

Image Compression Using Column, Row and Full Wavelet Transforms Of Walsh, Cosine, Haar, Kekre, Slant and Sine and Their Comparison with Corresponding Orthogonal Transforms

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Abstract:- In this paper, image compression using orthogonal wavelet transforms of Walsh, Cosine, Haar, Kekre, Slant and Sine is studied. Wavelet transform of size $N^2 \times N^2$ is generated using its corresponding orthogonal transform of size $N \times N$. These wavelet transforms are applied on R, G, and B planes of $256 \times 256 \times 3$ size colour images separately. In each transformed plane rows/columns are sorted in their descending order of energy, and lowest energy coefficients are eliminated to compress the image. This procedure is repeated for different compression ratios and in each case image is reconstructed. Root Mean Square Error (RMSE) between original image and reconstructed image is calculated to measure the performance of transform. Wavelet transforms are applied in three different ways: Column wavelet, Row wavelet and Full wavelet and their performance is compared using RMSE. From the results it has been observed that, RMSE obtained using full wavelet transform is nearly half than column and row wavelet transform. Also, results of wavelet transforms are compared with results of their orthogonal transforms. Full DCT wavelet transform outperforms all other transforms.

Keywords:- Image compression, Wavelet Transform, Orthogonal Transform, DST, Kekre's Transform, and Slant Transform.

I. INTRODUCTION

Evolution of digital technology has resulted in use of digital images to large extent. It has accelerated development of many image processing softwares. Since storing and transmission of digital images is of major concern, different image compression algorithms have been proposed till now. Transform based coding, vector quantization, predictive coding are some popular techniques of image compression. When transform is applied to an image, it de-correlates the image coefficients, converting it into transformed coefficients [1]. Concept of wavelet was first introduced by Jean Morlet in 1982[2]. Wavelet analysis was originally introduced for signal analysis by Daubechies [3]. Wavelet transformation is an essential coding technique for both spatial and frequency domains, where it is used to divide the information of an image into approximation and detail sub signals [4]. Advantage of decomposing images into approximate and detail parts is that it enables to isolate and manipulate the data with specific local properties. Wavelets are advantageous over traditional Fourier methods. Fourier analysis is a global scheme. Using Fourier coefficients, local properties of a signal cannot be detected. This drawback is overcome by classical Short Time Fourier Transforms (STFT). But it gives only local properties and not global properties. Wavelet transform can be considered as an alternative to classical short time Fourier transforms. The STFT analyses the signal by using single window size whereas wavelet transforms use variable window sizes that change along the frequency range [5].

DCT is widely used transform method for image compression. Still it has its own shortcomings. To apply DCT on image, image needs to be split into non overlapping blocks. It does not eliminate correlation across boundaries which results in blocking artifacts at higher compression ratio [6]. High energy compaction property of wavelet transforms results in better image compression than DCT [7]. Multiresolution property of wavelets makes it useful for speech and image coding. Applications of wavelets are not limited to compression of data. DNA analysis [8], ECG analysis [8,9] incorporate use of wavelet transforms. Quantum mechanics, molecular dynamics [10] and many more areas of physics have also seen shift from well-known Fourier transform to wavelet transform. In this paper orthogonal discrete wavelet transform is used which is generated from existing orthogonal transforms[8,9]. Thus using existing orthogonal transform like DCT, Walsh and Haar transform, DCT wavelet, Walsh wavelet and Haar wavelet transform are generated respectively. In [10], Kekre Wavelet transform is generated from Kekre transform [11]. In addition to these orthogonal transforms and their

corresponding wavelet transforms, use of Slant, slant wavelet, DST and DST wavelet for image compression are also studied in this paper.

II. RELATED WORK

Haar wavelets have been studied and used popularly in compression so far. In an analysis done by Arora et al [1] 2-D Haar, Symlet, coiflet and db4 wavelets were used for image compression and it was observed that Haar transform gives better results. A fractal image compression scheme based on wavelet transform with diamond search was proposed by Yi Zhang and Xing Yuan Wang in [12]. But fractal image compression takes more time for image coding whereas predictive coding shows poor compression ratio. As discussed in [13] min-image is used to test the wavelets and then EZW coding is applied on transformed wavelet coefficients in order to achieve better compression ratio. Combination of artificial neural network and wavelet transform is used in [14]. A Novel Hybrid Image Compression Technique was projected by Dwivedi et al. in [15]. In this scheme wavelet transform based compression was integrated with modified forward-only counter propagation neural network (MFOCPN) scheme. Method of wavelet decomposition coefficients in MFOCPN by interpolation is discussed in [16]. It uses cosine interpolation method which helps to find smooth and sharp coefficients and mapping of these coefficients. It gives better PSNR values and image quality. A Neuro-Wavelet based approach for image compression was put forth by Singh et al. in [17]. Images are decomposed using wavelet filters into a set of sub bands with different resolution corresponding to different frequency bands. Different quantization and coding schemes are used for different sub bands based on their statistical properties. The coefficients in low frequency band are compressed by differential pulse code modulation (DPCM) and the coefficients in higher frequency bands are compressed using neural network. Using their proposed scheme one can accomplish satisfactory reconstructed images with large compression ratios.

III. PROPOSED TECHNIQUE

In this paper, column wavelet, row wavelet and full wavelet transform is used to compress the image. Wavelets of DCT, Walsh, Haar, Slant, Kekre Transform and Discrete Sine transform (DST) are generated from 2D orthogonal DCT, Walsh, Haar, Slant, Kekre Transform and DST matrix respectively, using the algorithm explained in [10] and [9].

Column wavelet transform of an image is obtained as follows:

$$[Wlt]*[f] = [F] \dots \dots \dots \text{Eq. (1)}$$

Where $[Wlt]$ is wavelet transform matrix

$[f]$ is 2D image $[F]$ is column wavelet transformed image.

Row wavelet transform of an image is given as:

$$[f]*[Wlt]^T = [F] \dots \dots \dots \text{Eq.(2)}$$

$[Wlt]^T$ indicates transpose of $[Wlt]$.

Whereas, full wavelet transform is given by:

$$[Wlt]*[f]*[Wlt]^T = [F] \dots \dots \dots \text{Eq.(3)}$$

Image compression is done using following steps:

1. Consider colour image of size 256x256x3. Separate Red, Green and blue planes of an image.
2. Wavelet transform matrix of 256x256 is generated from 16x16 size orthogonal matrix.
3. Column/row/full wavelet transform is applied on each plane.
4. For each transformed plane, energy of each row/column is calculated and rows/columns are sorted in descending order of their energy.
5. Rows/columns contributing lowest energy are removed in step of eight rows/columns and then image is reconstructed.
6. Root Mean Square Error (RMSE) between reconstructed image and original image is calculated as performance evaluation criteria.

It has been observed that, full wavelet transforms give more energy compaction and hence better compression ratio. Column and row wavelet transforms give high RMSE values and hence less compression ratio. Compression obtained by full wavelet transform is more effective than one obtained by full orthogonal transforms. RMSE values are reduced to half when full wavelet transforms are used instead of full orthogonal transforms. Quality of reconstructed image is considerably better when wavelet transform is used.

IV. RESULTS AND DISCUSSIONS

Techniques discussed in previous section were implemented on 256x256x3 colour images. Twelve different colour images are used for testing of an algorithm. Experiments are done using Matlab 7.2 on AMD dual core processor. Figure 1 shows twelve colour test images of size 256x256x3.

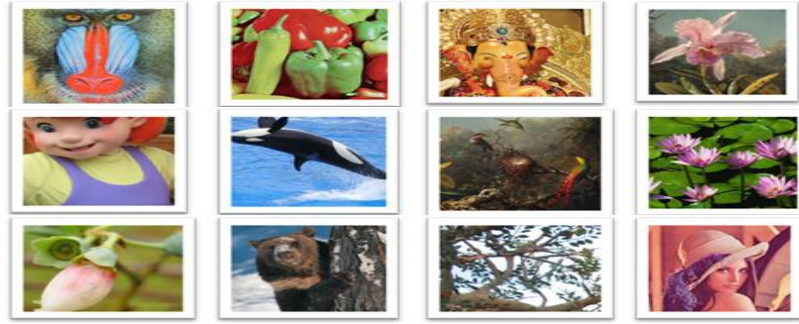


Fig.1: Set of twelve test images of different classes used for experimental purpose namely (from left to right and top to bottom) Mandrill, Peppers, Lord Ganesha, Flower, Cartoon, dolphin, Birds, Waterlily, Bud, Bear, Leaves and Lenna

Table I lists RMSE values for different column wavelet transforms whereas Table II gives RMSE values for row wavelet transforms. In both cases DCT gives better results than all other wavelet transforms. Performance of Row and column wavelet transforms is found to be almost similar.

Table I: comparison of Average RMSE values for various compression ratios when different column wavelet transforms are applied on test images

Compression ratio	Walsh	DCT	Haar	Kekre	Slant	DST
2	9.1	7.1	9.07	14.05	8.06	10.95389

Table II: comparison of Average RMSE values for various compression ratios when different row wavelet transforms are applied on test images						
Compression ratio	Walsh	DCT	Haar	Kekre	Slant	DST
2	9.313	7.26	9.182	14.391	8.215	10.881
3	13.484	11.282	13.283	18.526	12.124	19.286
4	15.311	13.247	15.088	21.133	13.981	23.603
5	17.7123	15.824	17.484	22.982	16.283	29.221
6	19.2	17.51	19.02	23.95	17.83	32.77
3	13.11	11.04	13.04	18.95	11.82	19.60708
4	14.96	12.97	14.79	20.69	13.65	23.94163
5	17.24	15.46	17.03	22.48	15.93	29.49461
6	18.68	17.13	18.56	23.46	17.45	33.06

Performance of full wavelet transforms is tabulated in Table III. It has been observed that, full DCT wavelet gives best performance in terms of RMSE values and hence gives better compression.

Table III: comparison of Average RMSE values for various compression ratios when different full wavelet transforms are applied on test images

Compression ratio	Walsh	DCT	Haar	Kekre	Slant	DST
2	5.09	3.57	5.12	7.76	4.27	4.666
3	6.54	4.75	6.6	10.13	5.61	6.572

4	7.02	5.17	7.07	10.96	6.08	7.329
5	7.54	5.62	7.57	11.73	6.56	8.115
6	7.78	5.85	7.81	12.1	6.8	8.53

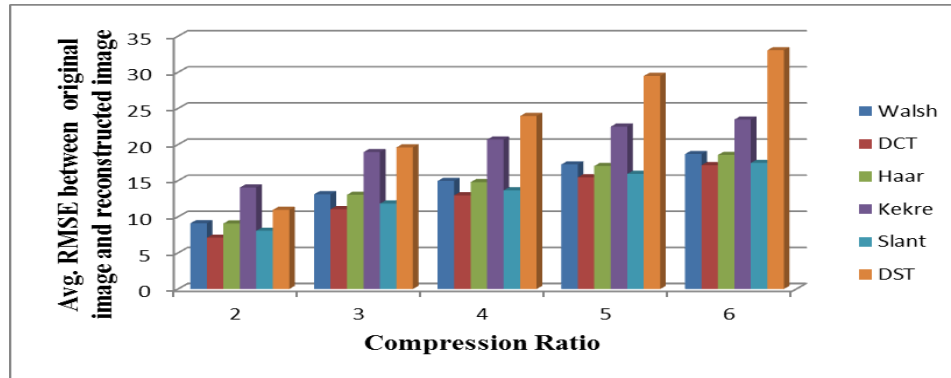


Fig 2. Comparison of RMSE values obtained in image compression using column level Walsh wavelet transform, Cosine wavelet transform, Haar wavelet transform, Kekre's wavelet transform, Slant wavelet transform and Sine wavelet transform.

Fig. 2 plots the graph of compression ratio vs. average RMSE for column wavelet transforms of Walsh wavelet, DCT wavelet, Haar wavelet, Kekre wavelet, Slant wavelet and Sine wavelet. Comparison of RMSE shows that DCT wavelet performs better than any other column wavelet transform.

Fig. 3 shows RMSE values obtained by applying row wavelet transform on an image. DCT wavelet gives better results than other row wavelet transforms. Overall RMSE values are almost equal to those obtained by column transforms.

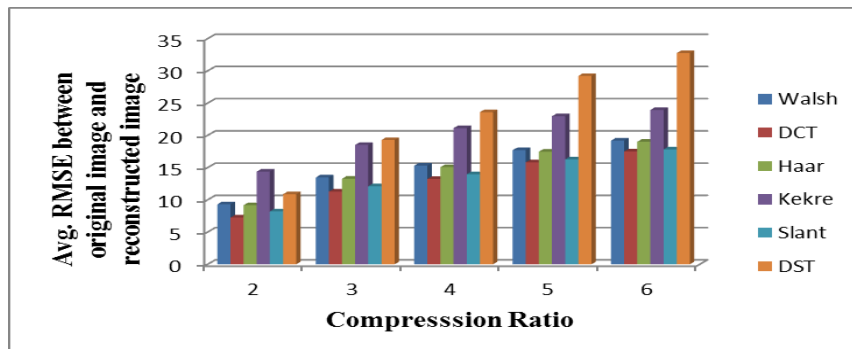


Fig. 3: Comparison of RMSE values obtained in image compression using Row level Walsh wavelet transform, Cosine wavelet transform, Haar wavelet transform, Kekre's wavelet transform, Slant wavelet transform and Sine wavelet transform.

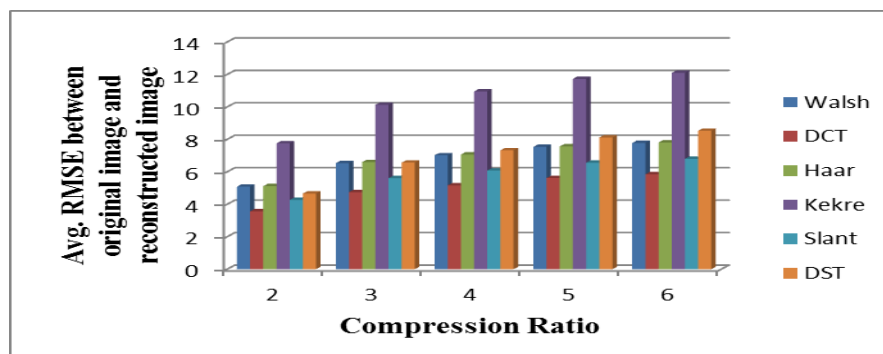


Fig. 4: Comparison of RMSE values obtained in image compression using Full Walsh wavelet transform, Cosine wavelet transform, Haar wavelet transform, Kekre's wavelet transform, Slant wavelet transform and Sine wavelet transform.

Fig. 4 compares RMSE values of full wavelet transforms namely Walsh, DCT, Haar, Kekre, Slant and DST wavelets for different compression ratios. It has been observed that, DCT wavelet transform gives best performance among all. Better image quality and least RMSE values are obtained using full DCT wavelet transform.

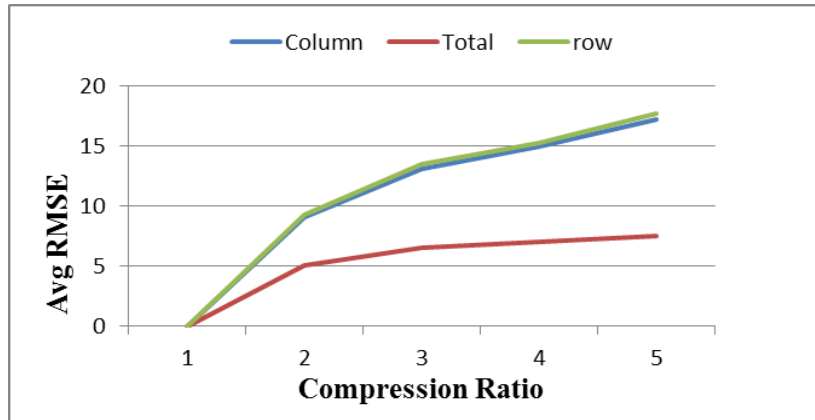


Fig. 5: Comparison of RMSE values against compression ratio using Column, Row and Full Walsh wavelet transform

Fig. 5 shows comparison of Root Mean Square Error (RMSE) difference between original and compressed image for three different cases of Walsh wavelet transform. Performance of Full Walsh wavelet transform is much better as compared to column and row Walsh wavelet transforms. RMSE values obtained by column and row Walsh wavelet transform are almost same.

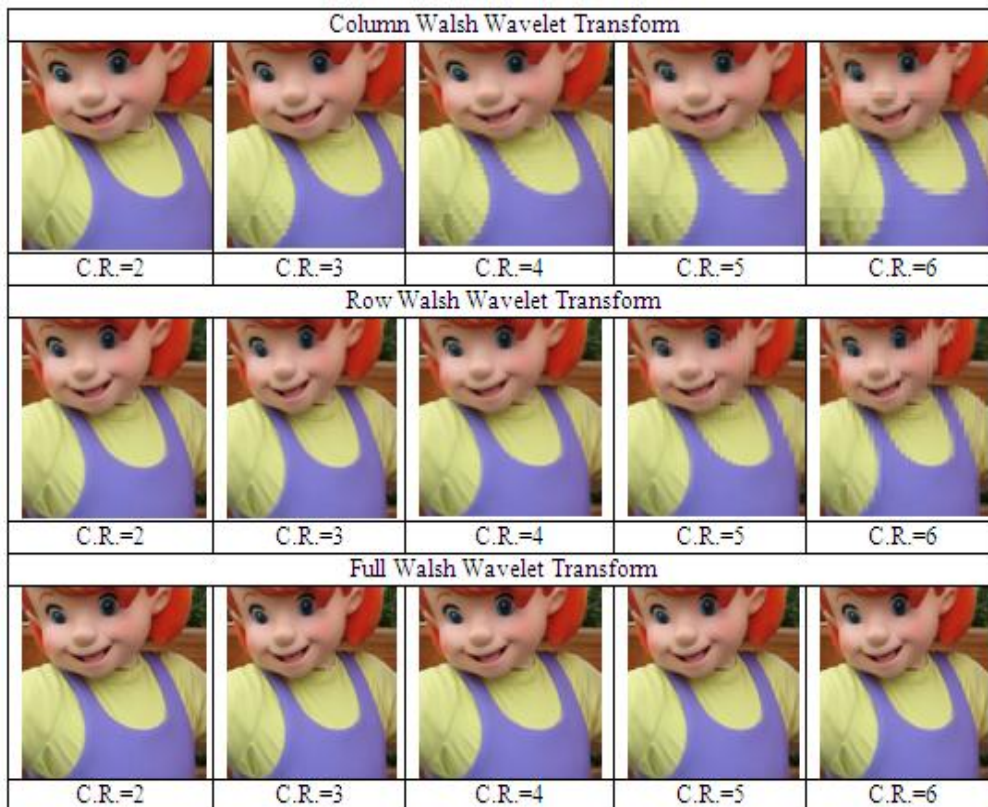


Fig.6: Reconstructed images of Column, Row and Full Walsh Wavelet Transform for Compression Ratios (CR) 2,3,4,5 and 6 respectively.

Fig. 6 shows reconstruction of 'Cartoon' image using column, row and full Walsh wavelet transform at different compression ratios from 2 to 6. For compression ratio 5 and 6, difference between column, row and full Walsh wavelet transform on an image can be clearly seen. Full Walsh wavelet shows better image quality.

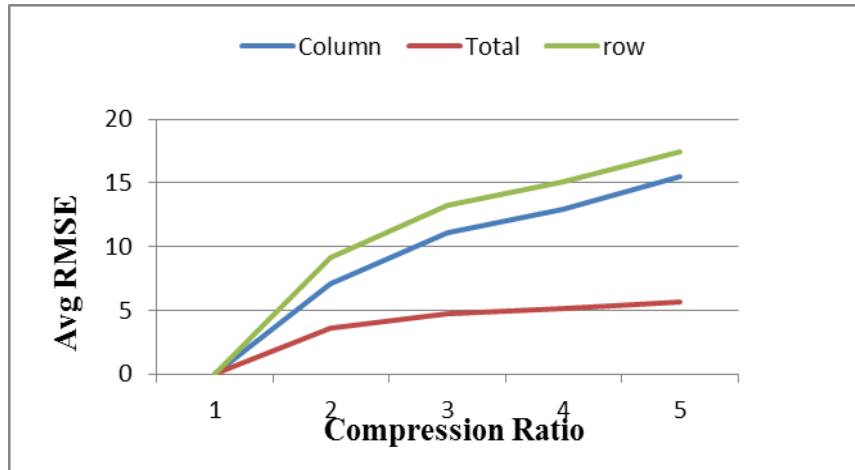


Fig. 7: Comparison of RMSE values against compression ratio using Column, Row and Full Cosine wavelet transform (DCT Wavelets)

Difference in RMSE values for row, column and full Cosine wavelet transform is plotted in Fig. 7. Row cosine wavelet transform gives higher RMSE values than column and full cosine wavelet transform. Full cosine wavelet transform gives lowest RMSE values and hence better compression than row and column cosine wavelet transform.

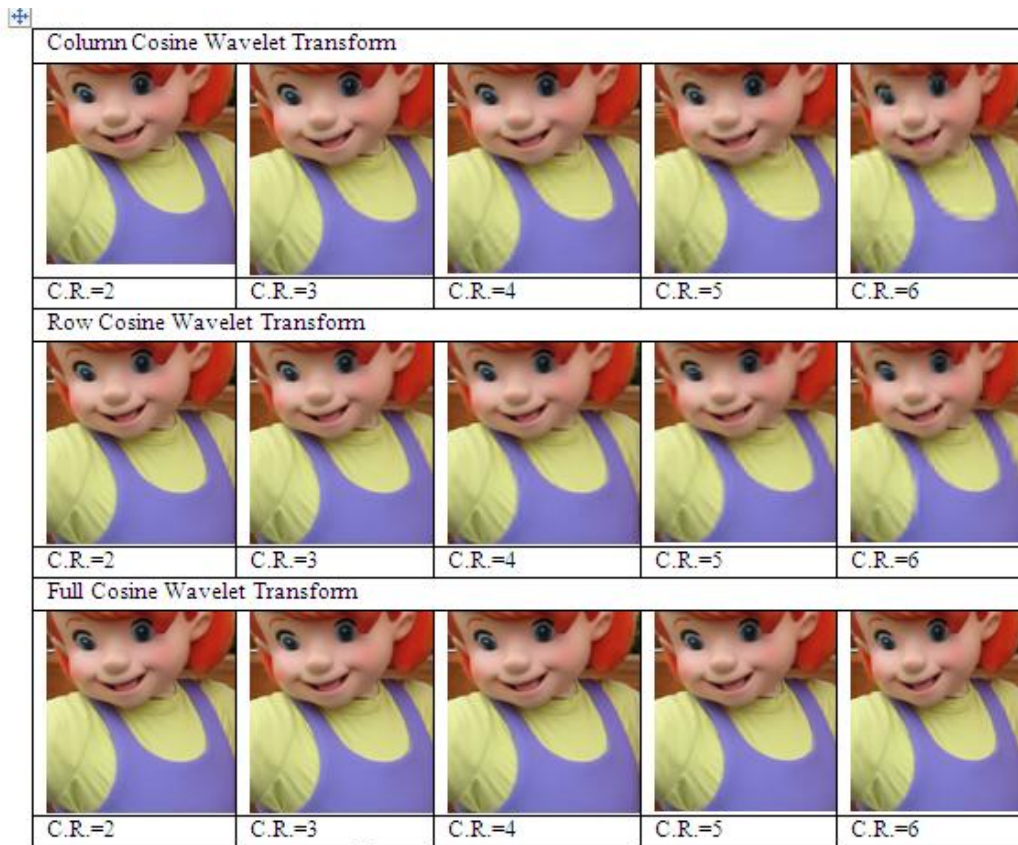


Fig.8: Reconstructed images of Column, Row and Full Cosine Wavelet Transform for Compression Ratios (CR) 2, 3, 4, 5 and 6 respectively

As shown in Fig. 8, Full Cosine Wavelet transform gives better reconstructed image than column and row cosine wavelet transform. Difference in the images can be seen clearly at compression ratio 5 and 6.

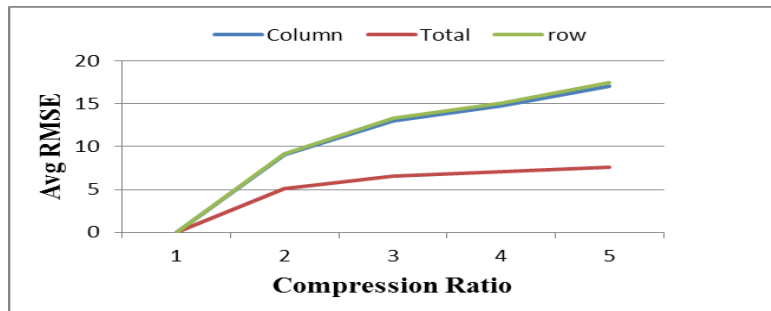


Fig.9: Comparison of RMSE values against compression ratio using Column, Row and Full Haar wavelet transform

RMSE for row, column and full Haar wavelet transform is plotted in Fig. 9. Performance of row and column Haar wavelet transform is nearly same as observed in graph. Full Haar wavelet transform gives RMSE values which are approximately half of obtained in row and column wavelet transform.



Fig.10: Reconstructed images of Column, Row and Full Haar Wavelet Transform for Compression Ratios (CR) 2, 3, 4, 5 and 6 respectively

As shown in Fig. 10 there is slight difference in image quality at higher compression ratio using column and row Haar wavelet transform. But clearer image is obtained by full Haar wavelet transform at compression ratio 6.

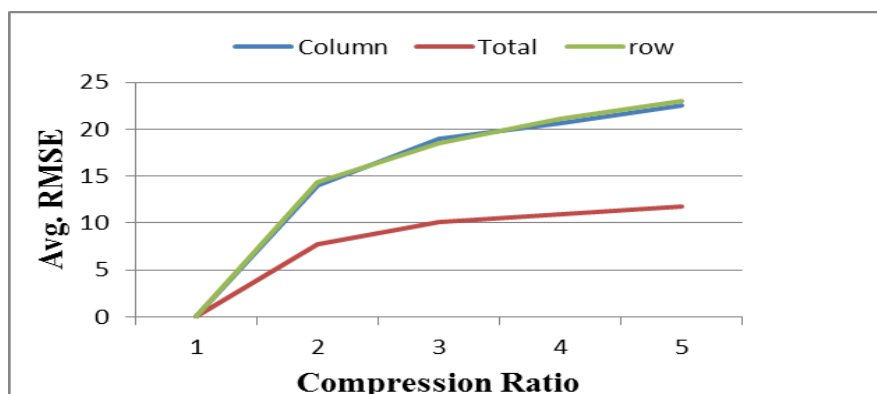


Fig. 11: Comparison of RMSE values against compression ratio using Column, Row and Full Kekre's wavelet

In Fig.11, performance of Row, Column and Full Kekre's wavelet transform is compared. In this case, again Full transform gives better results than row and column wavelet transform.

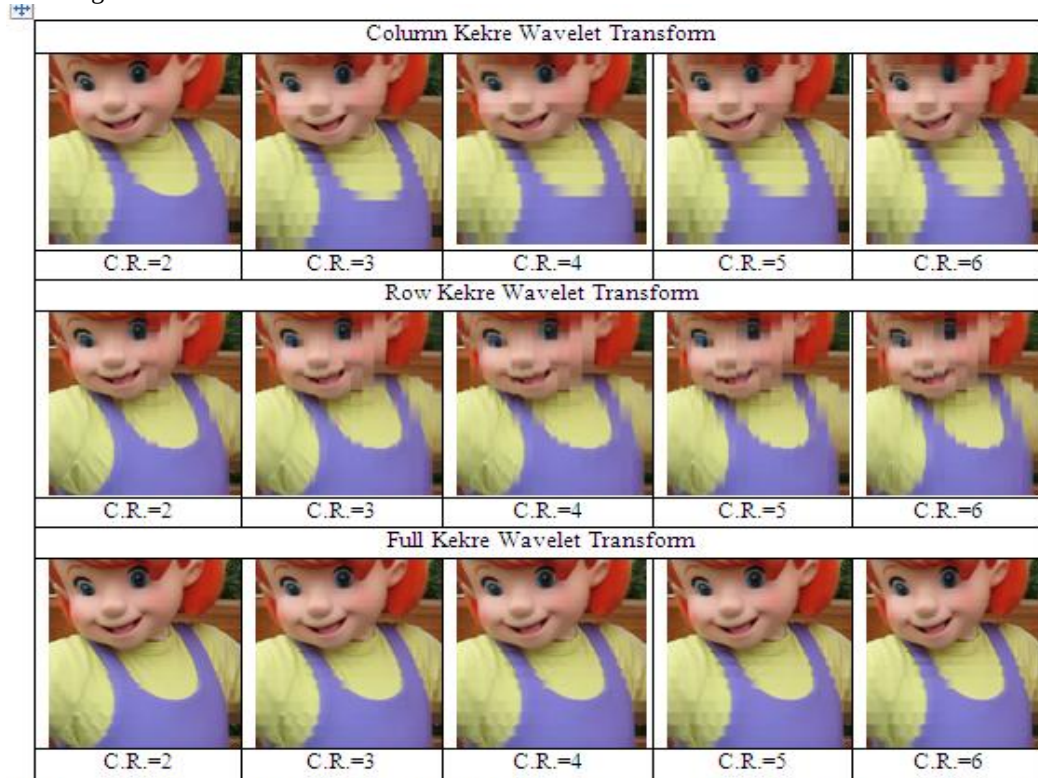


Fig.12: Reconstructed images of Column, Row and Full Kekre Wavelet Transform for Compression Ratios (CR) 2, 3, 4, 5 and 6 respectively

Fig. 12 shows that using full Kekre wavelet transform, slightly blurred image is obtained at high compression ratio. But column and row kekre wavelet transform show more blurred image. So again full wavelet transform is better in this case also.

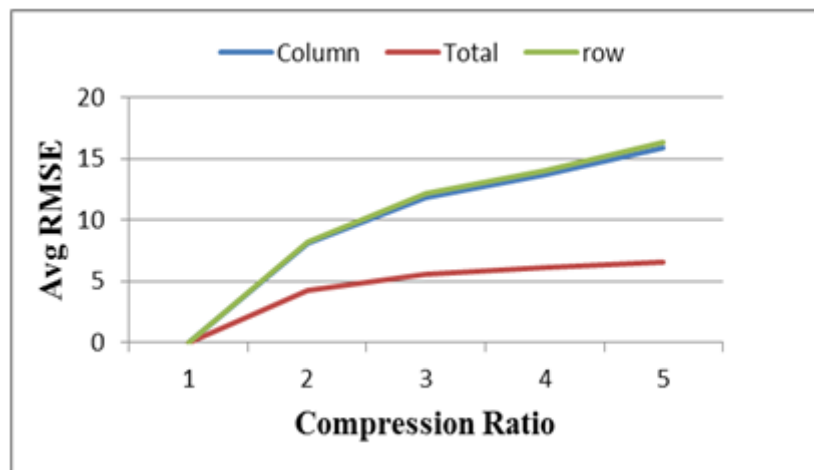


Fig. 13: Comparison of RMSE values against compression ratio using Column, Row and Full Slant wavelet transform

Graphs plotted in Fig. 13 and 15 compares performance of Slant wavelet and Sine wavelet transform respectively for three different cases namely: row, column and full wavelet transform. In both cases, row and column wavelet transform give poor performance than full wavelet transform. Full wavelet transform is very much effective and gives RMSE values which are less than one fourth than obtained by row and column wavelets in both transforms.



Fig.14: Reconstructed images of Column, Row and Full Slant Wavelet Transform for Compression Ratios (CR) 2, 3, 4, 5 and 6 respectively

Fig. 14 indicates that almost similar images are obtained using column and row slant wavelet transforms. More clear images are obtained using full Slant wavelet transform even at compression ratio 6.

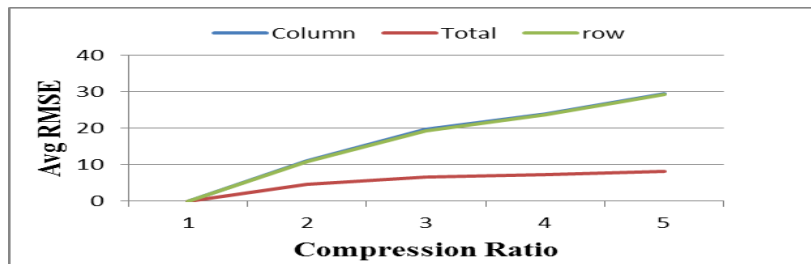


Fig.15: Comparison of RMSE values against compression ratio using Column, Row and Full Sine wavelet transform

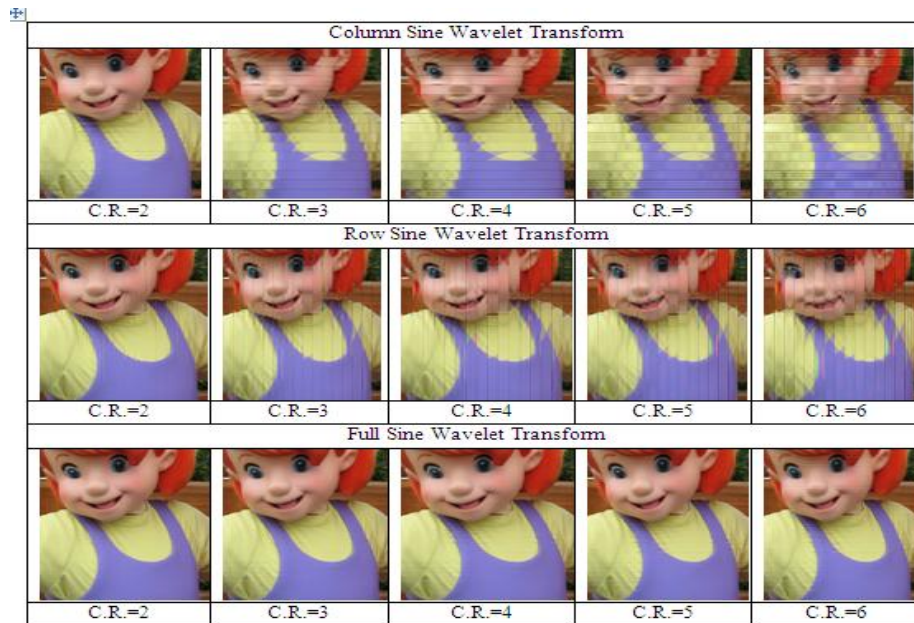


Fig.16: Reconstructed images of Column, Row and Full Sine Wavelet Transform for Compression Ratios (CR) 2, 3, 4, 5 and 6 respectively

As shown in Fig. 16, Image quality of row and column Sine Wavelet transformed images is poor as compared to other row and column wavelet transformed images. Whereas full Sine wavelet transform gives acceptable image quality at compression ratio 6 also.

Fig.17 shows comparison of Avg RMSE values between Column Transform and its column wavelet transform. Walsh, DCT, Haar, Kekre, Slant and Sine transforms and their wavelets are considered for this purpose. Performance of column wavelet transforms is slightly better than their corresponding column transforms. Column DST wavelet shows exactly reverse performance. Its performance is poor as compared to orthogonal column Discrete Sine Transform. DCT column wavelet transform shows better performance among all.

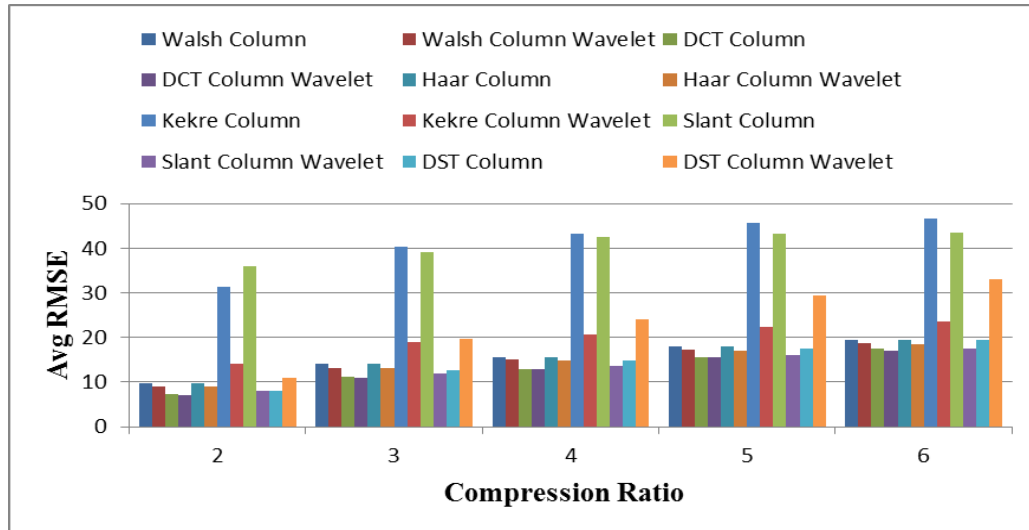


Fig.17: Comparison of Avg RMSE values against compression ratio using different Column and column wavelet transform

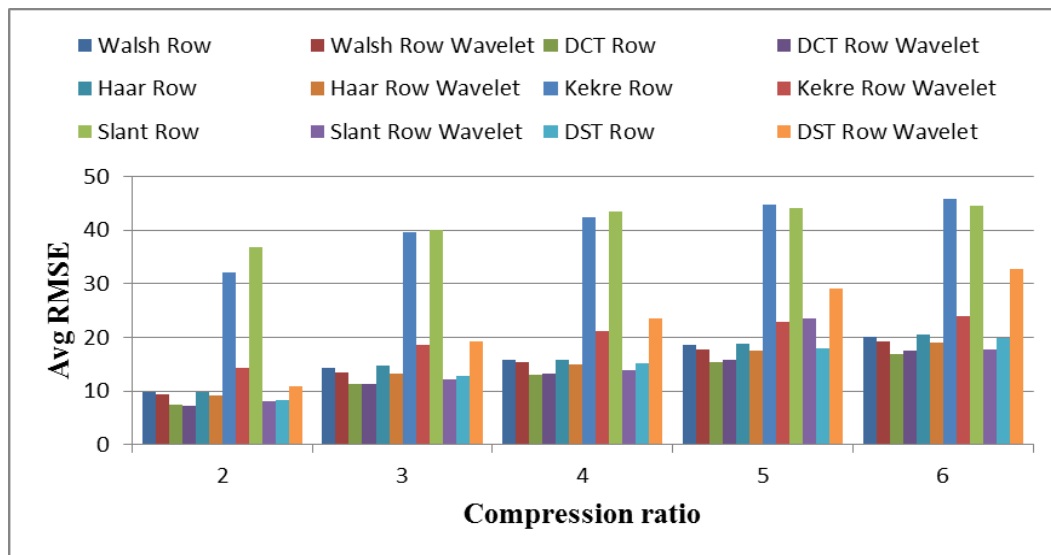


Fig. 18: Comparison of Avg RMSE values against compression ratio using different Row and Row wavelet transform

Row transforms of Walsh, DCT, Haar, Kekre, Slant and DST and corresponding Row wavelet transforms are considered in Fig.18 to compare average RMSE obtained in each case. Except row sine wavelet transform, all other row wavelet transforms perform slightly better than their corresponding orthogonal Row transforms. Considerable difference is observed between Row Kekre Transform and Row Kekre wavelet transform and also between Row Slant and Row Slant wavelet Transform. In both these cases, Row wavelet transform performs better.

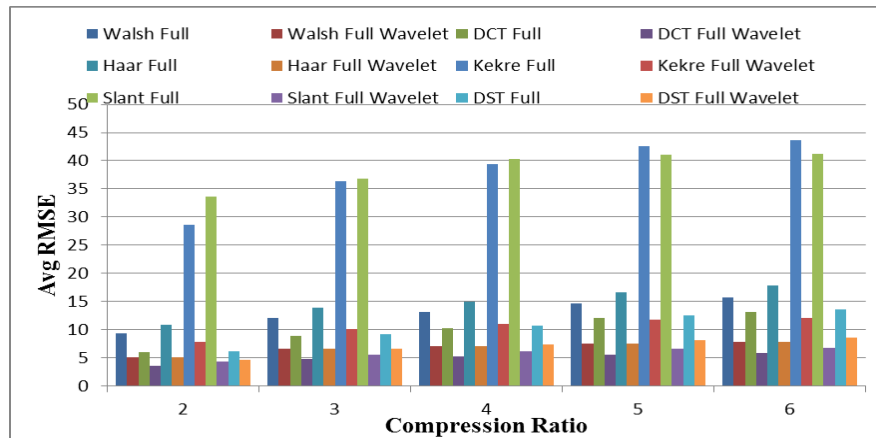


Fig. 19: Comparison of Avg RMSE values against compression ratio using different Full and Full wavelet transform

Fig.19 shows comparison of average RMSE values between Full and corresponding Full wavelet transforms. Average RMSE value is approximately reduced to half in each full wavelet transform than that of in corresponding full orthogonal transform including wavelet of Sine transform. Best results are obtained by Full DCT wavelet transform.

V. CONCLUSIONS

In this paper performance of orthogonal transforms is compared with orthogonal wavelet transforms. From the results and graphs plotted above, it has been observed that, orthogonal wavelet transforms perform much better than corresponding orthogonal transform except wavelet of sine transform. Among column wavelet, row wavelet and full wavelet transforms, the best performance is given by full wavelet transforms. In full wavelet transforms RMSE values reduces to half than that of in full orthogonal transforms and also give better image quality. Minor difference is observed in RMSE values between column transform and column wavelet transforms and also between row transform and row wavelet transform. Considerable improvement is observed in the results of full Kekre's wavelet transform than full Kekre's Transform and in full Slant wavelet transform than full Slant transform. Column Sine wavelet and row Sine wavelet exhibit poor performance than corresponding orthogonal column and row sine transform. Full sine wavelet transform follows same trend like other full wavelet transforms and gives better results than orthogonal full sine transform.

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