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Hybrid Lossy Predictive-Huffman Coding

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Abstract — *In the present world, a huge amount of information is stored, processed and transmitted digitally every moment through multimedia. Governments, corporates, students, businesses, researchers, and individuals create, obtain, process, store and share a wide variety of data through the internet and other digital media. Considerable amount of this information is graphical or illustrative in nature and uses significant amount of memory. Image compression is the art and science of reducing the amount of data required to represent an image. It is one of the most useful and commercially fruitful technologies in the digital image processing domain. Based on the requirement, image compression can be lossless or lossy. This paper proposes a hybrid lossy compression technique that exploits the properties of Linear Predictive Coding and the Huffman algorithm, and gives appreciable results on a number of benchmark images.*

Keywords- *Image compression, Lossless compression, Lossy compression, Huffman coding, Linear Predictive coding*

I. INTRODUCTION

Digital image processing[1]-[11] is a rapidly evolving field with growing applications in science and engineering. It has the potential to develop the eventual machine for artificial vision that could emulate all the optical functions carried by human beings. This would require great scientific breakthroughs before such a machine could be made. However, before we reach that point, there are a myriad of image processing applications that can be used for the benefit of society with the currently available and predicted technology.

Digital image processing has a broad spectrum of applications, including image processing and storage for multimedia applications, medical processing, remote sensing, robotics, military, sonar, acoustic image processing and automation.

With the growth of multimedia technology over the past decades, the demand for digital information has increased dramatically. The advances in technology have made the use of digital images prevalent to a large extent. Still images are widely used in applications like medical and satellite images. Digital images require an enormous amount of data storage. Reduction in the size of the image data for both storing and transmission of digital images is becoming increasingly important.

Image compression[6]-[10] is one of the most prominent areas in the field of digital image processing. Image compression can be considered as a mapping from a higher dimensional space to a lower dimensional space. Image compression plays an important role in many multimedia applications, such as image storage and transmission. The basic goal of image compression is to represent an image with smallest number of bits while maintaining an allowable image quality. Image compression deals with ways to represent an image in a more condensed way. All image compression algorithms are aimed to remove statistical redundancy so as to reduce the quantum of data as far as possible.

Some data compression algorithms are lossless, while others are not. A lossless algorithm eliminates only redundant information, allowing exact retrieval of the image upon decompression of the file. Lossless compression is preferred in the areas of archives, medical imaging, technical drawings and caricatures. Methods for lossless image compression include Run-length encoding [12], Predictive Coding [13]-[14], Arithmetic coding [15], and Entropy encoding such as Huffman [16]-[19] coding. On the other hand, lossy compression techniques include Quantization[20]-[21], Transform coding including Discrete Cosine Transform[22]-[23], Karhunen-Lo`eve transform[24] and Wavelet Transforms[25]-[27]. This paper proposes a lossy compression technique incorporating Linear Prediction coding, Quantization and Huffman coding.

The rest of the paper is arranged as follows. Section II introduces the proposed methodology. The results are presented in section III while conclusion is presented in section IV.

II. PROPOSED METHODOLOGY

This hybrid technique consists of three stages: quantization, improved predictive coding and Huffman coding. The quantization stage is at the core of any lossy image encoding algorithm. Quantization is the process of partitioning the input data range into a smaller set of values. There are two main types of quantizers: scalar quantizers and vector quantizers. A scalar quantizer partitions the domain of input values into a smaller number of intervals. If the output intervals are equally spaced, the process is called uniform scalar quantization. If the output intervals are not equally spaced, it is called nonuniform scalar quantization. Vector quantization techniques is the extension of the fundamental principles of scalar quantization to multiple dimensions. Vector quantization based coding schemes are computationally efficient as compared to scalar quantization as the decoding is performed using lookup tables.

In the quantization step, the broad range of input values are mapped to a limited number of output values. As quantization is not a reversible process, it results in lossy data compression. The quantization levels can ideally range from 8 (256 gray levels) to 1(2 gray levels). However, the practical lower limit is usually confined to four.

The quantization step is followed by the modified predictive coding. Predictive coding techniques also takes advantage of interpixel redundancy. The basic philosophy is to encode only the new information in each pixel, which is usually defined as the difference between the actual and the estimated value of that pixel. Figure 1 shows the main blocks of a predictive encoder. In the normal technique, the first column of the image matrix is taken as the reference and the differences are taken along the horizontal direction. In the modified method, after processing in the horizontal direction, the first column itself is predictive coded. This helps in improving the performance of the system.

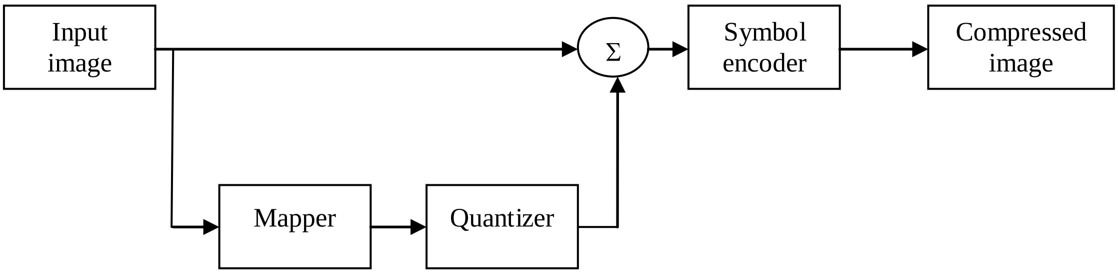


Fig. 1. Linear Predictive Encoder[1]

The key component is the predictor, whose function is to generate a predicted value for each pixel from the input image based on previous pixel values. The output of predictor is rounded off to the nearest integer and compared with the actual pixel value. The difference between these values, known as prediction error, is then encoded by a encoder. As it is likely that the prediction errors would be smaller than the original pixel values, the encoder is expected to generate shorter codewords.

There are several local, global, and adaptive prediction algorithms in the literature. In most cases, the predicted pixel value is a linear combination of previous pixels.

In the normal case, the first column of the image matrix is taken as reference and the difference are taken along the horizontal direction. In the modified case, after the processing is done in the horizontal direction, the first column itself is predictive coded which further improves the performance of the system.

This is then finally followed by Huffman coding.

The steps involving the modified predictive coding are as follows:

Stage 1: Quantization of the test image

Stage 2: Application of modified lossless predictive coding to the output of stage 1.

Stage 3: Application of Huffman coding to the output of stage 2 to determine the compression ratio of the resulting coded image matrix.

Stage 4: Repetition of the above three steps for the other three orientations viz. top right, bottom left and bottom right.

Stage 5: Comparison of the compression ratios of the image obtained by the four orientations.

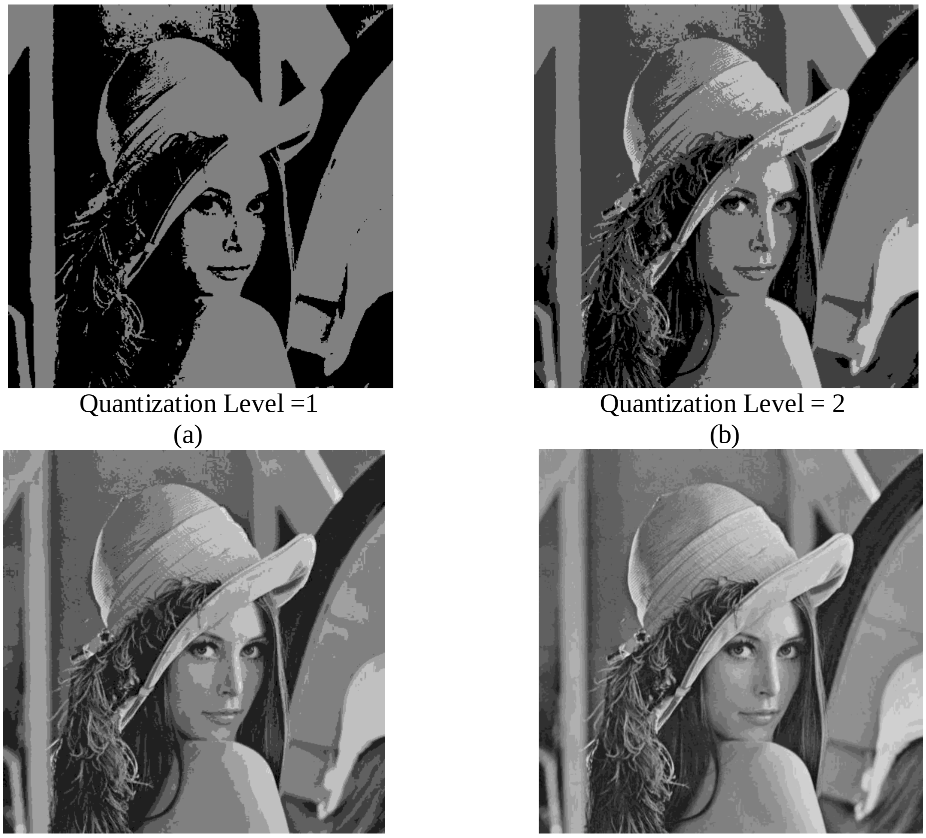
III. EXPERIMENTAL RESULTS

The Hybrid Lossy Prediction-Huffman Coding technique was applied to a wide variety of benchmark images and the compression results are tabulated as shown in Table 1.

TABLE 1

Comparison of Compression Results for Six Benchmark Images using proposed technique

Compression technique→ / Image↓	Huffman Coding	LPC Method	Proposed technique – Quantization level 1		2		3		4	
			CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR
Lena	**1.0698**	**1.6721**	**7.511**	**11.391**	**6.976**	**16.872**	**6.317**	**22.9956**	**5.071**	**29.228**
Peppers	**1.0492**	**1.5055**	**7.427**	**11.187**	**6.754**	**17.050**	**5.713**	**23.0937**	**4.544**	**29.303**
Barbara	**1.0535**	**1.2346**	**6.534**	**11.018**	**5.604**	**16.961**	**4.121**	**22.9741**	**3.002**	**29.246**
Lighthouse	**1.0676**	**1.3572**	**7.334**	**10.235**	**6.013**	**16.822**	**5.007**	**22.8255**	**3.681**	**29.232**
Mandrill	**1.0469**	**1.1321**	**6.351**	**11.156**	**5.251**	**16.840**	**3.661**	**23.2270**	**2.589**	**29.294**
Grass	**1.0368**	**1.0858**	**5.871**	**11.475**	**4.636**	**16.894**	**3.255**	**23.0140**	**2.365**	**29.285**



Quantization Level =1
(a)

Quantization Level = 2
(b)

Quantization Level = 3
(c)

Quantization Level = 4
(d)

Fig. 2. Restoration Results of the proposed method for 'Lena' Image for (a) Quantization Level = 1 (b) Quantization Level =2 (c) Quantization Level =3 (d) Quantization Level = 4

Table 1 shows the compression ratios of this method for different quantization levels. Fig. 2 shows the qualitative results for various quantization levels for 'Lena' image. It can be seen that at the fourth quantization level, the compression ratio is reasonably high along with a good PSNR. The lower quantization levels result in poorer PSNR. However, the proposed algorithm gives significantly results.

IV. CONCLUSION

The Hybrid Lossy Prediction-Huffman Coding has been proposed in this method. In this method, the test image is initially quantized which is followed by the application of the modified Predictive coding. The Huffman coding is then applied and then the procedure is repeated for various scan orientations of the image viz. top right, bottom left and bottom right. The results are then compared to obtain the best compression ratios. This technique produces superior results as the quantization levels increase to level 4.

Future work should explore other scan orientations and should be directed to reduce the processing time.

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