A Novel Hybrid Linear Predictive Coding –Wavelet Compression

Sandip Mehta
Department of Electrical and Electronics Engineering,
J. I. E. T. Group of Institutions,
Jodhpur, India

Received Sept 12, 2017 Accepted Oct. 12, 2017

ABSTRACT *The last two decades have witnessed a transformation in the communication process that includes the ever-present, ever growing Internet, the explosive development of mobile communications; and the ever increasing importance of video communication. Data compression is one of the enabling technologies for each of these aspects of the multimedia revolution. It would not be practical to put images and video on websites if it were not for data compression algorithms. Cellular phones would not be able to provide communication with increasing clarity were it not for compression. The advent of digital TV would not be possible without compression. Data compression, which for a long time was the domain of a relatively small group of engineers and scientists, is now ubiquitous. Be it a long-distance call, a modem, a fax machine, MP3 players or a DVD, all benefit from compression. Image compression can be lossless or lossy. Except for a few areas including archives and medical images, in most of the fields, lossy compression is required for good compression ratio and reduced storage requirements. A number of transforms have been applied to the images for achieving this purpose. Wavelet transforms has emerged as one of the most powerful transforms in this direction. This paper proposes a hybrid technique using the features of Linear Predictive coding and Wavelet transforms. The results have been applied to benchmark images and the results outperform the JPEG2000 standard.*

Keywords: *Image compression, Lossless compression, Lossy compression, Linear Predictive Coding, JPEG2000, Wavelets, Compression Ratio, PSNR.*

I. Introduction

With the development in Internet and multimedia technologies over the past two decades, the amount of information that is handled by computers has grown very fast. This information requires large amount of storage space and transmission bandwidth. One of the possible solutions to this problem is to compress the information so that the storage space and transmission time can be reduced. Digital image compression[1]-[5] has thus become one of the major areas of research in the field of image processing. In general, there are two different compression categories: *lossless and lossy.* Thus, an image could be compressed and decompressed with and without losing any information.

Lossless[1]-[5] compression preserves the complete information in the image and the original data can be recovered exactly from the compressed data. Lossless compression is generally used for applications that cannot tolerate any difference between the original and reconstructed data. Situations that require lossless compression so that the reconstructed image is identical to the original include medical and legal records imaging, military and satellite photography.

In lossy[1]-[5] compression, the reconstructed image is degraded with respect to the original image. Here, a perfect reconstruction of the image is sacrificed due to the elimination of some less important details in the image to achieve a higher compression ratio as compared to lossless compression. The term 'visually lossless' is often used to characterize lossy compression schemes that result in no visible degradation under a set of designated viewing conditions.

In many applications, this lack of exact reconstruction is not a problem. For example, when storing or transmitting speech, the exact value of each phoneme of speech is not necessary. Depending upon the requirement of the quality of reconstructed speech, varying amounts of loss of information about the value of each sample can be tolerated. If the quality of the reconstructed speech is to be similar to that heard on the telephone, a significant loss of information can be tolerated. However, if the reconstructed speech needs to be of the quality heard on a compact disc, the amount of information loss that can be tolerated is much lower.

Similarly, when viewing a reconstruction of a video sequence, the fact that the reconstruction is different from the original is generally not important as long as the differences does not result in annoying artifacts. Thus, video is generally compressed using lossy compression.

Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate.

A number of techniques have been proposed in the literature during the last two decades for lossy image compression including the Transform coding. The Wavelet transforms have emerged as one of the most powerful transforms in this direction due to their multiresolution property.

The proposed hybrid technique employs Wavelets along with LPC [6][7] to obtain improved compression ratios. In Linear Prediction Coding, the information already available is used to predict future values, and the difference is coded. This is done in the image or spatial domain, and is relatively simple to implement and is readily adapted to local image characteristics. Differential Pulse Code Modulation (DPCM) is one particular example of predictive coding. Till this stage, the image is compressed losslessly. On the other hand, the Wavelet Transform[8]-[18] coding first transforms the image from its spatial domain representation to a different type of representation using various wavelets and then codes the transformed values (coefficients). This method further provides greater data compression.

The paper is arranged as follows. The proposed methodology is introduced in section II. The experimental results are presented in section III while the conclusions are presented in section IV.

II. PROPOSED METHODOLOGY

The proposed method uses a hybrid technique using the power of Linear Predictive Coding along with the multiresolution power of Wavelet transforms. The modified Linear Predictive Coding is applied to the original image to obtain the difference image. This Wavelet Transform is applied to decompose this difference image into various subbands. The coefficients of the various subbands are quantized and thresholded using modified Bayes threshold and then coded, first using Run length coding followed by Huffman coding. In the decoding process, the reverse process is followed. The block diagram of the proposed methodology is shown in Fig. 1.

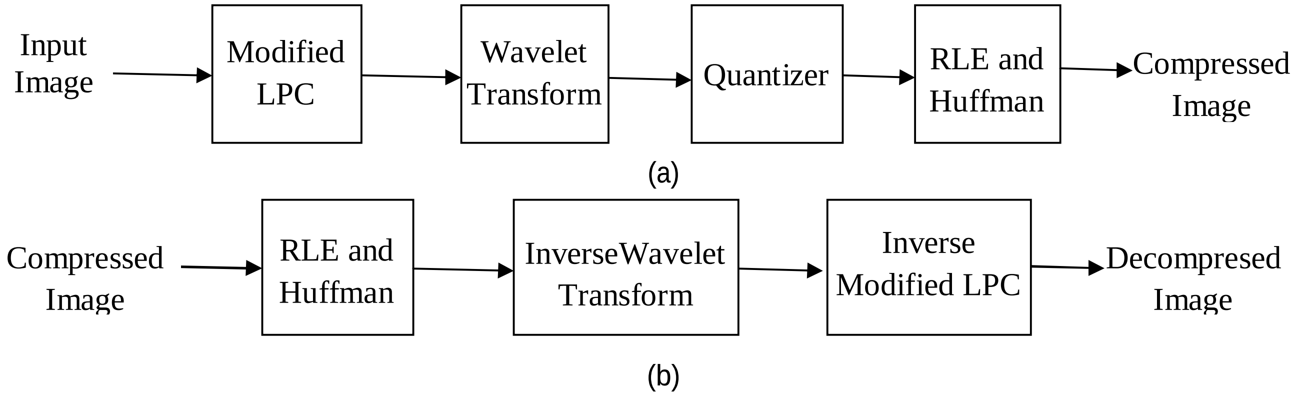


Fig. 1. Block Diagram of the Hybrid LPC –Wavelet Compression Method (a) Encoder (b) Decoder

The steps involved in the proposed algorithm for both coding and decoding are as follows:

A) Coding

Stage 1: Application of the modified lossless predictive coding as described in section 6.3 to the test image.
Stage 2: Decomposition of the output of step 1 into subbands at level *n* using Wavelet Transform. The db8 wavelet has been applied here.
Stage 3: Thresholding of the coefficients obtained in stage 2 by using modified Bayes method.
Stage 4: Coding of the Wavelet coefficients: The thresholded coefficients of stage 3 are first coded using Run length coding followed by Huffman coding.

B) Decoding

Stage 1: Decoding of coefficients: The Huffman coded coefficients are decoded using the Huffman decoder and Run length decoder.
Stage 2: Reconstruction of image: The inverse wavelet transform is applied to the output of the above step to produce the reconstructed image.

III. EXPERIMENTAL RESULTS

The performance of this technique is measured by using compression ratio (CR) and Peak-signal-noise-ratio (PSNR). Visual inspection is also carried out on the compressed images so as to judge the effectiveness of the compression method. The results for various levels of decomposition using various wavelets is shown in Table 1 to 6.

TABLE 1
Compression Results for 'Lena' Image using Proposed technique

Wavelet→	**db8**	
Decomposition levels↓	**CR**	**PSNR**
1	10.5467	48.2564
2	28.5641	35.2546
3	42.5462	32.1254
4	51.2315	29.2515

TABLE 2
Compression Results for 'Peppers' Image using Proposed technique

Wavelet→	**db8**	
Decomposition levels↓	**CR**	**PSNR**
1	8.7214	35.9546
2	25.2138	28.3254
3	38.1649	26.7029
4	523.2984	23.4158

TABLE 3
Compression Results for 'Barbara' Image using Proposed technique

Wavelet→	**db8**	
Decomposition levels↓	**CR**	**PSNR**
1	**8.5467**	**34.2514**
2	**24.2531**	**27.5164**
3	**37.2457**	**24.1249**
4	**52.1378**	**23.5861**

TABLE 4
Compression Results for 'Lighthouse' Image using Proposed technique

Wavelet→	**db8**	
Decomposition levels↓	**CR**	**PSNR**
1	9.2134	34.2546
2	23.4129	30.1129
3	34.3861	28.9871
4	46.533	26.2541

TABLE 5
Compression Results for 'Mandrill' Image using Proposed technique

Wavelet→	**db8**	
Decomposition levels↓	**CR**	**PSNR**
1	6.3549	31.2568
2	17.2642	22.6549
3	31.2654	21.5468
4	43.2154	19.2564

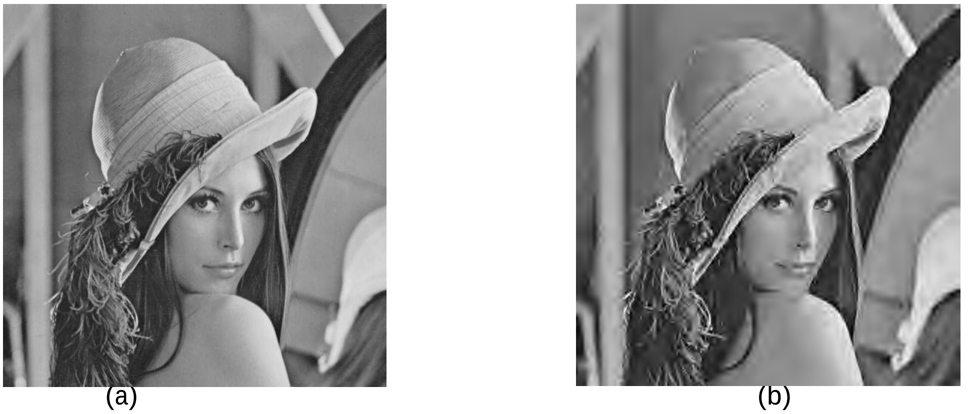
TABLE 6
Compression Results for 'Grass' Image using Proposed technique

Wavelet→	db8	
Decomposition levels↓	**CR**	**PSNR**
1	5.2645	33.2165
2	11.2546	25.2315
3	21.3546	22.3254
4	28.2546	18.2546

It can be seen from Table 7 that the proposed algorithm performs significantly better than the JPEG2000 [19] for all benchmark images in terms of both compression ratio and PSNR. The visual observations in Fig. 3 show that the blocking artifacts are not present in the reconstructed image.

TABLE 7
Comparison of Compression Results of proposed technique with JPEG2000 at Two Levels of Decomposition using db8 Wavelet

Technique →	JPEG2000	Proposed technique	JPEG2000	Proposed technique
Benchmark image ↓	**Compression Ratio(CR)**		**PSNR**	
Lena	26.4521	28.5641	34.9541	35.2546
Peppers	22.1548	23.4129	29.2541	30.1129
Barbara	23.4562	24.2531	27.2145	27.5164
Lighthouse	24.1587	25.2138	27.2135	28.3254
Mandrill	16.9841	17.2642	21.5487	22.6549
Grass	10.9519	11.2546	24.1524	25.2315



(a) (b)

Fig. 2. Compressed Image using HLPCWC (a) 'Lena' Image Compressed Image (CR= 51.23)

IV. CONCLUSION

The novel hybrid technique using Modified Linear Predictive Coding with Wavelet transforms has been proposed in this paper. The modified Linear Predictive Coding first compresses the images losslessly and then the Wavelet transform is applied to the resultant compressed image. The technique was applied to a number of benchmark images including Lena, Peppers, Barbara, Lighthouse, Mandrill and Grass. The db8 wavelet was applied and the results were compared with the JPEG2000 standard. It was found that the results outperform the JPEG2000 standard.

Future work should be directed towards further improving the compression ratio and reducing the processing time.

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