Reduction in Feature Vector Size of Colour Averaging based Image Retrieval Techniques using Walsh Wavelet Pyramid Levels

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ABSTRACT
The paper presents the reduction of feature vector size of the image by using Wavelet Pyramids based image retrieval techniques for Walsh Transform. The colour averaging methods like row & column mean (RCM), forward diagonal mean (FDM) and row column & forward diagonal mean (RCFDM) are applied on image wavelets generated at four levels of decomposition. The proposed content based image retrieval (CBIR) techniques are tested on a generic image database having 1000 images spread across 11 categories. For each proposed CBIR technique 55 queries (randomly selected 5 per category) are fired on the image database. To compare the performance of image retrieval techniques average precision and recall values are computed for all queries. When these results are compared with the colour averaging based image retrieval techniques applied on the original image itself, it has been observed that the precision recall crossover value for wavelet pyramid level 1 is almost same (up to 3 decimal places) for FDM and RCFDM. However the size of the feature vector in the proposed CBIR methods is significantly less than the original image. Thus the proposed CBIR methods prove to be better in terms of reduced computational complexity. In the discussed image retrieval methods, Walsh wavelet pyramid level 1 for RCFDM gives the highest performance as indicated by the precision recall crossover point.

Keywords
CBIR, Colour averaging, Row & Column Mean (RCM), Forward Diagonal Mean (FDM), Wavelet Pyramids, Walsh Transform.

1. INTRODUCTION
Computer system are facing technical challenges to store/transmit and index/manage image data effectively to make easy access to the image collections of tremendous size being generated due to large numbers of images generated from a variety of sources (digital camera, digital video, scanner, the internet etc.). Image compression deals with the challenge of storage and transmission, where significant advancements have been made [2,5,6]. The challenge to image indexing is studied in the context of image database [3,7,8,11,12], 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 [13,15], museums, archaeology [4], architecture design [9,14], geographic information systems [6], weather forecast [6,23], medical imaging [6,19], trademark databases [22,24], criminal investigations [25,26], image search on the internet [10,20,21].

1.1 Content Based Image Retrieval
In literature the term content based image retrieval (CBIR) was used for the first time by Kato et.al. [5], to describe his experiments into automatic retrieval of images from a database by colour and shape feature. The typical CBIR system performs two major tasks [17,18]. 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 [17,18,27].

For feature extraction in CBIR there are mainly two approaches [6] feature extraction in spatial domain and feature extraction in transform domain. The feature extraction in spatial domain includes the CBIR techniques based on histograms [6], BTC [2,3,17], VQ [22,26,27]. The transform domain methods are widely used in image compression, as they give high energy compaction in transformed image [18,25]. So it is obvious to use images in transformed domain for feature extraction in CBIR [24]. But taking transform of image is time consuming. Reducing the size of feature vector using pure image pixel data in spatial domain and getting the improvement in performance of image retrieval is the theme of the work presented in [1]. Here those colour averaging based image retrieval techniques are applied on image wavelets generated at four levels of decomposition. Many current CBIR systems use Euclidean distance [2-4,9-15] 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’.

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

2. ROW & COLUMN MEAN (RCM)

The row mean vector is the set of averages of the intensity values of the respective rows. The column mean vector is the set of averages of the intensity values of the respective columns. Both of these are combined to get row & column mean (RCM) [1,23,28] vector. Figure 1 is representing the sample image with size 'nxn', the row and column mean vectors for this image will be as given below in equation 2.

RCM Vector = [Avg(Row 1), Avg(Row 2), …., Avg(Row n), Avg(Col. 1), Avg(Col. 2), …., Avg(Col. n)] (2)

3. FORWARD DIAGONAL MEAN (FDM)

The forward diagonal mean vector is the set of averages of the intensity values of the all forward diagonal elements. Figure 2 represents the sample image with 'n' rows and 'n' columns, the forward diagonal mean (FDM) [1] vector for this image is given below in equation 3.

FDM Vector = [Avg(FDM 1), Avg(FDM 2), ..., Avg(FDM n)] (3)

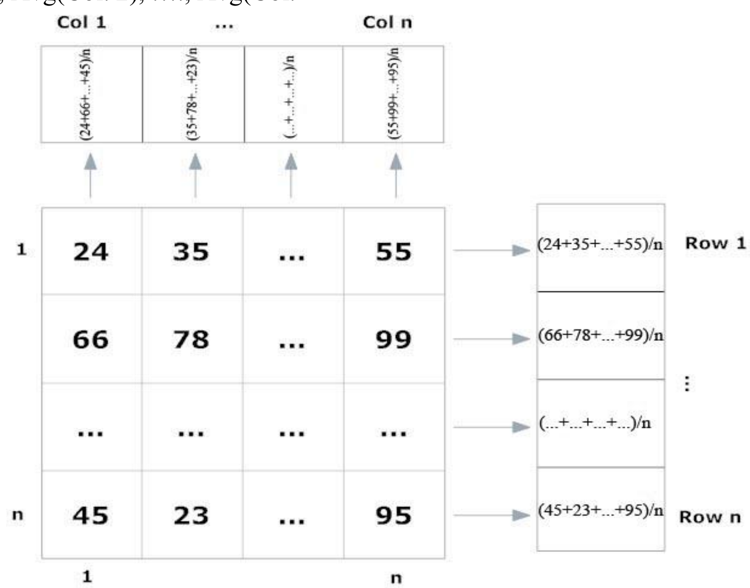

Figure 1. Sample Image Template (with size nxn) showing row & column mean vector

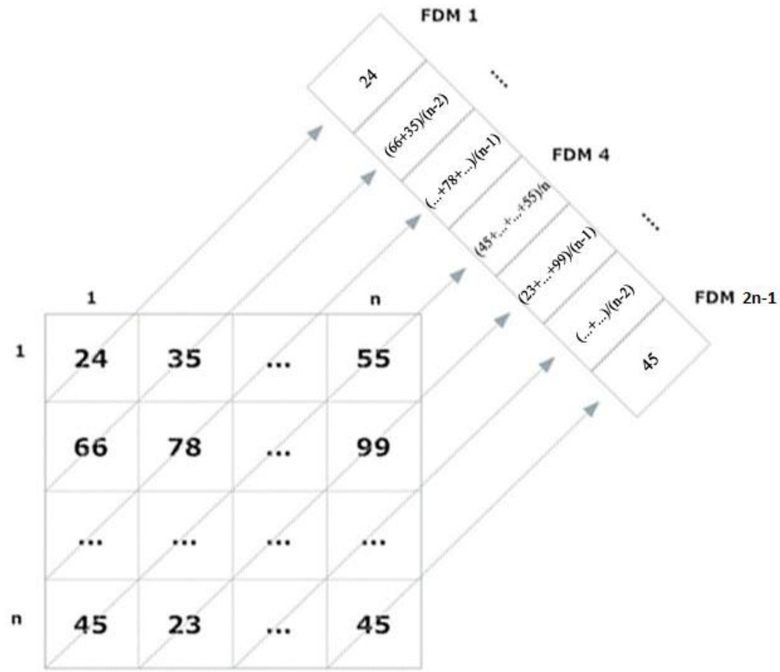

Figure 2. Sample Image Template (with size nxn) showing forward diagonal mean vector

4. WALSH TRANSFORM

The Walsh transform matrix [7,19,20] 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.
- Wj xWkT=0, for j k and Wj xWkT =N, for j=k.
- Wj has exactly j zero crossings, for j = 0, 1,...., N-1.
- Each row Wj is either 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.

5. WAVELETS OF TRANSFORM 'T'

The procedure of generating Wavelets of transform 'T' (T-Wavelets) [20,29] is shown in flowchart given in Figure 3 and can be explained as given in following steps. Let I_{NXN} be the image with size NxN of which T-Wavelets are to be obtained and TNxN be the desired transform matrix (Walsh transform) of size NxN.

A. Apply transform of size NxN on the image of size NxN to get transformed image withn approximation (tIA), horizontal (tIH), vertical (tIV) and diagonal (tID) components.

$$tI_{NxN} = [tIA, tIH, tIV, tID] = [T_{NxN}]\,[I_{NxN}]\,[T'_{NxN}] \quad (4)$$

B. Replace horizontal (tIH), vertical (tIV) and diagonal (tID) components with zero to get modified transformed image 'twI'.

$$twI_{NxN}=[tIA, Zero, Zero, Zero] \quad (5)$$

C. Apply inverse transform on the modifiedtransformed image to get t'wI.

$$t'wI_{NxN}=[T'_{NxN}]\,[twI_{NxN}]\,[T_{NxN}] \quad (6)$$

D. Down-sample the result of step'c' (t'wI) by taking alternate rows and columns to get imagewith size N/2xN/2.

$$dtI_{N/2xN/2}= downsample(t'wI_{NxN}) \quad (7)$$

E. Apply transform of size N/2xN/2 on down-sampled image ($dtI_{N/2xN/2}$) to get theT-Wavelet of level-1.

$$[T_{N/2xN/2}]\,[dtI_{N/2xN/2}]\,[T'_{N/2xN/2}] \quad (8)$$

F. Repeat steps b to e 'P-1' times on the level 1 T-Wavelet to get T-Wavelet of level 'P'.

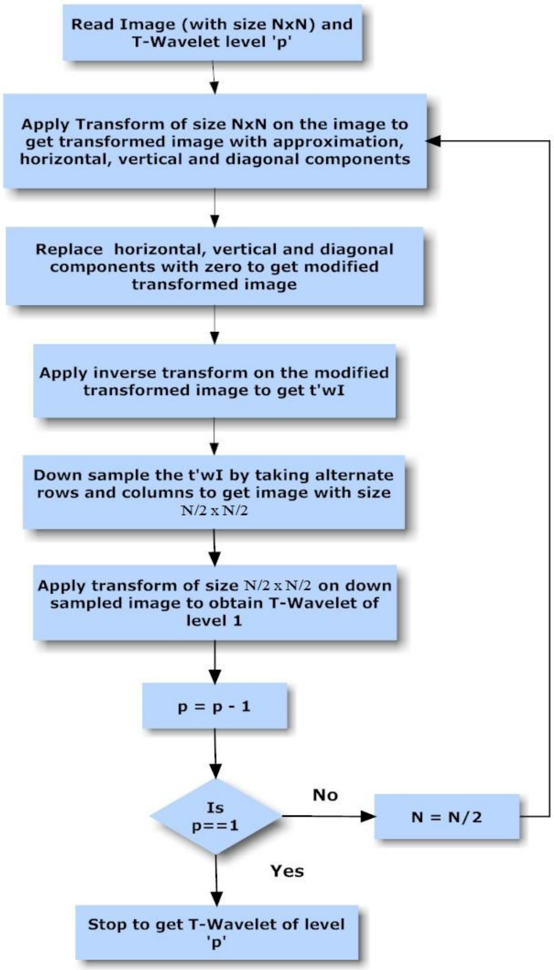

Figure 3. Flowchart for generating T-Wavelets of level 'p'

6. WAVELET PYRAMID OF TRANSFORM 'T'

The T-Wavelets of particular image, when considered together at different levels gives T-Wavelet Pyramid [20]. Here for the first level of T-Wavelet pyramid, transform is applied on the image to get approximation, horizontal, vertical and diagonal components. The approximation components of first level T-Wavelet is considered, transform is applied to it to get second level Wavelet. The T-Wavelet pyramid of a sample image from the database is shown in figure 4 given below where the flower image is decomposed into three levels of T-Wavelet pyramid as T-Wavelet level-1, T-Wavelet level-2 and T-Wavelets level-3.

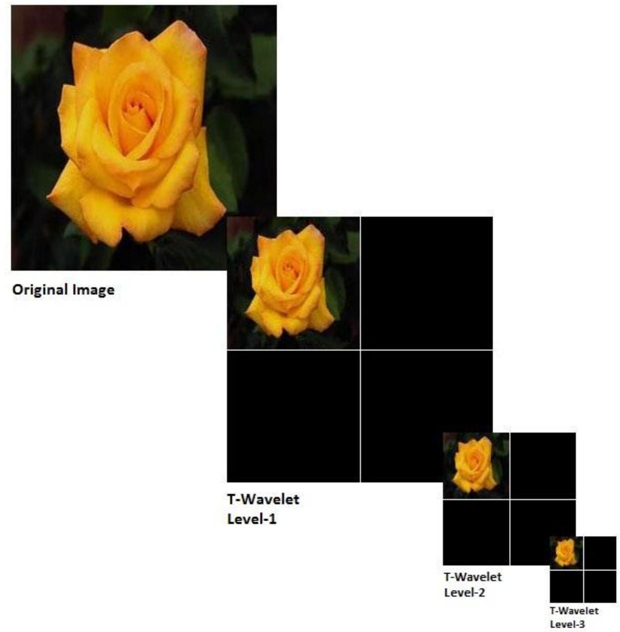

Figure. 4 Different Levels of T-Wavelet Pyramid [20]

7. PROPOSED CBIR TECHNIQUES

Here the approximate components of T-Wavelet level-1, T-Wavelet level-2,...., T-Wavelet level-4 are obtained for all images (resized to 256x256) in the database using Walsh transform and then colour averaging techniques RCM, FDM and RCFDM are applied on them, the results are stored as feature vectors for respective image. At level-1 T-Wavelet the feature vector size is N/2x3. At level-2 T-Wavelet the feature vector size is N/4x3 and so on. Thus the feature vectors up to level-4 T-Wavelets are extracted and feature vector database is generated. The feature set of T-Wavelet level-p is extracted for the query image using proposed technique of T-Wavelet generation. The obtained results are matched with T-Wavelet level-p feature vector database using Euclidian distance as similarity measure. As compared to applying complete transform on the image, the proposed method takes fewer computations to extract the feature set. The value of precision recall crossover point for Walsh Wavelet level 1 is almost same (up to 3 decimal places) in case of FDM and RCFDM as compared to that of FDM [30,31] and RCFDM [30,31] for original image. Thus proposed CBIR techniques prove to be better in terms of reduced feature vector size. The formulae for feature vector size of the proposed CBIR technique is given by equations 9 and 10. Table 1 shows the size of feature vector for different wavelet pyramid levels and original image.

$$FS_{RCM}=2*(N/2^{p})*3 \tag{9}$$

$$FS_{FDM}=[(2*N/2^{p})-1]*3 \tag{10}$$

Table 1. Comparison of Feature Vector Size of Proposed CBIR techniques with Original Image

CBIR Technique	Original Image	Walsh Wavelet Pyramid Level 1	Walsh Wavelet Pyramid Level 2	Walsh Wavelet Pyramid Level 3	Walsh Wavelet Pyramid Level 4
RCM	1536	768	384	192	96
FDM	1533	765	381	189	93
RCFDM	3069	1533	765	381	189

8. IMPLEMENATATION

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 [16] 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. Figure 5 gives the sample database images from generic image database.

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 5. Sample Images from Generic Image Database Spread across 11 Categories

To assess the retrieval effectiveness, we have used the precision and recall as statistical comparison parameters [2,3] for the proposed CBIR techniques. The standard definitions for these two measures are given by equations 11 and 12.

$$Precision = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_images\_retrieved} \quad (11)$$

$$Recall = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_relevent\_images\_in\_database} \quad (12)$$

9. RESULTS AND DISCUSSION

For testing the performance of each proposed CBIR technique, per technique 55 queries (randomly selected 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 in RGB plane based on colour averaging technique used. The average precision and recall values are plotted against the number of retrieved images (2-100) and the intersection of the two curves gives the crossover point. Higher crossover point indicates better performance.

Figure 6 indicates the performance comparison of proposed CBIR techniques indicated by the precision-recall crossover points plotted for all discussed image retrieval methods. It can be seen clearly from the graph that almost everywhere the value of crossover point decreases with the increase in level of Walsh wavelet pyramid, thus indicating that coarse texture contains more information about the image than fine texture. Moreover it can be seen that in case of FDM and RCFDM the value of crossover points is nearly same for Walsh wavelet pyramid level 1 and original image. Since the size of feature vector in wavelet pyramid is less than that of original image but gives the same performance, the proposed CBIR methods prove to be better in terms of reduced feature vector size.

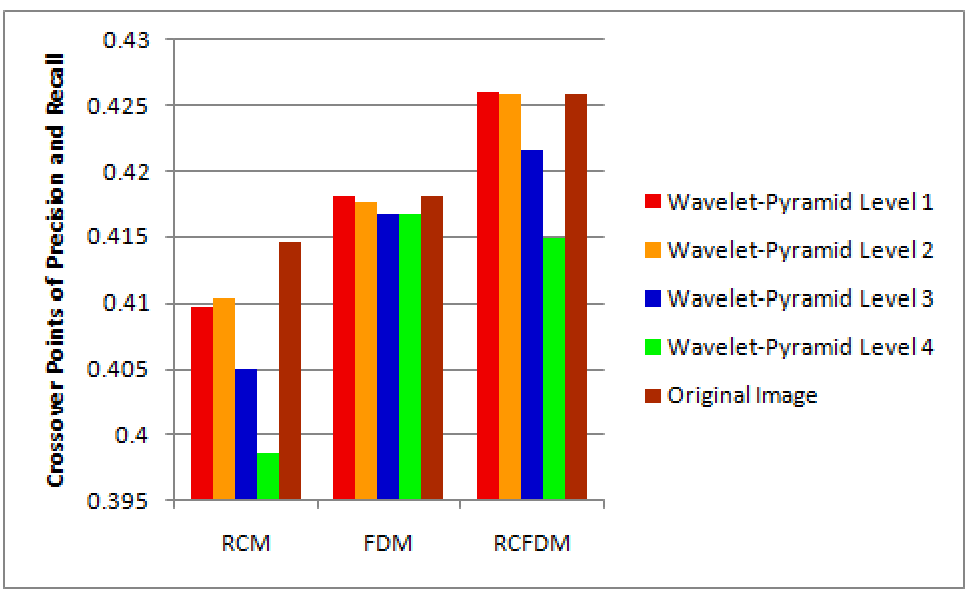

Figure 6. Performance Comparison of RCM, FDM & RCFDM for different Walsh Wavelet-Pyramid Levels with Original Image

10. CONCLUSION

In spite of many CBIR methods being proposed, the hunger of better and faster image retrieval techniques has still not been satisfied. The paper has presented a faster image retrieval technique without affecting the efficiency of image retrieval. Here in all 12 different image retrieval methods based on Walsh wavelet pyramids are tested on image database of 1000 images spread across 11 categories. The average precision and recall values and feature vector size have proved that the Walsh wavelet pyramid level 1 based RCFDM method is better than original image. Moreover the performance of the proposed CBIR methods decreases with increase in level of Walsh wavelet pyramid.

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Dr. Sudeep D. Thepade has Received B.E.(Computer) degree from North Maharashtra University with Distinction in 2003, M.E. in Computer Engineering from University of Mumbai in 2008 with Distinction, Ph.D. from SVKM's NMIMS (Deemed to be University) in July 2011, Mumbai. He has more than 08 years of experience in teaching and industry. He was Lecturer in Dept. of Information Technology at Thadomal Shahani Engineering College, Bandra(W), Mumbai for nearly 04 years. Currently working as Associate Professor in Computer Engineering at Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS (Deemed to be University), Vile Parle(W), Mumbai, INDIA. He is member of International Advisory Committee for many International Conferences, acting as reviewer for many referred international journals/transactions including IEEE and IET. His areas of interest are Image Processing and Biometric Identification. He has guided five M.Tech. projects and several B.Tech projects. He more than 115 papers in National/International Conferences/Journals to his credit with a Best Paper Award at International Conference SSPCCIN-2008, Second Best Paper Award at ThinkQuest-2009, Second Best Research Project Award at Manshodhan 2010, Best Paper Award for paper published in June 2011 issue of International Journal IJCSIS (USA), Editor's Choice Awards for papers published in International Journal IJCA (USA) in 2010 and 2011.

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