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Comparative Analysis of Wavelet Transform and Wavelet Packet Transform for Image Compression at Decomposition Level 2

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Abstract: Methods of digital image compression have been the subject of research over the past decade. Discrete Wavelet Transform (DWT) and Wavelet Packet Transform (WPT) have emerged as a popular technique for image compression. This paper compares Compression Ratio, Energy Ratio, Mean Square Error, and Peak Signal to Noise Ratio at different Threshold values for decomposition level 2 both for DWT and WPT.

Keywords: Basis selection, Wavelet transforms, Discrete Wavelet transform, wavelet packet transform, Image compression

1. Introduction

Visual communication in the area of multimedia, medical image, remote sensing image, education, communication etc. is becoming increasingly popular. Image is one of the most important media of information contributing to multimedia. Digital images are highly voluminous and consume very important resources of the system. It is desirable to transmit image at large distance for multitude of purposes. Large memory and high bandwidth are required for efficient storage and transmission of the image. The advancement of digital technology has motivated the need for better image compression algorithm. Image compression removes the redundancy in an image resulting in more compact representation [1, 2]

Methods for digital image compression have been the subject of research over the past few years but image compression using discrete wavelet transform (DWT) and wavelet packet transform (WPT) has been gaining wide popularity. It is an alternative to short time Fourier transform. The main advantage lies in its multiresolution decomposition capability. In contrast to Fourier-based transform, it offers better localization properties in both spatial and frequency domains. DWT is also well matched with the needs of Human Visual System (HVS) [3, 4].

2. Wavelet Analysis

Transformation, Quantization, Encoding are the steps involved in compressing a still image [5]. Selection of proper transform is one of the most important factors as it reduces the size of resultant data set as compared to source set. In the transformation stage, first level of decomposition results in four sets of wavelet coefficients corresponding to four 2-D frequency subbands. It consists of one smooth sub-band (LL) called image approximation representing image on lower scale concentrates less than 95% of the total energy. The left 5% is distributed in the other three detail sub-bands namely vertical sub-band (HL), horizontal sub-band (LH) and Diagonal sub-band (HH) [6]. Wavelet Packet offers a more complex and flexible analysis. It represents generalization of multi-resolution decomposition. In WT, approximation component is decomposed whereas in WPT, approximations as well as detailed components are decomposed. The second stage, Quantization/ Thresholding focuses on selecting a value that satisfies constraints of HVS for better visual quality and increased CR. The entropy encoder stage reduces the overall number of bits needed to represent the data set. It removes redundancy in the form of repetitive bit pattern in the output of quantizer. From the various entropy encoders, Shannon encoder is used in this work. [7, 8]

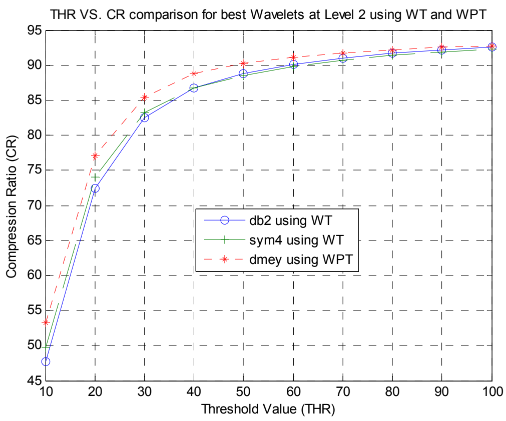
3. Experimental Results and Discussion

Wavelets namely daubechies, coiflets, symlets, haar, dmey and biorthogonal wavelets are used for image compression in the analysis process. These wavelets are tested over a standard Barbara image (256x256) on grey scale. The daubechies wavelet, db_N is tested for the order of filter, N= 1 to 10, coiflet wavelet $coif_N$ for the order of filter, N= 1 to 5, symlet wavelet $coif_N$ for the order of filter, N= 1 to 5, and biorthogonal wavelet $bior_N$ is tested for the order of filter, N= 1.1 to 6.8 and $rbio_N$ is tested for the order of filter, N= 1.1 to 6.8. The experimental results are calculated in terms of Compression ratio (CR), Energy ratio (ER), Mean Square Error (MSE), and Peak Signal to Noise Ratio (PSNR) for threshold value (THR) ranging from 10 to 100. MSE and PSNR are the important objective measures. A good reconstruction image is one with high PSNR and low MSE. The comparison results for the competing members of wavelets are given in Table 1.

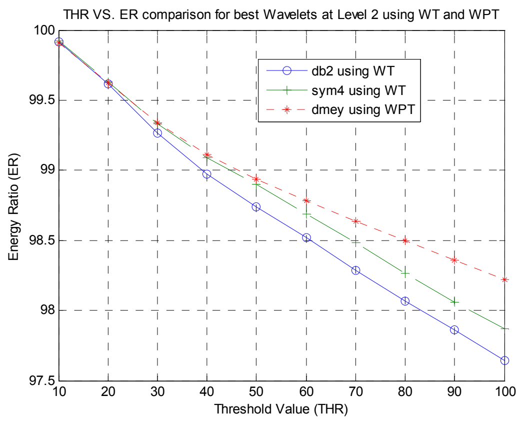
At Level 2 Wavelet Transform: In spite of having the highest CR in the entire threshold range, wavelet haar cannot be used for the image compression because it gives the lowest ER, very high value of MSE and the very low value of PSNR. In the low threshold range and low CR region, sym4, and in the high threshold range and high CR region, db2 are preferred for the image compression. Their PSNR values are above 20 dB in the entire threshold range because in this case the image degradation is within the tolerable limit.Wavelet dmey may be used for the image compression as it gives highest ER, lowest MSE and the highest PSNR in the entire threshold range but its CR value is not good compared to sym4 and db2.

At Level 2 Wavelet Packet Transform: The wavelet dmey is preferred for the image compression in the entire threshold range and CR range as it gives higher ER, lower MSE and higher value of PSNR comparatively.The results obtained above illustrate some important points that Wavelet sym4 and db2 in DWT and wavelet dmey in WPT are preferred respectively. The curves of THR vs CR, THR vs ER, THR vs MSE, and THR vs PSNR have been calculated and depicted in Fig. 1 (a), (b), (c) and (d) respectively at level 2 for best wavelets of DWT and DWPT.

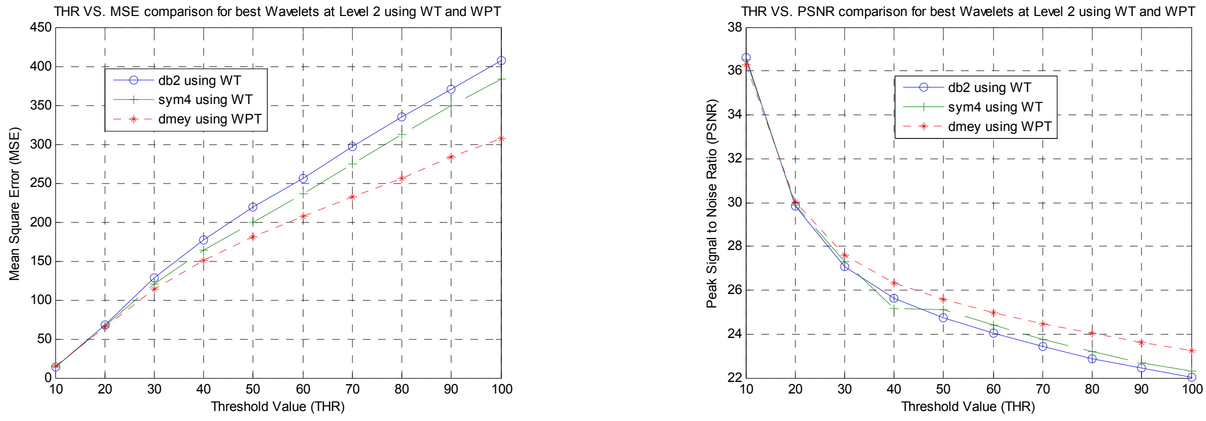
Wavelet dmey gives highest CR, highest ER, lowest MSE, and Higher PSNR for the complete Threshold range.



(a)



(b)



(c) **(d)**

Fig. 1: Simulations Results of image compression with 256*256 pixels (a) THR vs CR (b) THR vs ER (c) THR vs MSE (d) THR vs PSNR

4. Conclusion

In this paper, selection of mother wavelet on the basis of still image has been presented. Extensive results have been taken based on different wavelets. The curves for CR vs MSE and CR vs PSNR are shown in Fig. 2. Fig. 3 shows the original image and results of the compressed image using db2, sym4, and dmey. The results show that dmey performs significantly better in the entire threshold and CR range.

5. Acknowledgement

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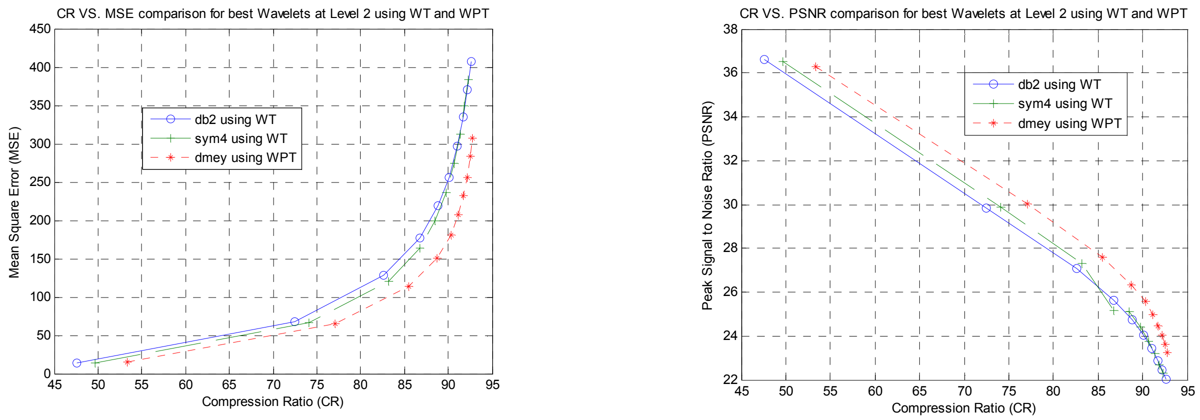

(a) **(b)**

Fig. 2: Simulations Results of image compression with 256*256 pixels (a) CR vs MSE (b) CR vs PSNR

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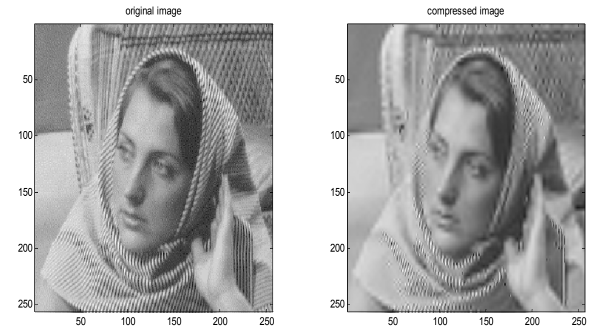
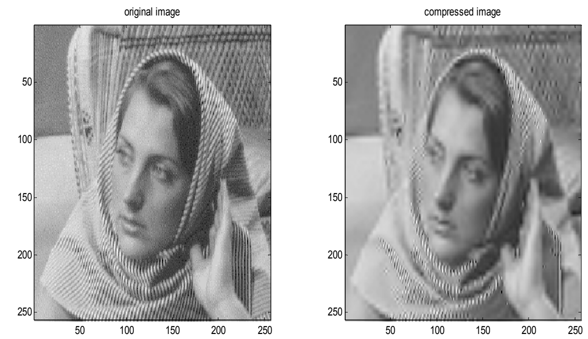
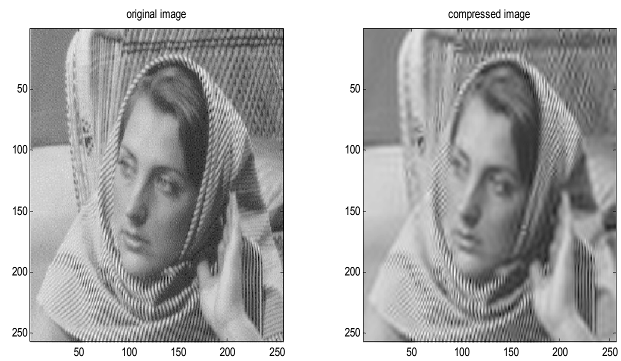


(a)



(b)



(c)

Fig. 3. Original and Decompressed images of (a) sym4 (b) db2 (c) dmey at threshold level 100

Table 1: Comparison of Image Compression Parameters at Decomposition Level 2 for

(a) Discrete Wavelet Transform (b) Wavelet Packet Transform

(a)

THR	Parameter	haar	dmey	db2	coifl	sym4	sym5	biorl.3	rbio3.1
5	CR	21.69	27.61	26.22	26.72	28.2	27.95	24.483	17.0921
	ER	99.99	99.99	99.99	99.99	99.99	99.99	99.991	99.9933
	MSE	1.143	2.309	2.108	2.099	2.264	2.271	1.7027	3.7536
	PSNR	47.55	44.5	44.89	44.91	44.58	44.57	45.819	42.3863
10	CR	46.51	48.25	47.64	48.16	49.69	50	45.418	30.3191
	ER	99.91	99.96	99.92	99.92	99.92	99.92	99.923	99.9524
	MSE	15.38	14.94	14.23	14.19	14.41	14.81	14.203	22.88
	PSNR	36.26	36.39	36.6	36.61	36.54	36.42	36.607	34.5362
20	CR	68.98	70.07	72.45	72.59	74.08	74.21	69.331	49.5642
	ER	99.61	99.81	99.61	99.62	99.63	99.64	99.627	99.7206
	MSE	65.44	66.52	67.18	66.28	66.47	66.69	68.273	122.8308
	PSNR	29.97	29.9	29.86	29.92	29.9	29.89	29.788	27.2377
30	CR	80.56	78.19	82.57	82.62	83.17	83.15	80.165	61.8038
	ER	99.19	99.65	99.26	99.28	99.33	99.35	99.257	99.3103
	MSE	134	116.6	127.8	126.6	121	120	134.38	285.8703
	PSNR	26.86	27.46	27.07	27.11	27.3	27.34	26.847	23.5691
40	CR	86.09	81.7	86.73	86.74	86.8	86.67	85.298	70.0462
	ER	98.8	99.51	98.98	99	99.09	99.11	98.909	98.7668
	MSE	199.5	155.8	177.5	176.1	164.4	161.4	194.33	499.5143
	PSNR	25.13	26.21	25.64	25.67	25.17	26.05	25.2450	21.1453
50	CR	88.54	83.6	88.81	88.8	88.54	88.49	87.896	75.9544
	ER	98.51	99.39	98.74	98.77	98.9	98.91	98.616	98.1245
	MSE	248.1	188.9	218.8	217.1	199.6	197	243.13	713.3064
	PSNR	24.18	25.37	24.73	24.76	25.13	25.19	24.272	19.598
60	CR	90.18	84.83	90.07	90.05	89.77	89.68	89.469	80.3273
	ER	98.22	99.27	98.52	98.55	98.69	98.72	98.347	97.4155
	MSE	297.1	219.3	256.5	254.7	236.7	232	287.1	939.9564
	PSNR	23.4	24.72	24.04	24.07	24.39	24.48	23.55	18.3997
70	CR	91.27	85.77	91.01	91.01	90.67	90.58	90.517	83.2316
	ER	97.94	99.14	98.29	98.32	98.48	98.51	98.096	96.7564
	MSE	343.3	253.6	296.1	295.6	274.4	268.2	362.91	1.13E+03
	PSNR	22.77	24.09	23.42	23.42	23.75	23.85	22.987	17.605
80	CR	91.93	86.53	91.7	91.71	91.36	91.26	91.271	85.5123
	ER	97.72	99	98.06	98.09	98.26	98.29	97.857	96.0685
	MSE	380.2	289.7	335	334.8	312.6	305.5	365.25	1.30E+03
	PSNR	22.33	23.51	22.88	22.88	23.18	23.28	22.505	16.9798
90	CR	92.45	87.13	92.19	92.23	91.88	91.79	91.886	87.217
	ER	97.49	98.86	97.86	97.88	98.06	98.09	97.604	95.4046
	MSE	417.1	325.8	369.9	372.1	349.2	343	405	1.49E+03
	PSNR	21.93	23	22.45	22.42	22.7	22.78	22.056	16.4087
100	CR	92.89	87.59	92.61	92.55	92.25	92.13	92.311	88.5251
	ER	97.26	98.72	97.64	97.71	97.87	97.92	97.604	94.7695
	MSE	456.3	360.7	407.7	401.5	383	373.7	439.4	1.63E+03
	PSNR	21.54	22.56	22.03	22.09	22.3	22.41	21.702	16.0023

(b)

THR	Parameter	haar	dmey	db2	db3	coifl	sym5	biorl.3	rbiol.3
5	CR	26.3	30.4	28.2	29.3	28.5	29.9	29.33	30.39
	ER	100	100	100	100	100	100	99.99	99.99
	MSE	2.22	2.41	2.26	2.35	2.26	2.38	2.197	2.335
	PSNR	44.7	44.3	44.6	44.4	44.6	44.4	44.71	44.45
10	CR	46.4	53.3	50.4	52	51	52.9	48.78	51.3
	ER	99.9	99.9	99.9	99.9	99.9	99.9	99.92	99.92
	MSE	13.6	15.3	14.8	15.1	14.8	15.3	14.47	15.07
	PSNR	36.8	36.3	36.4	36.3	36.4	36.3	36.53	36.35
20	CR	71.3	77	74.8	75.9	75	76.7	71.88	75.21
	ER	99.6	99.6	99.6	99.6	99.6	99.6	99.63	99.61
	MSE	66.5	65	66.7	65.7	65.7	65.4	66.91	66.54
	PSNR	29.9	30	29.9	30	30	30	29.88	29.9
30	CR	81.8	85.5	84	84.5	84.2	85.1	81.58	84.18
	ER	99.2	99.3	99.3	99.3	99.3	99.3	99.28	99.29
	MSE	129	114	122	117	120	115	124.9	119.2
	PSNR	27	27.6	27.3	27.4	27.3	27.5	27.17	27.37
40	CR	86.4	88.7	87.7	88	87.8	88.3	86.19	87.84
	ER	98.9	99.1	99	99.1	99	99.1	98.95	99.03
	MSE	183	151	166	160	165	153	177.5	163
	PSNR	25.5	26.3	25.9	26.1	26	26.3	25.64	26.01
50	CR	88.9	90.3	89.5	89.8	89.7	89.9	88.57	89.71
	ER	98.6	98.9	98.8	98.9	98.8	98.9	99	98.8
	MSE	232	180	203	194	202	186	222.9	200.8
	PSNR	24.5	25.6	25.1	25.2	25.1	25.4	24.65	25.1
60	CR	90.4	91.2	90.7	90.8	90.8	90.9	90.08	90.75
	ER	98.3	98.8	98.6	98.7	98.6	98.7	98.4	98.62
	MSE	278	207	237	227	236	215	265.4	234.8
	PSNR	23.7	25	24.4	24.6	24.4	24.8	23.89	24.42
70	CR	91.3	91.8	91.5	91.6	91.6	91.6	91.03	91.51
	ER	98.1	98.6	98.4	98.5	98.4	98.5	98.17	98.42
	MSE	318	233	272	259	271	244	302.3	270.6
	PSNR	23.1	24.5	23.8	24	23.8	24.3	23.33	23.81
80	CR	92	92.2	92.1	92.1	92.1	92.1	91.66	92
	ER	97.9	98.5	98.2	98.3	98.2	98.4	97.96	98.26
	MSE	356	256	304	288	305	272	334.4	300.6
	PSNR	22.6	24	23.3	23.5	23.3	23.8	22.89	23.35
90	CR	92.5	92.5	92.5	92.5	92.6	92.5	92.2	92.42
	ER	97.7	98.4	98	98.1	98	98.2	97.73	98.08
	MSE	388	284	333	316	336	302	370.1	333.7
	PSNR	22.2	23.6	22.9	23.1	22.9	23.3	22.45	22.9
100	CR	92.8	92.8	92.8	92.8	92.8	92.7	92.57	92.74
	ER	97.5	98.2	97.9	98	97.9	98.1	97.53	97.9
	MSE	421	307	361	344	361	326	400.3	362.9
	PSNR	21.9	23.3	22.6	22.8	22.6	23	22.11	22.53