

A MODIFIED ALGORITHM FOR CODEBOOK DESIGN USING VECTOR QUANTIZATION FOR IMAGE COMPRESSION

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Uncompressed multimedia (images, audio, video) data requires considerable storage capacity and transmission bandwidth despite rapid progress in mass storage density, processor speeds and digital communication system performance. The only solution is to compress multimedia data before its storage and transmission and decompress it at the receiver. This paper presents an efficient approach for image Compression using modified transform vector quantization for codebook generation. In this paper, a new codebook design algorithm is proposed for image coding. The method utilizes mean-squared error based selection schemes for good clustering of data vectors in the training space. As the clustering process terminates only in two steps, it is highly computationally efficient as compared to other reported methods. Simulation results are presented to show the superior performance of the proposed method in terms of peak signal-to-noise ratio as compared to the standard Linde-Buzo-Gray algorithm for codebook design.

Keywords: Image Compression, Vector Quantization, Code Vector, Codebook Generation, Compression Ratio (CR), Peak Signal-to-Noise Ratio (PSNR).

1. INTRODUCTION

Image compression is an important aspect of multimedia data transmission, especially through band limited, time-varying channels. The cost and limitation in bandwidth of wireless channels has made data compression a necessity. Compression makes it possible for creating file sizes of manageable, storeable and transmittable dimensions. A 4 MB image will take more than a minute to download using a 64 kbps channel, whereas, if the image is compressed with a ratio of 10:1, it will have a size of 400 KB and will take about 6 seconds to download. Moreover, due to the constraints of wireless channels, progressive image transmission has gained widespread acceptance. Compression refers to the representation of any data in compact form. It is achieved by exploiting the redundancy present in the data. Transmission and storage of multimedia data like text, speech, images, etc. is made efficient by compression. Compression can be classified into lossless or lossy, depending on whether all the information is retained or some of it is discarded during the compression process [1][7][9]. In the case of lossless compression, the recovered data is identical to the original, whereas, in the case of lossy compression, the recovered data is a close replica of the original. For data like text (ex. bank records), even a change of a single character can be disastrous. Similarly, for medical or satellite images, if there is any loss during compression, it can lead to artifacts in the reconstruction that may give wrong interpretation. Therefore, such applications require lossless compression. Lossy compression can be used for

signals like speech, natural images, etc., where the amount of loss in the data determines the quality of the reconstruction and does not lead to change in the information content. More compression is achieved in the case of lossy compression than lossless compression. Any compression algorithm is acceptable provided a corresponding decompression algorithm exists. The different compression algorithms can be compared based on certain performance measures. Compression Ratio (CR) is defined as the ratio of the number of bits required to represent the data before compression to the number of bits required after compression. Rate is the average number of bits per sample or pixel (bpp), in the case of image. Distortion is quantified by a parameter called Mean Square Error (MSE). MSE refers to the average value of the square of the error between the original signal and the reconstruction. The important parameter that indicates the quality of the reconstruction is the peak signal-to-noise ratio (PSNR). PSNR is defined as the ratio of square of the peak value of the signal to the mean square error, expressed in decibels. Some of the commonly used techniques are Transform coding, namely, Discrete Cosine Transform, Wavelet Transform, Gabor Transform etc, Vector Quantization, Segmentation and approximation methods, Spline approximation methods (Bilinear Interpolation/Regularization), Fractal coding etc. Images contain high redundancy due to the correlation between adjacent pixels and this makes them suitable for compression [2] [8]. Redundancy removal in images can be achieved by using a transform that operates on the image, resulting in a matrix of coefficients that are not correlated with each other. The image is sparsely represented by the coefficients of the transformation, which leads to compression.

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The goal of quantization is to encode the data from a source, with some loss, so that the best reproduction is obtained. Vector quantization (VQ) achieves more compression than scalar quantization [3], making it useful for band-limited channels. The algorithm for the design of optimal VQ is commonly referred to as the Linde-Buzo-Gray (LBG) [4] algorithm, and it is based on minimization of the squared-error distortion measure. The LBG algorithm starts with an initial codebook and iteratively partitions the training sequence into the Voronoi regions to obtain a new codebook that produces a lower distortion. Once the final codebook is obtained, it can be used on new data outside the training sequence with the optimum nearest neighbor rule. If the training sequence is sufficiently long, it yields good performance for future data produced by the source.

This paper is organized as follows. Section (2) gives the Vector Quantization. Section (3) describes codebook generation for image compression used in this paper. Section (4) describes the present works. The results are given in Section (5) and the paper concludes with Section (6).

2. VECTOR QUANTIZATION

Vector quantization (VQ) has been widely used for image and speech compression in recent years, since it provides two attractive features : optimal rate-distortion performance and quite simple decoder. VQ can be roughly classified into two categories : memoryless VQ and memory VQ [5] [6]. In memoryless VQ, the input image vector (block) are encoded independently, whereas the memory VQ exploits the correlation among neighboring block to further reduce the bit rate.

A Vector Quantizer is basically an approximator. The Original image is decomposed into N dimensional vectors. The vectors are blocks of pixel values or can be 3-D vector formed from the RGB color components. Code Vectors are vectors, with which the Input Image Vectors are approximated. The Collection of Code Vectors is called Code Book. The design problem of VQ is : the vector source has its statistical properties known. Given, Code Vectors and a distortion measure, the aim is to find a codebook and clusters of image pixels, approximated to Code Vectors, such that the average distortion is minimum.

VQ compression system contains two components : VQ encoder and decoder as shown in Figure 1. In VQ method , the given image is partitioned into set of non-overlapping image block $X = \{x_0, x_1, \dots, x_{m-1}\}$ of size 4×4 pixels each and a clustering algorithm, for example LBG [3], is used to generate a codebook $C = \{Y_0, Y_1, \dots, Y_{N-1}\}$ for the given set of image blocks. The codebook C consists of a set of representative image blocks called codewords. The VQ encoder finds a closest match codeword in the codebook for each image block and the index of the codeword is transmitted to VQ decoder. In the decoding phase, VQ

decoder replaces the index values with the respective codeword from the codebook and produces the quantized image, called as reconstructed image.

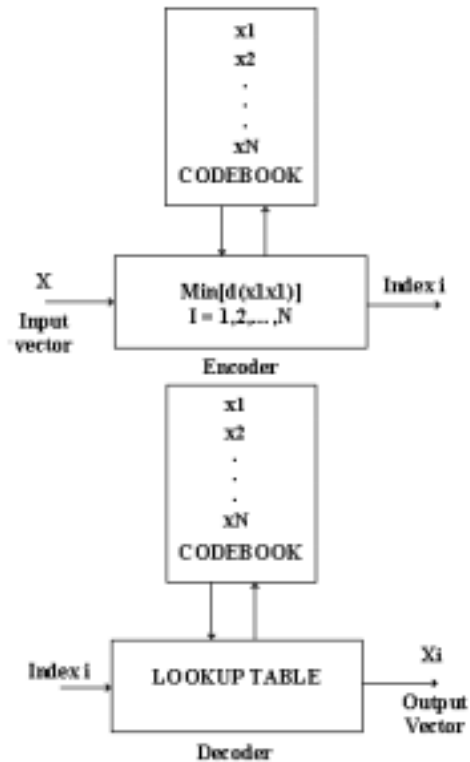


Figure 1: VQ Encoder and Decoder

3. CODEBOOK GENERATION USING VECTOR QUANTIZATION

We study the problem of generating a codebook for a vector quantizer (VQ). The aim is to find M code vectors (codebook) for a given set of N training vectors (training set). An image is first converted into the set of $X = x_1; x_2; \dots; x_N$ of N training vectors in a K -dimensional Euclidean space to find a codebook $C = c_1; c_2; \dots; c_M$ of M code vectors.

To generate the initial codebook, an image to be compressed is decomposed into a set of non-overlapped image blocks of size 2×2 pixels. Store the 4 pixels value of all 2×2 blocks in memory and we obtained initial codebook for the image as a text file after simulating our program.

When the image blocks are vector quantized, there likely to exist high correlation among the neighboring blocks. The similar blocks are eliminated from the initial codebook to obtain the codebook which will be treated as an optimized reference codebook. Thus, the redundancy present in the data, in the codebook are eliminated. If we select the image which contain all gray level to generate optimized codebook that may be used for any image as optimized reference codebook.

When the image blocks are vector quantized, there likely to exist high correlation among the neighboring blocks and hence among the corresponding codeword indices. In our scheme, the index of the codeword of a block is encoded exploiting the degree of the similarity of the block with previously encoded blocks. When the degree of similarity of the current block with one of the two previously encoded blocks is high, the index of the codeword of the block is encoded using the index of the neighboring codeword. i.e. the codeword index of the current block and that of the neighboring blocks are same. The other non-similar blocks are encoded using their original index value.

4. PRESENT WORK

In this paper, the given monochrome image, to be compressed is decomposed into a set of non-overlapped image (blocks of size 2×2 pixels). The initial codebook is generated as 4×256 . If similar code vectors in the codebook are eliminated comparing the each block with original image. Optimize codebook is obtained after eliminating similar code vector [10] [11]. The decoder uses the same set of codebooks as at the encoder. The encoder-decoder will work for any image within the training set used to design the codebook. If the training set is extended, it can be used for other images outside the set also. The decoder uses table look up to find the reproduction code vector, with the index received as the address of the codebook the reproduction code vector for each of the indices transmitted are concatenated to form the reproduction matrix of the lifting pixels of image. The quality of the reproduced image and the performance of the system has been evaluated using the CR and PSNR.

4.1 The Proposed Algorithm

The steps used in our compressor are.

1. An image to be compressed is decomposed into a set of non-overlapped image (blocks of size 2×2 pixels).
2. A codebook is generated for the image blocks using algorithm.
3. The redundancy present in the data, in the codebook are eliminated.
4. And final codebook is generated which is referred as final optimize reference codebook.
5. Assign indices to each code vector and sending these indices on communication channel for transmission at the decoder, in state of code vector.
6. Reverse process is apply at decoder to reconstruct the original image.

5. EXPERIMENTAL RESULTS

In this section, we present computer simulation results to

evaluate the performance of the proposed codebook design algorithm. Here, codebook is designed using four standard grayscale images of different size as training images for evaluation. The important parameter that indicates the quality of the reconstruction is the peak signal-to-noise ratio (PSNR). PSNR is defined as the ratio of square of the peak value of the signal to the mean square error, expressed in decibels. And compression ratio, which are defined as the ratio of the number of bits required to represent the data before compression to the number of bits required after compression. Distortion is quantified by a parameter called Mean Square Error (MSE). MSE refers to the average value of the square of the error between the original signal and the reconstruction.

$$\text{Compression Ratio} = \frac{\text{Uncompressed Size}}{\text{Compressed Size}} \quad (1)$$

$$\text{PSNR} = 10 \log_{10}(255^2/\text{MSE}) \quad (2)$$

$$\text{MSE} = 1/K \times K \sum_{i=1}^p \sum_{j=1}^p (X_{i,j} - Y_{i,j})^2 \quad (3)$$

where $K \times K$ is the total number of pixels in the image and $X_{i,j}$ and $Y_{i,j}$ represent (i,j) pixel values in the original and reproduced images, respectively.

Table 1
Experimental Results of the Proposed Approach

S.No	Images	CR (t)	PSNR (P)
1	Lena 512 (512 × 512)	50.87	30.67
2	Rice (256 × 256)	43.72	21.87
3	Saturn (1200 × 1500)	225.38	26.26
4	Westconcordorthphoto (364 × 366)	20.22	22.92

5.1 Observation

1. We observe that if the image has more details the MSE is higher.
2. As the number of iterations increase, the MSW increases. This is because, as the compression ratio increases, more sparse values are set to zero, resulting in larger error.
3. We also observe that Block Compression has the least MSE of all the cases.
4. The encoding time may be high, depending on the size of the codebook/image size; whereas decoding time is less as compare to encoding time, if we are using computing mechanism; whereas in hardware this time may reduces upto 1/100.
5. Block size increases [with truncation], which reduced codebook size, which required less time to transmit image with image degradation at receiver.

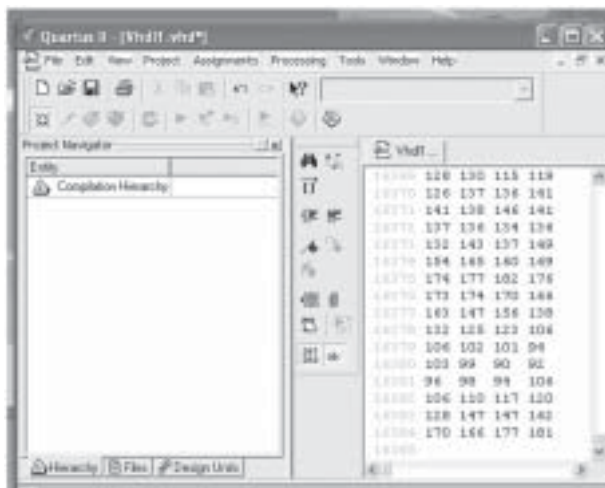
6. CONCLUSION

The test image 'Lena' and 'Rice' has been divided into a set of non-overlapped image(blocks of size 4×4) and the codebook is generated using proposed algorithm. The quality of the reconstruction depends on the code vector dimension. The algorithm can be applied to a standard set of images, if the same codebook is designed at the transmitter and receiver. It can also be used for other images, provided the training sequence is sufficiently long. The codebook need not be transmitted with every image, reducing the overhead. It is advantageous over other wavelet-based progressive techniques since it takes less encoding and decoding time. The encoding time is in the order of a few minutes, depending on the size of the codebook; decoding time is of the order of seconds. The algorithm is suitable for real-time applications, especially in hardware, because of the simplicity and savings in memory achieved by lifting. The exponential growth in size of the codebook is one of the disadvantages of VQ.

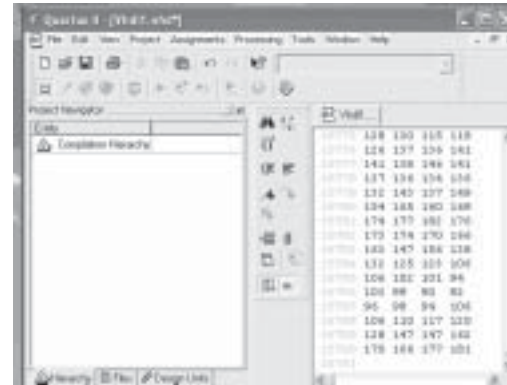
The work can be further extended by increasing the dimension of the code vectors for the details in different levels of the decomposition. This may lead to more compression at the cost of slight increase in distortion. Also, an optimization algorithm can be used for rate allocation among the different sub-bands that will minimize the distortion or maximize the PSNR. Using wavelets other than Haar may also lead to better image quality.

We can get 1/4 compression if we apply the Wavelet Transform to image further. The details coefficients of the transformed data gives the one fourth compression, which we can apply to VQ encoder to generate codebook and assign index to each code vector which we can sent to decoder for reconstruction of original image.

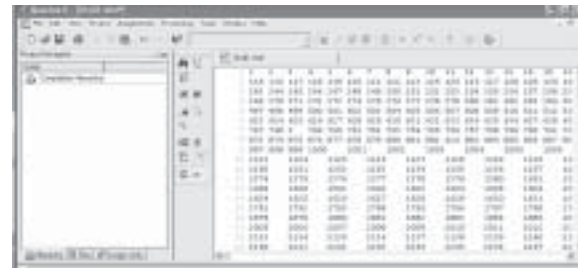
Simulated Result



Initial Codebook.



Optimize Codebook.



Indexing

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