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Lossy Images Compression Based on Multiresolution

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Abstract

A hybrid lossy compression system was presented in this paper. It was based on combining the multiresolution coding together with a polynomial approximation of linear base to decompose grey images followed by an efficient coding.

The test results showed promising performance where the compression ratio improved about three times or more compared with the results of the traditional linear predicting coding system.

Keywords Lossy image compression, Multiresolution, and Linear prediction

الخلاصة

تم في هذا البحث تقديم طريقة ضغط ضياعي هجينة. حيث اعتمدت على دمج طريقة التعدد بالقرار مع التنبوء الخطي وذلك لتحليل الصور الرمادية يتبعها ترميز كفوء.

بينت النتائج اداء واعد حيث تم تحسين نسبة الضغط بما يعادل 3 مرات او اكثر مقارنة مع نتائج نظام التنبوء الخطي التقليدي.

Introduction

Image compression techniques are developed rapidly to compress large quantity of image data; it aims to minimize image redundancy (i.e. reducing the image size without affecting the quality of the real image) to store or transmit it through the network in an efficient form.

The concept redundancy is an important issue in image compression; it stands for unnecessary or similar pixel values in an image. According to the way of redundancy removal; image compression techniques can be classified into two categories (lossless and lossy). In lossless; the compressed image can be reconstructed exactly as the original; while in lossy compression ; the reconstructed image might be slightly different from the original but it is quite close to it [1], it Yields a much higher compression ratio compared with lossless techniques.

Wavelet transform is one of the most interested developments in image compression field during the past decades and a significant number of wavelet based lossy compression algorithms [2, 3, 4] were proposed to provide high quality reconstructed images. The Multi-resolution has received an increasing interest since 1993; where Das and Burgett showed an efficient use of the traditional predictive coding and multiresolution predictive coding versus other lossless techniques. It could be utilized for image compression efficiently due to its simplicity, higher compression rates, fast and easy to implement. Generally, the implementation of multiresolution is composed of two steps “filtering and decimation”, more details can be found in [5, 6].

On the other hand, the polynomial linear based on first order Taylor series adopted by [7-11] is utilized efficiently to compress images, it is based on modelling the distance between image pixels and the centre.

In this paper, a hybrid lossy compression technique was presented to compress gray images by utilizing the multi-resolution technique with a polynomial representation of linear base.

Materials and Methodologies

The following steps were adopted in this study. See Figure 1:

1. Input: grayscale image (I) of size N usually Overburdened with redundancy.
2. Apply multi-wavelet transforms (multiresolution) that decompose the input image into two layers such that:
   - First layer: where the image is decomposed into four sub bands each of size (N/2×N/2) (LL1, LH1, HL1 and HH1) which corresponds to medium resolution image.
   - Second layer: The approximation subband (LL1) from the first layer is used to create the second layer that also will be decomposed into approximation and details sub bands each of size (N/4×N/4) (LL2, LH2, HL2, and HH2) which corresponds to low resolution image.
3. Apply prediction process of polynomial linear base on LL2 sub band by determining the following steps:
   a. partition the approximation sub band (LL2) into fixed non overlapped blocks of size n×n such that:

$$\text{Number of Blocks} = (N/n)^2 \quad (1)$$

   b. For each block estimates polynomial linear model coefficients using equations (2, 3, and 4) [2, 12, 15].

$$a_0 block(br, bc) = \frac{1}{n \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL2\ (i, j) \quad (2)$$

$$a_1 block(br, bc) = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL2\ (i, j) \times (j - x_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (j - x_c)^2} \quad (3)$$

$$a_2 block(br, bc) = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL2\ (i, j) \times (i - y_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (i - y_c)^2} \quad (4)$$

$$xc = yc = \frac{n-1}{2} \quad (5)$$

Where i=j= 0,….n-1 and br=bc=1…..N/n

   c. Quantize/De-quantize the coefficients by using the following equations [12,15]:

$$a_0Q = round(\frac{a_0}{Step_{a0}}) \quad (6)$$

$$a_1Q = round(\frac{a_1}{Step_{a1}}) \quad (7)$$

$$a_2Q = round(\frac{a_2}{Step_{a2}}) \quad (8)$$

$$a_0D = a_0Q \times Step_{a0} \quad (9)$$

$$a_1D = a_1Q \times Step_{a1} \quad (10)$$

$$a_2D = a_2Q \times Step_{a2} \quad (11)$$

Where $Step_{a0}$, $Step_{a1}$ and $Step_{a2}$ are the quantization steps of the coefficients of the Quantization and Dequantization process.

   d. Create the approximated image ($LL2^{\sim}$) for sub band LL_2 using the quantized polynomial coefficients:

$$LL2^{\sim} = a_0D + a_1D(j - x_c) + a_2D(i - y_c) \quad (12)$$

   e. Find the residual (prediction error) between the original image (and in this case is LL2 sub band) and the estimated image ($LL2^{\sim}$).

$$Resd = LL2 - LL2^{\sim} \quad (13)$$

   f. Quantize and de quantize the Lossy residue to remove the psycho-visual redundancy using the following equations [2,12]:

$$ResdQ = round(\frac{Resd}{Step_{Resd}}) \quad (14)$$

$$ResdD = ResdQ \times Step_{Resd} \quad (15)$$

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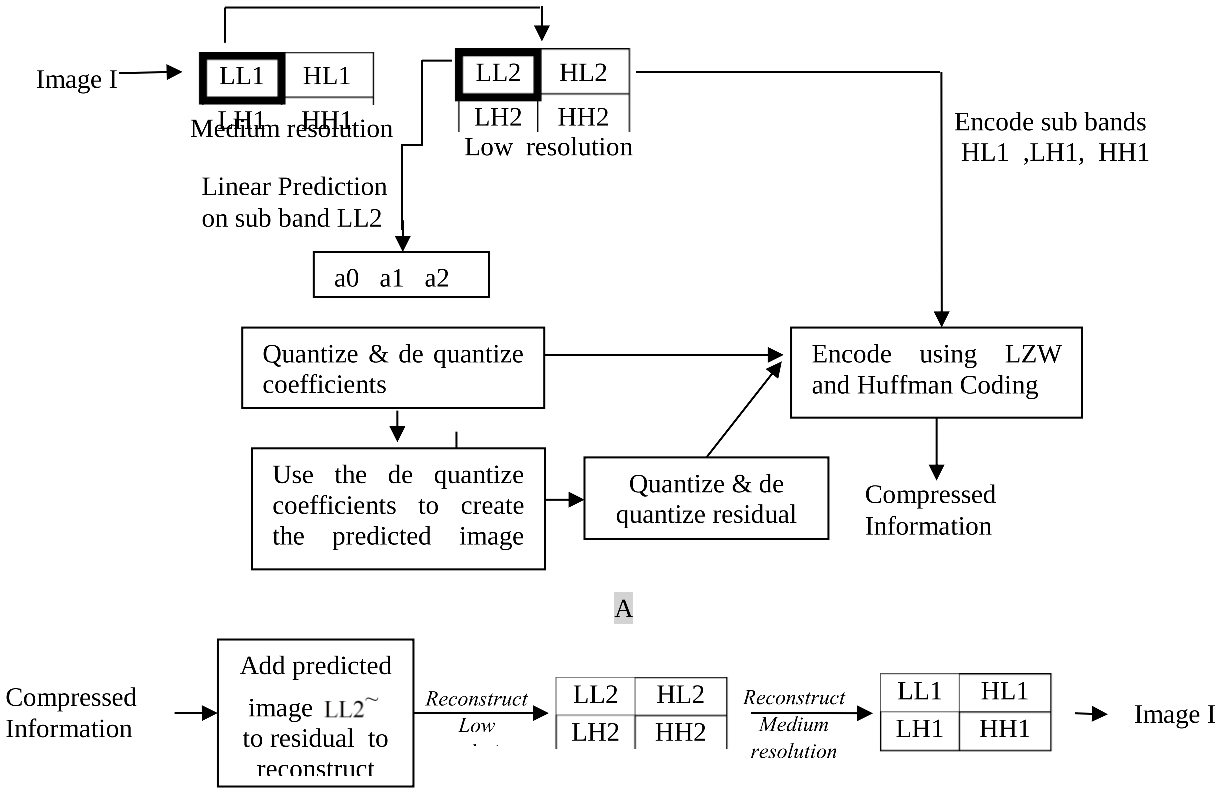

B

Figure 1: The Suggested Loosy Compression System Structure.
a- compression system, b- ecompression system.

4. Encode the modeled information of coefficients, residual and the details sub bands of first and second layer LH1, HL1, HH1, LH2, HL2 and HH2 using LZW and then pass the residual code to Huffman coding techniques to remove the rest of coding redundancy.
5. Reconstruct the compressed image as follows:
   a. Reconstruct the low resolution approximation sub band image (LL2) of layer 2; by adding the predicted (approximated) sub band $LL2^{\sim}$ image to the de quantized residual:

$$LL2 = LL2^{\sim} + ResdD \tag{16}$$

   b. Exploits the low resolution to reconstruct the approximation sub band (LL1) that corresponds to medium approximation resolution sub band
   c. Apply the inverse wavelet transform on the medium resolution sub bands to reconstruct image I.

Results and Discussion

The most commonly used distortion measures as a guide to determine the system performance efficiency in lossy compression were [1, 15]:

1. The compression ratio: stands for the ratio between the original and the compressed image.

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Figure 2:Tested Images

2. Peak Signal to Noise Ratio (PSNR) [2,12,15]:

$$PSNR = 10\log_{10}\frac{(N)^2}{\frac{1}{N\times N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}[I(x,y)-\hat{I}(x,y)]^2} \quad (17)$$

Where I the original image, $\hat{I}$ is the decoded image.

All tested images were square of 256 gray levels (8bits/pixel) and of size 256×256, as shown in Figure 2.

Clearly, the suggested hybrid lossy technique achieved high compression rates (see Tables 1, 2) and good image quality as compared with the results of the traditional compression system results (see Tables 3 & 4) for both block sizes 4 & 8; where the compression rate was improved about three times more or less. This due to the utilization of multiresolution technique that preserver image information as much as possible before compression in addition to the utilization of the polynomial approximation coefficients in an efficient way to remove the spatial redundancy.

Figures 3 & 4 illustrates the output decoded image quality (for both suggested multi resolution compression system and traditional one) using block size of 4 with Quantization step for coefficients (1, 1, 1) and quantization residual of 5, 50 respectively.

Figures 5, 6 shows the output decoded image quality (for both suggested multi resolution compression system and traditional one) using block size of 8 with Quantization step for coefficients (1, 1, 1) and quantization residual of 5 and 50 respectively.

Conclusions

In this paper an efficient algorithm for lossy image compression based on multiresolution technique has been developed.

The traditional coding technique is characterized by simplicity but unfortunately gives low compression ratio as a spatial domain utilization, which is basically affected by the mathematical model of linear or nonlinear base.

The performance of the suggested lossy multiresolution system varied according to the image details and the quantization levels utilized, where low compression rates obtained for detailed images.

The results of the proposed method illustrated clearly the effect of the *block size on the* compression ratio; whenever the block size gets bigger; less coefficients were needed (i.e., 3 coefficients for larger block sizes). This implicitly improved the compression ratio.

In future multi-resolution image decomposition technique might be combined with other coding techniques to improve the results; also the proposed algorithm used in this paper could be extended to real time video compression.

Table 1: Results of the Suggest Multiresolution System with Block Size =4

Tested Image		Quantization step for coefficients 1,1,1			Quantization step for coefficients 1,2,2		
	Quantization Res	Compressed image size	CR	PSNR	Compressed image size	CR	PSNR
Lena	5	2493	26.2880	69.1043	2543	25.7711	69.1856
	10	2297	28.5311	62.9519	2327	28.1633	62.9434
	20	1988	32.9658	56.9451	2014	32.5402	56.9281
	30	1824	35.9298	53.4631	1865	35.1399	53.4583
	40	1714	38.2357	50.9568	1745	37.5564	50.9407
	50	1615	40.5796	49.0562	1654	39.6227	49.0527
pepper	5	2608	25.1288	69.0534	2661	24.6283	69.0483
	10	2408	27.2159	62.9240	2438	26.8811	62.9056
	20	2139	30.6386	57.0536	2178	30.0900	57.0527
	30	1981	33.0823	53.4374	2016	32.5079	53.4318
	40	1857	35.2913	50.8798	1898	34.5290	50.8768
	50	1757	37.2999	49.0524	1799	36.4291	49.0458
Rose	5	2572	25.4806	69.0755	2631	24.9092	69.0772
	10	2362	27.7460	63.0886	2400	27.3067	63.1027
	20	2098	31.2374	57.1152	2146	30.5387	57.1192
	30	1942	33.7467	53.6097	1989	32.9492	53.6079
	40	1819	36.0286	50.9154	1873	34.9899	50.9181
	50	1717	38.1689	49.0552	1770	37.0260	49.0643

Table 2: Results of the Suggest Multiresolution System with Block Size =8

Tested Image		Quantization step for coefficients 1,1,1			Quantization step for coefficients 1,2,2		
	Quantization Res	Compressed image size	CR	PSNR	Compressed image size	CR	PSNR
Lena	5	2383	27.5015	69.0139	2391	27.4095	69.0124
	10	2172	30.1731	62.9767	2191	29.9115	62.9663
	20	1914	34.2403	56.9031	1930	33.9565	56.9102
	30	1734	37.7947	53.4813	1745	37.5564	53.4681
	40	1616	40.5545	50.9868	1633	40.1323	50.9925
	50	1514	43.2867	49.0441	1540	42.5558	49.0417
pepper	5	2409	27.2046	69.1131	2417	27.1146	69.1067
	10	2266	28.9214	62.9904	2284	28.6935	63.0002
	20	2034	32.2203	56.8785	2044	32.0626	56.8829
	30	1859	35.2534	53.4735	1871	35.0273	53.4849
	40	1733	37.8165	50.8871	1750	37.4491	50.8805
	50	1651	39.6947	49.0798	1667	39.3137	49.0866
Rose	5	2445	26.8041	69.1323	2450	26.7494	69.0134
	10	2267	28.9087	62.9647	2270	28.8705	62.9631
	20	2029	32.2997	56.9913	2031	32.2678	56.9979
	30	1859	35.2534	53.4822	1869	35.0647	53.4649
	40	1733	37.8165	50.8668	1741	37.6427	50.8604
	50	1644	39.8637	49.0184	1651	39.6947	49.0186

Table 3: Results of the Traditional Prediction System with Block Size =4

Tested Image		Quantization step for coefficients 1,1,1			Quantization step for coefficients 1,2,2		
	Quantization Res	Compressed image size	CR	PSNR	Compressed image size	CR	PSNR
Lena	5	15835	4.1387	45.0256	15274	4.2907	45.0201
	10	12642	5.1840	39.3291	12054	5.4369	39.3012
	20	9875	6.6366	34.9348	9287	7.0567	34.9135
	30	8830	7.4220	32.6910	8228	7.9650	32.6720
	40	8220	7.9727	31.1589	7623	8.5971	31.1426
	50	7850	8.3485	30.0512	7249	9.0407	30.0366
pepper	5	14685	4.4628	45.4686	14182	4.6211	45.4495
	10	11812	5.5483	40.1211	11327	5.7858	40.1009
	20	9536	6.8725	35.7327	9014	7.2705	35.6955
	30	8584	7.6347	33.3989	8070	8.2610	33.3775
	40	8065	8.1261	31.8245	7534	8.6987	31.8072
	50	7761	8.4443	30.7833	7250	9.0394	30.7622
Rose	5	13305	4.9257	45.5553	12859	5.0965	45.4949
	10	10685	6.1335	40.4278	10210	6.4188	40.3562
	20	8680	7.5502	36.4108	8151	8.0402	36.3577
	30	7857	8.3411	34.4462	7331	8.9396	34.4059
	40	7413	8.8407	33.3011	6897	9.5021	33.266
	50	7179	9.1288	32.5719	6660	9.8402	32.5447

Table 4: Results of the Traditional Prediction System with Block Size =8

Tested Image		Quantization step for coefficients 1,1,1			Quantization step for coefficients 1,2,2		
	Quantization Res	Compressed image size	CR	PSNR	Compressed image size	CR	PSNR
Lena	5	13011	5.0370	44.9868	12859	5.0965	45.0004
	10	9583	6.8388	39.0650	9465	6.9240	39.0653
	20	6630	9.8848	33.8676	6458	10.1480	33.8522
	30	5346	12.2589	31.1402	5200	12.6031	31.1357
	40	4613	14.2068	29.3434	4460	14.6942	29.3337
	50	4136	15.8453	28.0529	4004	16.3676	28.0438
pepper	5	12487	5.2483	45.1292	12360	5.3023	45.1313
	10	9255	7.0811	39.4269	9170	7.1468	39.4109
	20	6593	9.9402	34.3982	6463	10.1402	34.3778
	30	5475	11.9700	31.6393	5342	12.2681	31.6246
	40	4810	13.6249	29.7728	4671	14.0304	29.7610
	50	4385	14.9455	28.4006	4256	15.3985	28.3895
Rose	5	11191	5.8561	45.1754	11092	5.9084	45.1581
	10	8203	7.9893	39.4741	8065	8.1260	39.4552
	20	5796	11.3071	34.3926	5687	11.5238	34.3830
	30	4694	13.9617	31.7382	4566	14.3530	31.7289
	40	4038	16.2298	30.0865	3903	16.7912	30.0755
	50	3597	18.2196	28.9481	3465	18.9137	28.9399

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Traditional System with Quantization step for coefficients 1,1,1

The Suggested System with Quantization step for coefficients 1,1,1

Figure 3: Results of Decoded Images using the suggested Lossy Multiresolution against the Traditional System using block size 4, and quantization residual of 5

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Traditional System with Quantization step for coefficients 1,1,1

The Suggested System with Quantization step for coefficients 1,1,1

Figure 4: Results of Decoded Images using the suggested Lossy Multiresolution against the Traditional System using block size 4 and quantization residual of 50

Figure 5: Results of Decoded Images using the suggested Lossy Multiresolution against the Traditional System using block size 8, and quantization residual of 5

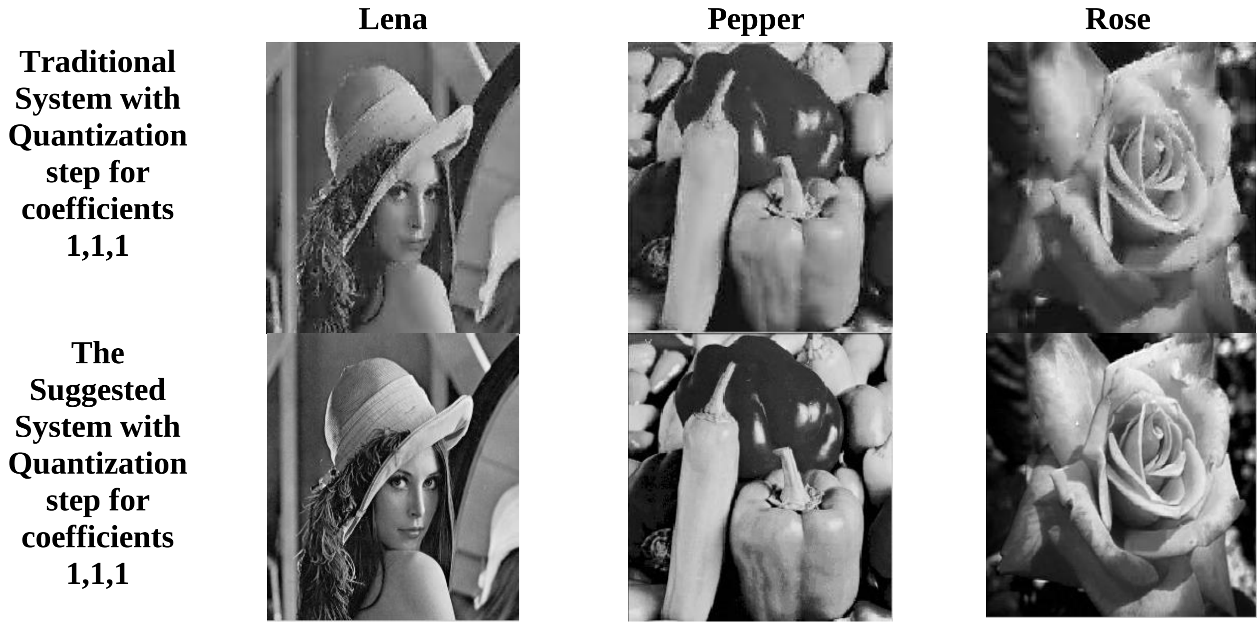

Figure 6: Results of Decoded Images using the Suggested Lossy Multiresolution against the Traditional System using block size 8, quantization residual of 50

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