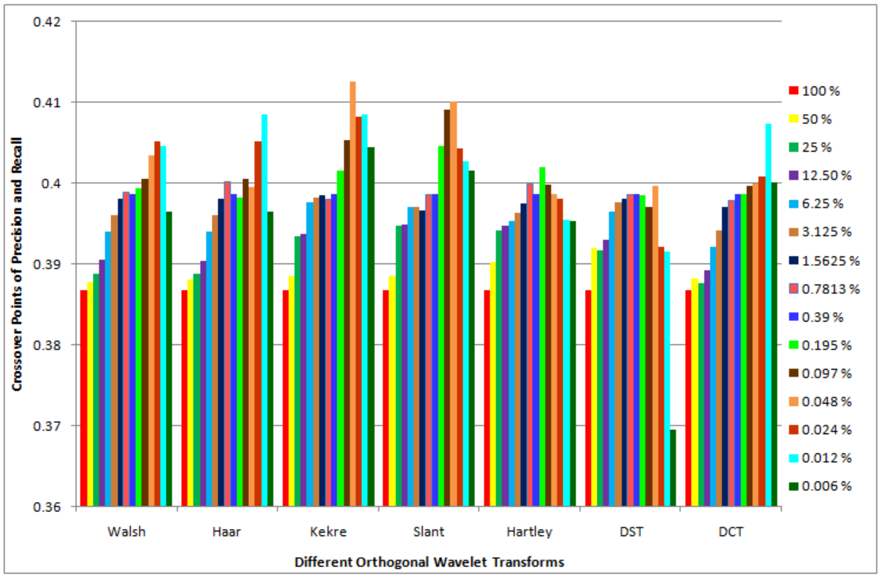

Figure 4. Performance comparison of the proposed CBIR methods for 7 different orthogonal wavelet transforms

The average and precision and recall values are found for all proposed CBIR methods and plotted against the number of retrieved images (1 – 100). The intersection of plotted precision and recall curves gives the crossover point. The crossover point of precision and recall is computed for all the proposed CBIR methods. The CBIR technique with higher value of crossover point indicates better performance. Figure 3 shows the performance comparison of the proposed CBIR methods for different levels of fractional coefficients. It is observed that almost in all cases the performance of the proposed CBIR methods increases with the reduction in fractional coefficients of the transformed image content up to a certain level (which is different for different transforms). Beyond this level the performance of the proposed CBIR methods decreases as indicated by the precision-recall crossover point values. For 100 % content of the transformed image, the performance of all the 7 transforms is same as indicated by the graph.

Figure 4 shows the performance comparison of the proposed CBIR methods for 7 different orthogonal wavelet transforms. In case of Hartley and DST wavelet transforms, the increase in value of crossover point with reduction in fractional coefficients is comparatively less as compared to other five transforms indicating that the energy distribution in these wavelet transforms is distributed throughout the transformed image rather than being concentrated at the top left corner of the transformed image as in the case of other five wavelet transforms. This indicates that energy compaction is less in Hartley and DST wavelet transforms.

Table 3. Crossover Point Values for different orthogonal wavelet transforms matrices

Percentage of Fractional Coefficients	Walsh	Haar	Kekre	Slant	Hartley	DST	DCT
100	0.3868	0.38681116	0.3868	0.38681116	0.3868	0.3868	0.38681115
50	0.38784	0.38807222	0.388488	0.38843091	0.3902	0.392	0.38827669
25	0.388842	0.38884187	0.393419	0.39479	0.3941115	0.3916819	0.38768871
12.5	0.3906	0.390367	0.39367327	0.39485	0.39466315	0.393	0.3892
6.25	0.394	0.394077	0.39762574	0.397	0.395315	0.39641384	0.39213
3.125	0.396	0.3960776	0.39822	0.397	0.3962725	0.3976566	0.394153
1.5625	0.39808	0.398	0.39852	0.396675	0.39755	0.398	0.397
0.7813	0.3989255	0.40014904	0.398	0.39859	0.3999	0.398512	0.39791286
0.39	0.39871319	0.39871317	0.3987132	0.39871317	0.3987132	0.39871318	0.39871317
0.195	0.399355	0.3982	0.40147328	0.40454157	**0.401943**	0.39848	0.398695
0.097	0.400455	0.400456	0.405334	0.40913568	0.39981824	0.397	0.399655
0.048	0.403434	0.3995	**0.4125**	**0.41007889**	0.39863321	**0.3997**	0.4
0.024	**0.4051865**	0.4051865	0.4082225	0.40435334	0.398	0.39216315	0.40085
0.012	0.404566	**0.4085172**	0.40855	0.40263285	0.39541367	0.3916	**0.4074**
0.006	0.3964893	0.39648928	0.4045068	0.401473	0.395335	0.3694538	0.40014

Table 4. Crossover Point Values for different orthogonal transform matrices

Percentage of Fractional Coefficients	Walsh	Haar	Kekre	Slant	Hartley	DST	DCT
100	0.385	0.385	0.385	0.385	0.385	0.385	0.385
50	0.3867	0.387	0.395	0.40125	0.39425	0.388	0.3864
25	0.3867	0.3885	0.4	**0.4125**	0.39475	0.38725	0.3852
12.5	0.388	0.391	0.4125	**0.4125**	0.39465	0.38775	0.3864
6.25	0.3914	0.394	**0.4195**	0.4065	0.39375	0.39225	0.3904
3.125	0.3931	0.396	0.418	0.4065	0.3935	0.3925	0.3911
1.5625	0.4	0.398	0.411	0.4015	0.39275	0.3935	0.3998
0.7813	0.401	0.399	0.413	0.4015	0.3935	0.39363	0.3994
0.39	0.3992	0.3985	0.4105	0.4015	0.39275	0.39275	0.3992
0.195	0.3995	0.398	0.4107	0.4015	0.39265	0.3915	0.399
0.097	0.4006	0.4003	0.4035	0.40125	0.39065	0.3955	0.3992
0.048	0.4033	0.399	0.4025	0.40125	0.392	**0.396**	0.4
0.024	**0.4052**	**0.4052191**	0.4026	0.40135	0.393	0.3875	0.4
0.012	0.4043	0.405	0.3963	0.40135	0.39	0.395	**0.4084**
0.006	0.3973	0.397	0.396	0.4014	**0.39525**	0.358	0.4018

Table 3 and Table 4 show the crossover point values for orthogonal wavelet transforms and orthogonal transforms respectively. On comparing these two tables, it is observed that the proposed CBIR methods using Wavelet transforms have better efficiency than the normal transforms. In case of Walsh, the performance of orthogonal wavelet transforms and orthogonal transforms is almost same. In case of Haar and Kekre, the proposed CBIR method outperforms the orthogonal transforms both in terms of higher crossover value and reduced feature vector size. In case of Slant, the value of crossover point is slightly less in wavelet transforms as compared to normal transforms though the feature vector size in case of wavelet transform is considerably less. In case of Hartley and DST matrices the proposed CBIR methods performed better as compared to the normal transform. In case of DCT matrix, the crossover point value for orthogonal wavelet transform is slightly less than the normal orthogonal transforms.

Overall, the proposed CBIR methods using orthogonal wavelet transforms prove to be better than normal orthogonal transforms.

The highest crossover point value per wavelet transform and their corresponding fractional coefficients values are shown in Table 5. It can be observed that the performance of the proposed CBIR methods is increased with reduction in fractional coefficients and the feature vector size is also reduced significantly as shown in Table 1. Among all the wavelet transforms, Slant wavelet transform gives the best performance with 0.048 % reduced fractional coefficients.

Table 5. Highest Crossover Point Values per Wavelet Transforms and Corresponding Fractional Coefficient Value

Wavelet Transforms	Highest Crossover Point Value	Corresponding Fractional Coefficient
Walsh	0.4051865	0.024
Haar	0.4085172	0.012
Kekre	**0.4125**	**0.048**
Slant	0.41007889	0.048
Hartley	0.401943	0.195
DST	0.3997	0.048
DCT	0.4074	0.012

6. CONCLUSION

In the proposed CBIR methods, the performance of image retrieval is improved using fractional coefficients of wavelet transformed image at reduced computational complexity and feature vector size. For wavelet transform generated using Kekre transform matrix, the feature set with 0.048% fractional coefficient of the total transformed image gives the best performance. It is also observed that performance of the proposed CBIR methods increases with reduction in fractional coefficients up to a certain level which is different for each transform.

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