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

Dr. H. B. Kekre
Senior Professor
Computer Engineering Department
SVKM`s NMIMS (Deemed-to-be University)
Vile Parle (W), Mumbai, India

Dr. Sudeep D. Thepade
Associate Professor
Computer Engineering Department
SVKM`s NMIMS (Deemed-to-be University)
Vile Parle (W), Mumbai, India

Dr. Tanuja K. Sarode
Assistant Professor
Computer Engineering Department
Thadomal Shahani Engg. College
Bandra ((W), Mumbai, India

Varun K. Banura
B. Tech Student
Computer Engineering Department
SVKM`s NMIMS (Deemed-to-be University)
Vile Parle (W), Mumbai, India.

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)

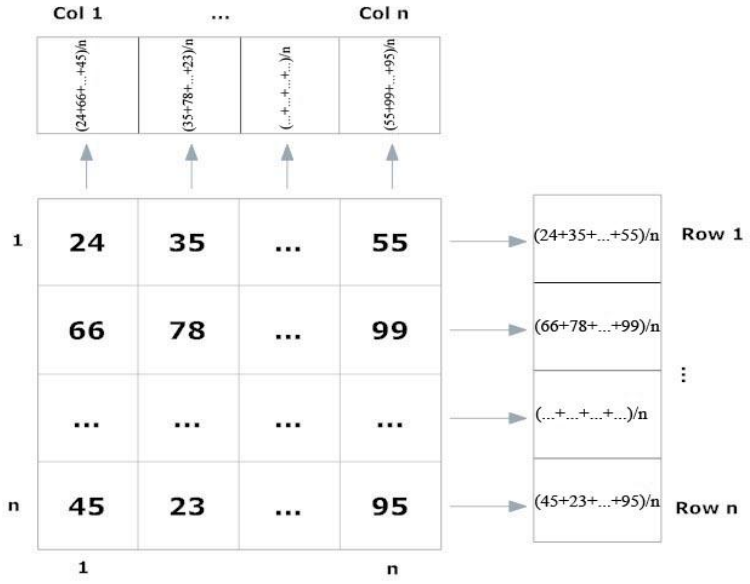

Figure 1. Sample Image Template (with size nxn) showing row & column mean vector

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)

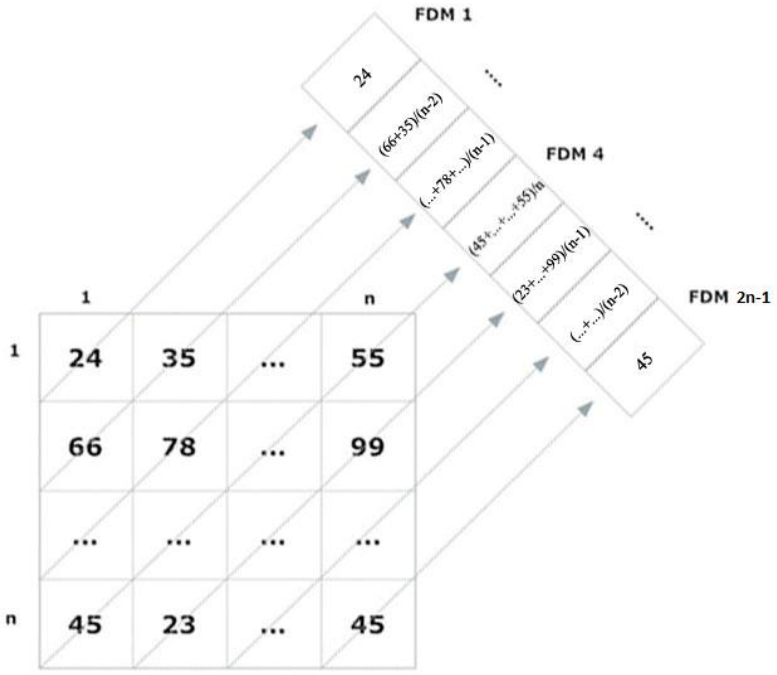

Figure 2. Sample Image Template (with size nxn) showing forward diagonal mean vector

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.

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

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'.

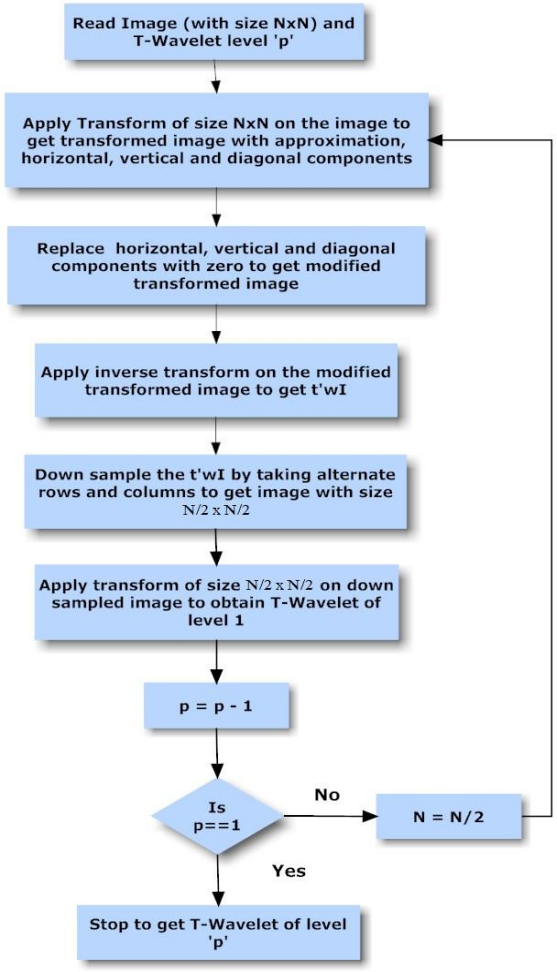

Figure 3. Flowchart for generating T-Wavelets of level 'p'

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.

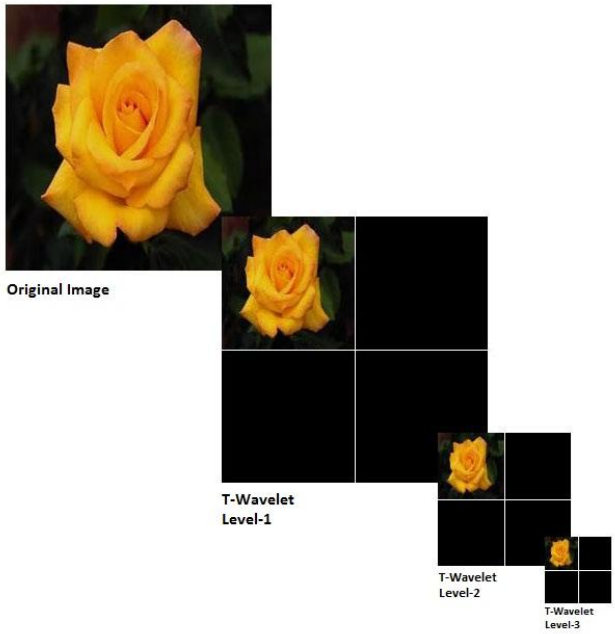

Figure. 4 Different Levels of T-Wavelet Pyramid [20]

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.

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

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

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.

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

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

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.

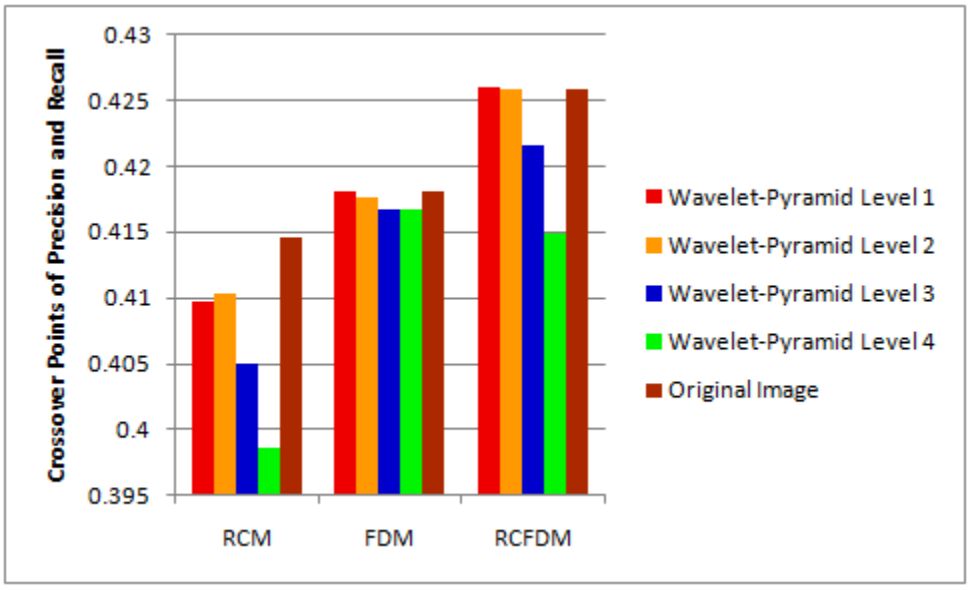

Figure 6. Performance Comparison of RCM, FDM & RCFDM for different Walsh Wavelet-Pyramid Levels with Original Image

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.

11. REFERENCES

[1] Dr. H.B.Kekre, Sudeep D. Thepade, Akshay Maloo, "Query by Image Content Using Colour Averaging Techniques", International Journal of Engineering Science and Technology (IJEST), Volume 2, Issue 6, 2010.pp.1612-1622 (ISSN: 0975-5462) Available online at http://www.ijest.info.

[2] Dr. H.B.Kekre, Sudeep D. Thepade, "Boosting Block Truncation Coding using Kekre's LUV Color Space for Image Retrieval", WASET International Journal of Electrical, Computer and System Engineering (IJECSE), Volume 2, Number 3, pp. 172-180, Summer 2008. Available online at http://www.waset.org/ijecse/v2/v2-3-23.pdf

[3] Dr. H.B.Kekre, Sudeep D. Thepade, "Image Retrieval using Augmented Block Truncation Coding Techniques", ACM International Conference on Advances in Computing, Communication and Control (ICAC3-2009), pp. 384-390, 23-24 Jan 2009, Fr. Conceicao Rodrigous College of Engg., Mumbai. Is uploaded on online ACM portal.

[4] Dr. H.B.Kekre, Sudeep D. Thepade, "Scaling Invariant Fusion of Image Pieces in Panorama Making and Novel Image Blending Technique", International Journal on Imaging (IJI), www.ceser.res.in/iji.html, Volume 1, No. A08, pp. 31-46, Autumn 2008.

[5] Hirata K. and Kato T. "Query by visual example – content-based image retrieval", In Proc. of Third International Conference on Extending Database Technology, EDBT'92, 1992, pp 56-71

[6] Dr. H.B.Kekre, Sudeep D. Thepade, "Rendering Futuristic Image Retrieval System", National Conference on Enhancements in Computer, Communication and Information Technology, EC2IT-2009, 20-21 Mar 2009, K.J.Somaiya College of Engineering, Vidyavihar, Mumbai-77.

[7] Minh N. Do, Martin Vetterli, "Wavelet-Based Texture Retrieval Using Generalized Gaussian Density and Kullback-Leibler Distance", IEEE Transactions On Image Processing, Volume 11, Number 2, pp.146-158, February 2002.

[8] B.G.Prasad, K.K. Biswas, and S. K. Gupta, "Region –based image retrieval using integrated color, shape, and location index", International Journal on Computer Vision and Image Understanding Special Issue: Colour for Image Indexing and Retrieval, Volume 94, Issues 1-3, April-June 2004, pp.193-233.

[9] Dr. H.B.Kekre, Sudeep D. Thepade, "Creating the Color Panoramic View using Medley of Grayscale and Color Partial Images ", WASET International Journal of Electrical, Computer and System Engineering (IJECSE), Volume 2, No. 3, Summer 2008. Available online at www.waset.org/ijecse/v2/v2-3-26.pdf.

[10] Stian Edvardsen, "Classification of Images using color, CBIR Distance Measures and Genetic Programming", Ph.D. Thesis, Master of science in Informatics, Norwegian university of science and Technology, Department of computer and Information science, June 2006.

[11] Dr. H.B.Kekre, Tanuja Sarode, Sudeep D. Thepade, "DCT Applied to Row Mean and Column Vectors in Fingerprint Identification", In Proceedings of International Conference on Computer Networks and Security (ICCNS), 27-28 Sept. 2008, VIT, Pune.

[12] Zhibin Pan, Kotani K., Ohmi T., "Enhanced fast encoding method for vector quantization by finding an optimally-ordered Walsh transform kernel", ICIP 2005, IEEE International Conference, Volume 1, pp I - 573-6, Sept. 2005.

[13] Dr. H.B.Kekre, Sudeep D. Thepade, "Improving 'Color to Gray and Back' using Kekre's LUV Color Space", IEEE International Advanced Computing Conference 2009 (IACC'09), Thapar University, Patiala, INDIA, 6-7 March 2009. Is uploaded at online at IEEE Xplore.

[14] Dr. H.B.Kekre, Sudeep D. Thepade, "Image Blending in Vista Creation using Kekre's LUV Color Space", SPIT-IEEE Colloquium and International Conference, Sardar Patel Institute of Technology, Andheri, Mumbai, 04-05 Feb 2008.

[15] Dr. H.B.Kekre, Sudeep D. Thepade, "Color Traits Transfer to Grayscale Images", In Proc.of IEEE First International Conference on Emerging Trends in Engg. & Technology, (ICETET-08), G.H.Raisoni COE, Nagpur, INDIA. Uploaded on online IEEE Xplore.

[16] http://wang.ist.psu.edu/docs/related/Image.orig (Last referred on 23 Sept 2008)

[17] Dr. H.B.Kekre, Sudeep D. Thepade, "Using YUV Color Space to Hoist the Performance of Block Truncation Coding for Image Retrieval", IEEE International Advanced Computing Conference 2009 (IACC'09), Thapar University, Patiala, INDIA, 6-7 March 2009.

[18] Dr. H.B.Kekre, Sudeep D. Thepade, Archana Athawale, Anant Shah, Prathmesh Verlekar, Suraj Shirke,"Energy Compaction and Image Splitting for Image Retrieval using Kekre Transform over Row and Column Feature Vectors", International Journal of Computer Science and Network Security (IJCSNS),Volume:10, Number 1, January 2010, (ISSN: 1738-7906) Available at www.IJCSNS.org.

[19] Dr. H.B.Kekre, Sudeep D. Thepade, Archana Athawale, Anant Shah, Prathmesh Verlekar, Suraj Shirke, "Walsh Transform over Row Mean and Column Mean using Image Fragmentation and Energy Compaction for Image Retrieval", International Journal on Computer Science and Engineering (IJCSE),Volume 2S, Issue1, January 2010, (ISSN: 0975–3397). Available online at www.enggjournals.com/ijcse.

[20] Dr. H.B.Kekre, Sudeep D. Thepade, "Image Retrieval using Color-Texture Features Extracted from Walshlet Pyramid", ICGST International Journal on Graphics, Vision and Image Processing (GVIP), Volume 10, Issue I, Feb.2010, pp.9-18, Available online www.icgst.com/gvip/Volume10/Issue1/P1150938876.html

[21] Dr. H.B.Kekre, Sudeep D. Thepade, "Color Based Image Retrieval using Amendment Block Truncation Coding with YCbCr Color Space", International Journal on Imaging (IJI), Volume 2, Number A09, Autumn 2009, pp. 2-14. Available online at www.ceser.res.in/iji.html.

[22] Dr. H.B.Kekre, Tanuja Sarode, Sudeep D. Thepade, "Color-Texture Feature based Image Retrieval using DCT applied on Kekre's Median Codebook", International Journal on Imaging (IJI), Volume 2, Number A09, Autumn 2009,pp. 55-65. Available online at www.ceser.res.in/iji.html (ISSN: 0974-0627).

[23] Dr. H.B.Kekre, Sudeep D. Thepade, Akshay Maloo "Performance Comparison for Face Recognition using PCA, DCT &WalshTransform of Row Mean and Column Mean", ICGST International Journal on Graphics, Vision and Image Processing (GVIP), Volume 10, Issue II, Jun.2010, pp.9-18, Available online http://209.61.248.177/gvip/Volume10/Issue2/P1181012028.pdf..

[24] Dr. H.B.Kekre, Sudeep D. Thepade, "Improving the Performance of Image Retrieval using Partial Coefficients of Transformed Image", International Journal of Information Retrieval**,** Serials Publications, Volume 2, Issue 1, 2009, pp. 72-79 (ISSN: 0974-6285)

[25] Dr. H.B.Kekre, Sudeep D. Thepade, Archana Athawale, Anant Shah, Prathmesh Verlekar, Suraj Shirke, "Performance Evaluation of Image Retrieval using Energy Compaction and Image Tiling over DCT Row Mean and DCT Column Mean", Springer-International Conference on Contours of Computing Technology (Thinkquest-2010), Babasaheb Gawde Institute of Technology, Mumbai, 13-14 March 2010, The paper will be uploaded on online Springerlink.

[26] Dr. H.B.Kekre, Tanuja K. Sarode, Sudeep D. Thepade, Vaishali Suryavanshi,"Improved Texture Feature Based Image Retrieval using Kekre's Fast Codebook Generation Algorithm", Springer-International Conference on Contours of Computing Technology (Thinkquest-2010), Babasaheb Gawde Institute of Technology, Mumbai, 13-14 March 2010, The paper will be uploaded on online Springerlink.

[27] Dr. H.B.Kekre, Tanuja K. Sarode, Sudeep D. Thepade, "Image Retrieval by Kekre's Transform Applied on Each Row of Walsh Transformed VQ Codebook", (Invited), ACM-International Conference and Workshop on Emerging Trends in Technology (ICWET 2010),Thakur College of Engg. And Tech., Mumbai, 26-27 Feb 2010, The paper is invited at ICWET 2010. Also will be uploaded on online ACM Portal.

[28] Dr. H.B.Kekre, Tanuja Sarode, Sudeep D. Thepade, "DCT Applied to Row Mean and Column Vectors in Fingerprint Identification", In Proceedings of Int. Conf. on Computer Networks and Security (ICCNS), 27-28 Sept. 2008, VIT, Pune.

[29] H.B.Kekre, Sudeep D. Thepade Akshay Maloo, "Query by Image Content using Color-Texture Features Extracted from Haarlet Pyramid", International Journal Computer Applications (IJCA), Special issue on Computer Aided Soft Computing Techniques for Imaging and Biomedical Applications, August 2010.

[30] Dr. H.B.Kekre, Sudeep D. Thepade, Varun K. Banura, "Amelioration of Colour Averaging Based Image Retrieval Techniques using Even and Odd parts of Images", International Journal of Engineering Science and Technology (IJEST), Volume 2, Issue 9, (ISSN: 0975-5462) Available online at http://www.ijest.info.

[31] Dr. H.B.Kekre, Sudeep D. Thepade, Varun K. Banura, "Augmentation of Colour Averaging Based Image Retrieval Techniques using Even part of Images and Amalgamation of feature vectors", International Journal of Engineering Science and Technology (IJEST), Volume 2, Issue 10, (ISSN: 0975-5462) Available online at http://www.ijest.info

12. AUTHORS PROFILE

Dr. H. B. Kekre has received B.E. (Hons.) in Telecomm. Engineering. from Jabalpur University in 1958, M.Tech (Industrial Electronics) from IIT Bombay in 1960, M.S.Engg. (Electrical Engg.) from University of Ottawa in 1965 and Ph.D. (System Identification) from IIT Bombay in 1970 He has worked as Faculty of Electrical Engg. and then HOD Computer Science and Engg. at IIT Bombay. For 13 years he was working as a professor and head in the Department of Computer Engg. at Thadomal Shahani Engineering. College, Mumbai. Now he is Senior Professor at MPSTME, SVKM's NMIMS University. He has guided 17 Ph.Ds, more than 100 M.E./M.Tech and several B.E./B.Tech projects. His areas of interest are Digital Signal processing, Image Processing and Computer Networking. He has more than 350 papers in National / International Conferences and Journals to his credit. He was Senior Member of IEEE. Presently He is Fellow of IETE and Life Member of ISTE Recently ten students working under his guidance have received best paper awards and two have been conferred Ph.D. degree of SVKM's NMIMS University. Currently 10 research scholars are pursuing Ph.D. program under his guidance.

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.

Dr. Tanuja K. Sarode has Received Bsc.(Mathematics) from Mumbai University in 1996, Bsc.Tech.(Computer Technology) from Mumbai University in 1999, M.E. (Computer Engineering) degree from Mumbai University in 2004, Ph.D. from Mukesh Patel School of Technology, Management and Engineering, SVKM's NMIMS University, Vile-Parle (W), Mumbai, INDIA. She has more than 12 years of experience in teaching. Currently working as Assistant Professor in Dept. of Computer Engineering at Thadomal Shahani Engineering College, Mumbai. Engineering, SVKM's NMIMS University, Vile-Parle (W), Mumbai, INDIA. She has more than 12 years of experience in teaching. Currently working as Assistant Professor in Dept. of Computer Engineering at Thadomal Shahani Engineering College, Mumbai. She is life member of IETE, member of International Association of Engineers (IAENG) and International Association of Computer Science and Information Technology (IACSIT), Singapore. Her areas of interest are Image Processing, Signal Processing and Computer Graphics. She has 90 papers in National /International Conferences/journal to her credit.

Varun K. Banura is currently pursuing B.Tech. (CE) from MPSTME, NMIMS University, Mumbai. His areas of interest are Image Processing and Computer Networks. He has 12 research papers in International Conferences/Journals to hi**s** credit. He has received one best paper award in IJCA (U.S. based Journal) April 2011 and has one invited paper published at ACM portal.