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Performance Comparison of Walsh Wavelet, Kekre Wavelet and Slant Wavelet Transform in Image Compression

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Abstract: This paper proposes use of wavelet transforms in image compression. Wavelet transform is generated from respective orthogonal transform. Image compression using Walsh wavelet, Kekre Wavelet and Slant Wavelet transforms are generated from Walsh transform, Kekre Transform and Slant Transform respectively. Four different size combinations of component orthogonal transforms are used. Size of local component transform is varied as N=32, 16, 8 and 4. Experiments are performed on twenty sample colour images of size 256x256x3. Performance of three wavelet transforms is measured in terms of compression ratio and bit rate. Each wavelet transform gives different performance at different component size. Acceptable image quality is obtained even at higher compression ratio 32. From results it has been observed that Slant wavelet transform gives best performance among all, for component transform size M=N= 16 (16-16) up to compression ratio 8. When compression ratio exceeds 8, component transform size in slant wavelet is M=32, N=8 (32-8) that gives minimum RMSE. Kekre Wavelet gives smallest error with component transform size (32-8) for all compression ratios up to 32. Walsh wavelet shows better performance with component size 32-8 up to compression ratio 6.4. Using Kekre Transform, Kekre Wavelet Transform matrix of any size can be generated. Hence there is no restriction on image size that it should be of power of two. It has been also observed that at minimum bit rate of 0.25 BPP, acceptable image quality is obtained using all three Wavelet Transforms.

Keywords: Kekre Wavelet Transform, Slant Wavelet Transform, Walsh Wavelet Transform, Bit Rate

I. INTRODUCTION

Since long ago images are essential part of communication. It is basic way to express information. As advancements were introduced, this information was digitized. Now these digital Images comprises significant portion of information in multimedia communication. Numbers of images are generated by various sources and used in day to day life. Transmission of such digital images requires large bandwidth and more time. Therefore need of some compression technique arises. Image compression reduces the number of bits required to represent the image. It saves memory space required to store the image as well as time needed to transmit it. Various image compression methods are today available. They are broadly classified as lossless and lossy compression. Lossless compression is required in medical images, text data compression where decompressed data should be exact replica of original input data. Lossy compression is especially useful in image data compression where some loss in decompressed data is acceptable. It eliminates the redundant information that is not perceptible to human eye. Hence lossy compression can provide high compression ratio. Transform domain techniques are powerful tools for image compression [1]. Along with image compression, they also contribute in other applications like information hiding [2], feature extraction, biometrics applications [3,4], CBIR [5,6], image enhancement, image texture analysis etc. Most widely used transforms are Discrete Cosine Transform (DCT) [7], Discrete Sine Transform (DST), Haar transform [8,9] and Walsh Transform. DCT separates low frequency components and high frequency components of an image. Low frequency components that contribute to most important contents of an image are shifted to top left corner and high frequency components to which human eyes are less sensitive can be eliminated.

II. LITERATURE REVIEW

A. *Discrete Cosine Transform (DCT)*

Generally to apply DCT image is divided into blocks. But it eliminates correlation across the boundaries and hence results in blocking artifacts. This drawback can be avoided by using wavelet transforms. Its excellent energy compaction property has made wavelets more popular in recent years. More energy compaction gives higher compression ratio.

B. *Walsh Transform*

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Walsh transform is non-sinusoidal orthogonal transform that decomposes a signal into a set of orthogonal rectangular waveforms called Walsh functions. The transformation has no multipliers and is real because the amplitude of Walsh functions has only two values, +1 or -1. Walsh functions are rectangular or square waveforms with values of -1 or +1. An important characteristic of Walsh functions is sequency which is determined from the number of zero-crossings per unit time interval. Every Walsh function has a unique sequency value. Walsh wavelet is generated from Walsh Transform using steps in [10].

C. *Slant Transform*

Concept of orthogonal transform containing Slant basis vector was first introduced by Enomoto and Shibata [11]. Slant transform matrix is orthogonal with a constant function for the first row. The elements in other rows are defined by linear functions of the column index. Properties of Slant transform are: It has orthonormal set of basis vectors. First basis vector is constant basis vector, one slant basis vector, the sequency property, variable size transformation, fast computational algorithm and high energy compaction. Definition of slant transform and its properties are given in [12,13].

D. *Kekre Transform*

Kekre Transform [14] matrix can be of any size. It need not to be an integer power of 2 like other orthogonal transforms. Hence it can be used for images of any size. In this matrix, all upper diagonal and diagonal elements are 1 whereas lower diagonal elements except the elements just below diagonal are zero. Kekre transform matrix can be represented using following formula [16]:

$$K_{xy}= \begin{cases} 1 & x<=y \\ -N+(x-1) & x=y+1 \\ 0 & x>y+1 \end{cases}$$

The basic concept of wavelet transform is to select appropriate wavelet function called mother wavelet and then perform an analysis using shifted and dilated versions of mother wavelet. Wavelet transform gives time frequency analysis of a signal [15].Initially in study of wavelets Haar wavelet transform was emphasised. In recent study [16] wavelets of Walsh, Hartley, Kekre have been proposed and experimented. Experimental work in [16] has shown that wavelet transforms obtained from component orthogonal transform performs better in image compression than orthogonal transform.

III. PROPOSED METHODOLOGY

In this paper, wavelet transforms of Walsh, Kekre and Slant Wavelet Transforms are generated using respective orthogonal component transforms [10]. Size of component transforms is varied to obtain wavelet transform of same size. For example, 256x256 size wavelet can be generated using components of different sizes like: M=8 and N=32, M=16 and N=16 etc. Effect of variation in component transform size on quality of reconstructed image has been observed and presented in this paper.

Generation of Wavelet transform from component orthogonal transform [17] is done using equation (1)

$$T_{AB}= \begin{pmatrix} A_m \otimes B_n(1) \\ I_m \otimes B_n(2) \\ I_m \otimes B_n(3) \\ \vdots \\ I_m \otimes B_n(n) \end{pmatrix} \quad (1)$$

T_{AB} is Wavelet Transform matrix generated from component transforms A and B. If A is of size MxM and B is of size NxN then T_{AB} will be of size MNxMN.

Red, Green and Blue plane of images are separated and generated wavelet transform is applied on each plane of the image. Thus the transformed image is obtained. Energy of each transformed coefficient is calculated. To compress the image, specific number of low energy coefficients (i.e.256x8) are made zero in each iteration. It gives us image compressed at different compression ratios. Then by applying inverse transform image is reconstructed. Root Mean Square Error between reconstructed image and original image is calculated. Performance is compared at different compression ratios. Also, for different compression ratios, bits required per pixel are calculated and graph of error versus bit rate is plotted. Size of component transforms is varied and effects on RMSE values are observed with increase in compression ratio.

IV. EXPERIMENTAL WORK AND RESULTS

Experimental work consists of test set of twenty different colour images. Each image is of size 256x256x3.Test images are shown in Fig.1.

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Fig. 1 Set of twenty test images of different classes used for experimental purpose

Wavelet transform is generated using four different combinations of component transforms. Component sizes chosen are 8-32, 16-16, 32-8, 64-4. For each combination, compression ratio is varied up to 32 and change in RMSE values is observed. Also plot of error versus bit rate is plotted. From graph plotted in fig.2 it has been observed that slant wavelet transform generated from component transforms of size 16-16 performs better than all other wavelet transforms with different combinations. Fig. 3 shows Rate-Distortion graph for various bit rates. As less number of bits is used to represent a pixel, more error is introduced. Lowest bit rate of 0.25 is considered for observation and then it is increased from 1 to 8 with step-size of one and RMSE values are compared. Slant wavelet with component size M=N=16 gives better results than all. Kekre wavelet with component size M=8 and N=32 shows higher values of RMSE than slant wavelet and Walsh wavelet at observed range of bit rates. Increase in bit rate shows reduction in error.

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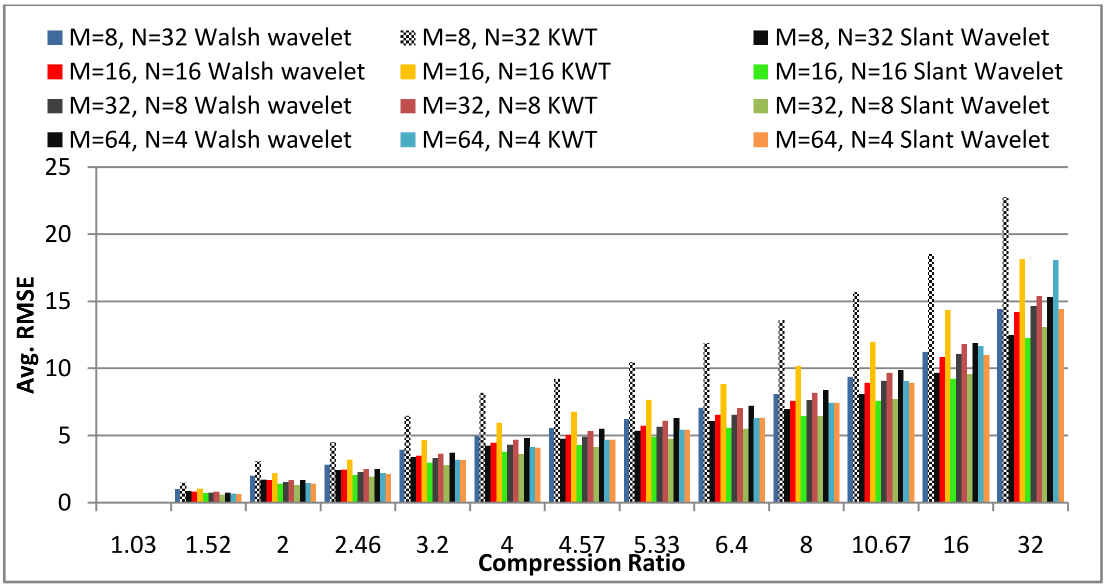

Fig. 2 Average RMSE against Compression Ratio for Walsh Wavelet, Kekre Wavelet and Slant Wavelet Generated using Respective Component Transform of Different Size

Fig. 3 shows Rate-Distortion graph for various bit rates. As less number of bits is used to represent a pixel, more error is introduced. Lowest bit rate of 0.25 is considered for observation and then it is increased from 1 to 8 with step-size of one and RMSE values are compared. Slant wavelet with component size M=N=16 gives better results than all. Kekre wavelet with component size M=8 and N=32 shows higher values of RMSE than slant wavelet and Walsh wavelet at observed range of bit rates. Increase in bit rate shows reduction in error.

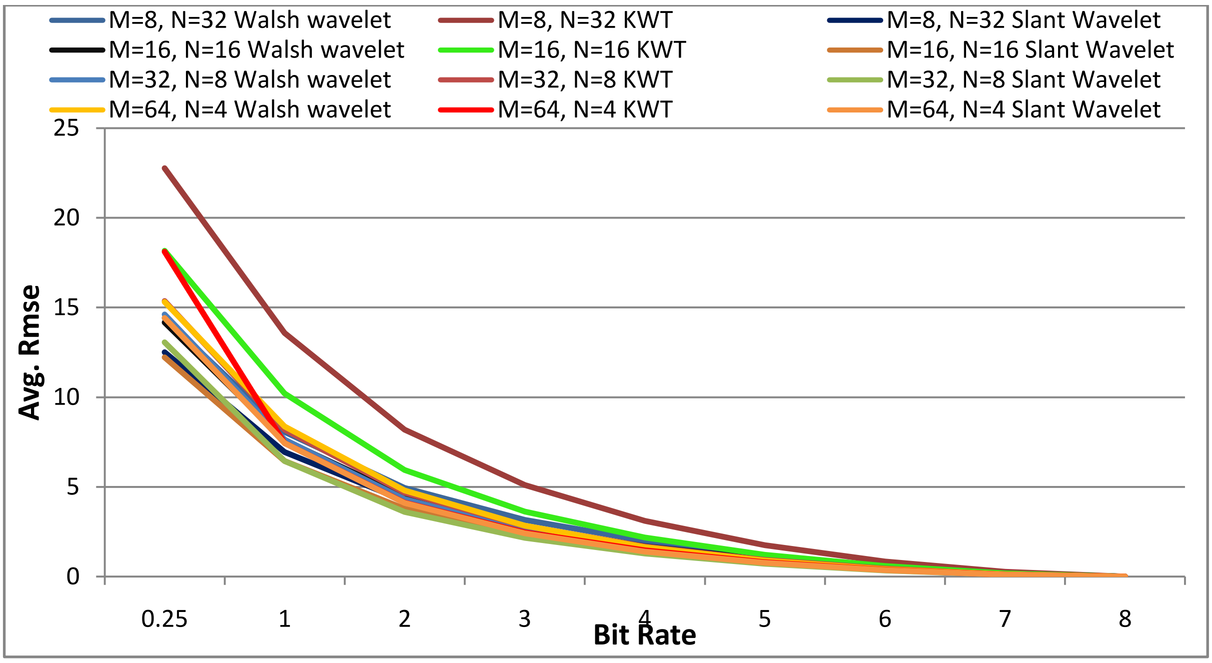

Fig. 3 Error versus Bit Rate for Walsh Wavelet, Kekre Wavelet and Slant Wavelet Generated using Respective Component Transform of Different Size

Fig.4 shows sample reconstructed image ‘balloon’ using different component sizes of Walsh wavelet, Kekre Wavelet and Slant Wavelet transform. This image is reconstructed at lowest Bit Rate. From figure it can be observed that in Slant Wavelet and Walsh wavelet Transform generated from component size M=16 and N=16 lowest error is obtained. In Kekre wavelet transform component size selection for lowest error is 32-8. Walsh Wavelet ranks second in performance whereas Kekre Wavelet Transform gives highest error at component size 8-32.

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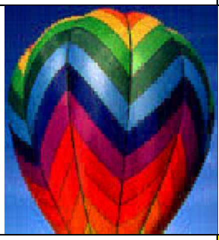
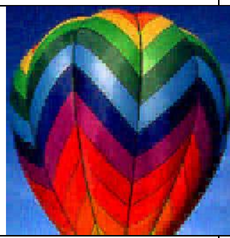
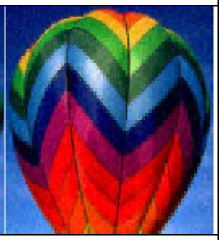
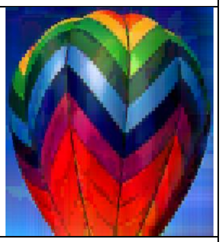
Bit Rate=0.25				
Component Transform Sizes	M=8, N=32	M=16, N=16	M=32, N=8	M=64, N=4
Walsh Wavelet				
RMSE	15.87	15.53	15.93	17.11
Kekre Wavelet				
RMSE	27.57	21.32	16.88	20.02
Slant Wavelet				
RMSE	13.18	12.61	13.81	16.00

Fig. 4 Reconstructed Image 'Flower' with RMSE values in Walsh Wavelet, Kekre Wavelet and Slant Wavelet Transform

In Fig. 5, reconstructed image 'Cartoon' is shown at Bit Rate 0.25. It shows similar pattern of error as observed in Figure 4. As less number of local features is incorporated by wavelet transform, RMSE value increases. Blocking effect is observed in reconstructed images. In Walsh Wavelet and Slant Wavelet, blocking effect increases with decrease in size of local component transform. In Kekre Wavelet transform as more local features are included, less blocking effect is observed.

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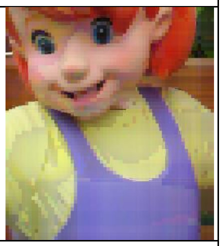
Bit Rate=0.25				
Component Transform Sizes	M=8, N=32	M=16, N=16	M=32, N=8	M=64, N=4
Walsh Wavelet				
RMSE	8.801	8.751	9.056	9.471
Kekre Wavelet				
RMSE	15.429	11.587	9.202	12.234
Slant Wavelet				
RMSE	7.289	7.177	7.855	8.808

Fig. 5 Reconstructed Image 'Face' with RMSE values in Walsh Wavelet, Kekre Wavelet and Slant Wavelet Transform

V. CONCLUSION

This paper compares the performance of three different Wavelet Transforms: Walsh Wavelet, Kekre Wavelet and Slant Wavelet Transform. Each wavelet transform is generated using respective orthogonal transform. Size of component orthogonal transforms is varied as 8-32, 16-16, 32-8 and 64-4. Each wavelet transform shows different performance at different sizes of component transforms. Slant wavelet transform gives superior performance than Walsh wavelet and Kekre wavelet transform. From results it has been observed that Slant wavelet transform gives best performance among all, for component transform size M=N= 16 (16-16) up to compression ratio 8. When compression ratio exceeds 8, component transform size in slant wavelet is M=32, N=8 (32-8) that gives minimum RMSE. Kekre Wavelet gives smallest error with component transform size (32-8) for all compression ratios up to 32. Walsh wavelet shows better performance with component size 32-8 up to compression ratio 6.4. Each wavelet transform gives different performance at different component size. Acceptable image quality is obtained even at higher compression ratio 32.

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BIOGRAPHIES

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,

He has guided 17 Ph.Ds, more than 100 M.E./M.Tech and several B.E. / B.Tech projects, while in IIT and TSEC. His areas of interest are Digital Signal processing, Image Processing and Computer Networking. He has more than 450 papers in National / International Journals and Conferences to his credit. He was Senior Member of IEEE. Presently He is Fellow of IETE, Life Member of ISTE and Senior Member of International Association of Computer Science and Information Technology (IACSIT). Recently fifteen students working under his guidance have received best paper awards. Currently eight research scholars working under his guidance have been awarded Ph. D. by NMIMS (Deemed to be University). At present eight research scholars are pursuing Ph.D. program under his guidance.

Dr. Tanuja K. Sarode has received M.E. (Computer Engineering) degree from Mumbai University in 2004, Ph.D. from Mukesh Patel School of Technology, Management and Engg. SVKM's NMIMS University, Vile-Parle (W), Mumbai, INDIA. She has more than 11 years of experience in teaching. Currently working as Assistant Professor in Dept. of Computer Engineering at Thadomal Shahani Engineering College, Mumbai. She is member of International Association of Engineers (IAENG) and International Association of Computer Science and Information Technology (IACSIT). Her areas of interest are Image Processing, Signal Processing and Computer Graphics. She has 150 papers in National /International Conferences/journal to her credit.

Ms. Prachi Natu has received M.E. (Computer) degree from Mumbai University in 2011. Currently pursuing Ph.D. from NMIMS University. She has 08 years of experience in teaching. Currently working as Assistant Professor in Department of Computer Engineering at Mukesh Patel School of Technology, Management and Engineering. Vile Parle (Mumbai). Her areas of interest are Image Processing, Database Management Systems and Operating Systems. She has 18 papers in International Conferences/journal to her credit.