International Journal of Engineering & Technology, 7 (3.34) (2018) 895-899

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Comparative Study of Vector Quantization in Image Compression

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Abstract

Image Compression holds a technique of compressing the data which encodes the standard image with fewer amount of bits, which results from particular sampling values using quantization methods. Quantization is a lossy compression technique, which is done by minimizing a set of bits into single quantum bit. In Vector Quantization, codebook is the significant part. The various techniques for quantization are explained in this paper. Some popular quantization techniques consume less memory and computation time such as LBG80, FBP, BPNN, ENN and Simple nearest neighbor algorithm. The resultant values of different quantization are explained in an experimental part, with the use of standard performance measure of MSE and PSNR. This approach gives an effective Codebook with minimum computational time and includes excellent Peak Signal to Noise Ratio values (PSNR).

Keywords: *Compression, Transformation - Discrete Cosine Transformation (DCT), Discrete Wavelet Transformation (DWT), Quantization-LBG algorithm.*

1. Introduction

The objective of image compression is to denote the standard input image by shrinking the bulk of data without reducing the quality of regenerated image, regarding the bits. The scope of this scheme is to degrade the size and the quantity and also decodes the image monitored in system which is corresponding to standard image [1]. The image compression, classified into Lossless & Lossy compression techniques. In lossless compression, the data is not lossed while compressing the image, simultaneously it degrades total bits needed to demonstrate the image. In Lossy image compression, the information is lossed while compressing the image again, and the values which were lost are measured by Peak Signal Noise Ratio values (PSNR) [1]. JPEG & JPEG2000 [1] are the well-known standards in Lossy compression scheme. The compression of image is performed in two ways: spatial and frequency domain. In spatial domain, amount of bits is reduced to show the image by assigning on original image directly. The following step in frequency domain includes transformation, quantization and encoding. The transformation has an action of changing the pixels into uncorrelated domain. In transformation coding, image is scattered into short segment and transformation is practiced to each block. The well-known transforms used for compressing the images are Fourier Transformation (FT), Discrete Cosine Transformation (DCT) and Discrete Wavelet transformation (DWT) [1, 2, 17].In these transformation techniques, DCT is based in block orthogonal transformations. DWT [1] is multi-resolution wavelet transformations that provide good space frequency localization and block artifacts are removed. After transformation, quantization is applied to reduce the actual bits and helps to attain enormous compression ratio. In this method, every pixel in image takes lower number of data by decreasing quantity of storage. Quantization is of two types; Scalar Quantization (SQ) & Vector Quantization (VQ). The Scalar Quantization maps the input value (x) into the resultant value (y) using the function (Q).

The Linde-Buzo-Gray (LBG) [10] algorithm is to introduce the design optimal vector quantization and squared-error distortion is minimized. Those set of image vectors are represents as code-words are designed and they shows the image blocks. Typical code words generate the codebook in (VQ). Generally, VQ [4, 5] is classified into following procedures: 1.codebook design procedure, 2.image encoding procedure, and 3.the decoding procedure. Design procedure of code word is done before encoding & decoding the image. Image compression is significant operation that is able to reduce the data for applications such as image storage, taking the reputation in data present in an image. VQ [6, 7] It is frequently used when the compression ratios is high which is required. The transformed image is coded as vectors and the each vectors are then approximated and placed again in code-book through the index. The required data is index for every block of pixels in standard image thus bit rate of transmission is minimized. The main intention of the code-book design technique is used to design the appropriate codebook that is used in image encoding, decoding procedures. Among other algorithms, the LBG [10, 11] algorithm is used for designing codebook when related with ENN [4] algorithm, BPNN [13, 14] algorithm and FBP [4] algorithm. According to encoding procedure, image is separated into set of non-overlapping image blocks of (m x n) pixels. The m x n pixels is arranged in the k-dimensional blocks image, let k is considered as n x n pixels. The neighboring code-word in codebook for the vectorsare resolved. The reduced codes in VQ [6, 7] are basic of nearest code-word for the all the image in codebook. Vectorsincodebook is called as code vectors and it choose to representvectors, which we can produce from the output. Each code vector is in the binary index form. During encoding, the input is relatedwith other code vector to know which is nearest to the given input vector. To instruct the decoder about the code vector, this was founded as the closest input vector, stored in binary index. Since the decoders haveaccurate codebook, it will recover the code-vector denotedin binary index. In this paper the Section [II, B- (i)], codebook design by generalized LBG VQ Algorithm will be discussed. Next, the efficient IDE-LBG Algorithm [V, 5] is discussed.

2. Types of Quantization Techniques in Image Compression

Two types of quantization: Scalar Quantization (SQ) and Vector Quantization (VQ).

2.1. Scalar Quantization

It is general type, it is denoted as x=Q(y) is the method of using quantized function (Q) to map (1D) input value of scalar (x) to an output value (y).Scalar quantization techniques come under the lossy data compression, which means during quantization few data are lost. It is attained by using Uniform scalar and Non-uniform scalar quantization.

The uniform scalar quantization is done by partitioning the given values in equal space interval except the outer interval. It is classified into Midrise and Mid-thread. In Midrise quantization, output levels consists even numbers and in Mid-thread quantization, output levels consists of odd numbers which include zeros.

Let us consider an eight level midrise uniform scalar quantization with the input variable X, where X is continuous sampling/image or discrete sampling/image. If the input values are continuous we have infinite values between the two points and if it is discrete, the finite values can mapped to single value. To define a uniform scalar quantization we need know decision boundary of quantization levels

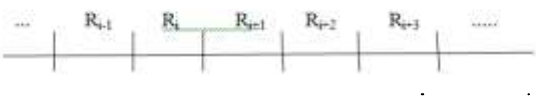
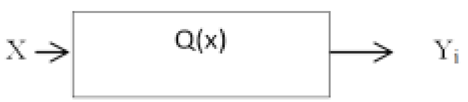


Fig 1: Uniform Scalar Quantization

The level is denoted as $R_{i,}$ the values between quantization levels will be quantized. During quantization the extreme end occurs a high level of errors and middle part occurs low level of errors. Errors are detected by using MSE and PSNR. Let us assume source variable x with decision boundary.



Where di-1<x<di be decision boundary levels and yi be quantization or reconstructed levels.The quantization error is derived using decision boundary with some difference between source image and quantized image of square multiple with the original source. The average rate is measured by using codebook length with decision boundary. The optimum quantization is evaluated by using Max-Lloye quantize algorithm. Non-uniform scalar quantization takes an unequal space levels the spacing is optimized by the Single to the Noise ratio for particular signal. In this quantization we commonly use two companders: µ-law and A-law.

2.2. Vector Quantization

It plays a major part in quantization. VQ is lossy technique;
certain bits can be overlapped with one another. The vector compression has two components: Encoder and Decoder. In this method, image is separated into non-overlapping blocks X= $\{x_0, x_{1......}x_{m-1}\}$ of size 4 x 4 pixels and clustering algorithm. It produces a codebook C= $\{Y_0, Y_{1.......}Y_{N-1}\}$ for setof given image blocks. Codebook C is group of image blocks which are called as code words.

Encoder finds the nearest matching code word in transmitted to decoder and remaining image blocks are encoded by correlation with neighbor blocks. During decoding, it changes the index value with the code-word and forms the quantized image, called reconstructed image.

Vector quantization is vector block coding technique, which is incremental for compressing the image.

Generating a code word, for encoding phase reduces a distortion among the initial image and reconstructed image with reduced computational time.

The size of image (n x n) is quantized, and is sub classified into Nb blocks with n x n, where Nb= (N/n x N/n). These image blocks which are subdivided, consists of size with n x n pixels, represented with Xi , where(i=1, 2, 3, . . ., Nb), where i^{th} code word is represent as Ci where(i=1, 2, . . ., Nc) where Nc is an entire total of code words in codebook. By closest match approach every vector is subdivided and approximately expressed as index of code-words. Similarly for decoding phase the reconstructed image, is appeared by using codebook and translate the index to original code word, then a distortion among original (or) restored image is calculated.

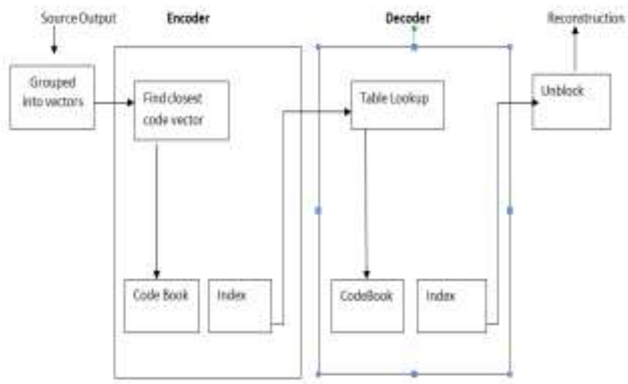


Fig 2: Codebook Design

The procedure for generating a codebook for vector quantization uses the Lloyd-Buzo-Gray Algorithm is:

Step 1: Assume set m = 1, initial distortion ID1=0 and an initial codebook IC1=0 of size N.

Step 2: From the group of coaching vectors one block vector is selected and compared with all code-words from codebook, Cm-1 = {Yi}.

Step 3: Use the condition of nearest neighbor to find closest code-word and at last code-word set is combined

Step 4: Once if all blocks are combined into code words using the step [3], the center of all the code word sets are evaluated to give an improved codebook Cm.

Step 5: Next, the entire distortion of all code-word sets from the respective centroid points is calculated and then next average distortion is mentioned as Dm.

Step 6: If | (Dm-1 - Dm)| = e, the algorithm terminates and the present codebook is recorded as the final answer. Otherwise, m = m + 1, the present codebook is adapted for initial codebook in step [1] and the entire process will be repeated.

LBG Algorithm assures the reduction for distortion with increase in iteration number. But the assurance is not regarding the resulting codebook, whether it becomes optimum or not. It is seen that the initial condition for codebook has significant effect in the results. So the original codebook selection is of prime importance in LBG [4, 5] algorithm. Thus we propose to combine an efficient modified heuristic the improved differential evolution (IDE) with LBG, and the problem initial codebook selection is approached.

3. Block Diagram of Image Compression with Quantization

The representation of the block diagram gives the complete overview of techniques in this process.

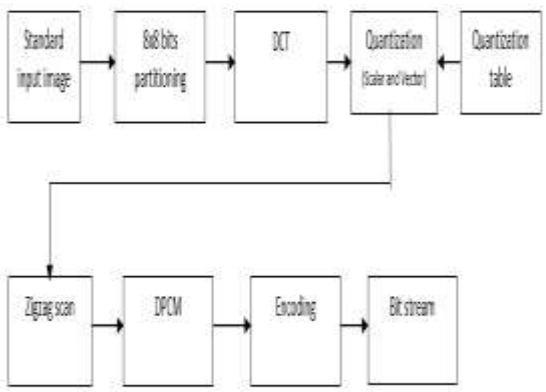


Fig 3: Block diagram of quantization

From the Fig 3, the standard input image is separated into 8x8 bits and transformed into DCT. In DCT [1, 2], the image space is mapped into frequency though it’s an orthogonal transform. Then quantization is accomplished by fetching the values from quantization table. Quantization is separating the transformed DCT image with the help of quantization coefficients. An outcome values from the matrix are rounded off. After quantization, the "zigzag" arrangement orders are quantized by encoding with lower frequencies. After zigzag scanning DPCM [1] is done and it is process of converting analog to digital signal in which a bit stream of image formed.

4. Methodology of Vector Quantization Based Image Compression

Step 1: The standard input image with size of (m x n)
Step 2: The standard image is separated into 8x8 bits Partitioning in gray scale conversion
Step 3: Apply transformation to every block
Step 4: Quantities the values through quantization matrix
Step 5: the quantized matrixes are evaluated in Zigzag order and find the EOB to remove the repeated zero coefficient
Step 6: Apply DPCM to each DC coefficient block
Step 7: Apply an encoding techniques to quantized transformed coefficients and convert it into bit stream

5. Different Types of Algorithms Used in Vector Quantization

5.1. ENN Algorithm

The Equitz Nearest Neighboring algorithm (ENN) [4], produce the small codebook, compared with LBG algorithm. The volume of code word in codebook is denoted as m x n pixels, where n - dimension of image block. This algorithm acquires low computation time and less storage for the codebook.
In ENN Algorithm, convergence time is reduced and the performance is slightly increased when comparing to LBG [10, 11] algorithm, since LBG selects the starting codebook values in random. For the k nearest neighbors’ algorithm, the idea of ENN can be readily extended to predict a continuous value, by the dependent variable’s mean value.

5.2. BPNN Algorithm

The Back Propagation Neural Network (BPNN) [13, 16] algorithm is mainly used for training a neural network with increased performance and it decreased convergence time. It helps to compress an image and it improves the images in the vector quantization. BPNN algorithm classified into three layers: 1. Input layer, 2. Hidden layer, 3. Output layer. An amount ofneurons present in aninput layer will be equal to output layer. The input layer has original block pixels; output layer represents the regenerated image block pixels and hidden layer denotes the code word element which is the 1 – D arrays of neutrons. Few consequences faced when correlated to remaining algorithms the ENN [1, 2], it occurs high training time and high complexity, and it takes less time for generating the codebook.

5.3. FBP Algorithm

The Fast Back Propagation algorithm (FBP) [4] helps for training the BPNN [2] to shorten the convergence time and develop the alternative training criteria. After the earliest adaption cycles, this algorithm is mainly based on reduction of objective function. It requires the similar storage and length of code-book and code-word which is similar to BPNN algorithm. For encoding/decoding process, computational load is lower compared to previous algorithm [4]. The performance is good than others which is been discussed. And it increase by modifying the network itself by changing input layer and hidden layer neurons

5.4. LBG Algorithm

This algorithm is also called as Generalized Lloyd Algorithm (GLA). An improvement of the simple nearest neighbor algorithm in reported in [LBG80], consist of sequence of iteration in which at every step a new quantize it forms a total distortion. The LBG [11, 12] algorithms suppose initial codebook that is in the most case randomly generated.
The algorithm consists in the steps mentioned below:
Step 1: given the starting codebook compute a partition of input space according to m x n condition
Step 2: given the partition computed in step 1, a new codebook is computed according centroid condition. The algorithm exits when the quantized distortion remains unchanged.
The LBG, finally finds an optimum quantized. That quantize depends essentially of initial codebook and is often very far for a required solution a bad initialization could leads to impossibility of finding a good quantize. Relating with above mentioned algorithm such as ENN, BPNN and FBP algorithm [3, 15], this algorithm designs very large codebook, it requires large storage for codebook and it takes huge time for generating the codebook. Convergence time is very high but the performance is not too good.

5.5. IDE-LBG Algorithm

Differential Evolution (DE) is a global optimization technique.It is successfully applied to diverse fields including patterns recognition, communication. In this algorithm we have consumed the DE/Current; we have modified DE to IDE with certain modification in the mutations strategy and boundary control strategy. In mutation strategy, we assume a different scaling factor. The boundary control strategy is improved such that when the limits are crossed based on probability.

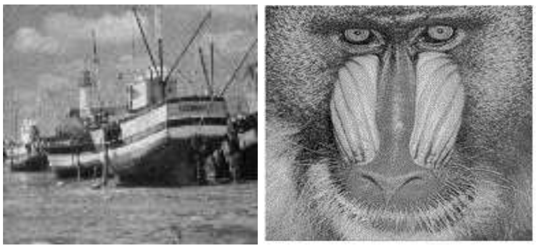
6. Experimental Results

The various vector quantization algorithms has been tested with two sample images viz. Boat and baboon images of size (256 x 256) with pixel values in the range 0-255 are presented in fig 9.1(a) and fig 5.1(b) respectively. The input images are partitioned into non overlapping regions of size (8x8) and are applied with the discrete cosine transform. The transform coefficients are quantized with different quality factors as mentioned, then are reordered in zigzag order. In this proposed scheme, the DC coefficients are subjected to different algorithm techniques, where the DC value of the current block is replaced by taking the difference between current block DC and previous block DC. Finally, all the coefficients converted into a bit stream using the different type of encoding algorithm technique.
In Scalar Quantization, the algorithm achieves a Compressed Ratio (CR) of 93.7% with the PSNR of 26.34 dB for boat image and a CR of 92.46% with PSNR of 24.63 for baboon image, when the quality factor is 10 and the resulting outputs are shown in fig 9.2(a) and (b).
In Vector Quantization, the FBP algorithm achieves a Compression Ratio (CR) of 91.13% with PSNR of 29.81 dB for Boat image and a CR of 90.02% with PSNR of 24.05 dB for baboon image, and resulting outputs are shown in fig 9.3(a) and (b). The BPNN algorithm achieves a Compression Ratio (CR) of 92.53% with PSNR of 26.57 dB for Boat image and a CR of 92.53% with PSNR 23.18 dB for baboon image and resulting outputs are shown in fig 9.4(a) and (b). The proposed algorithm achieves a Compression Ratio (CR) of 92.95% with PSNR of 31.64 dB for Boat image and a CR of 92.72% with PSNR 24.68 dB for baboon image and resulting outputs are shown in fig 9.5(a) and (b). The experimental results of IDE-LBG algorithm are compared with FBP and BPNN, and it shows that, the proposed algorithm gives a very good result of compression ratio with the same quality of PSNR in vector quantization. Hence, the Vector Quantization based IDE-LBG algorithm achieves a good CR and quality of reconstructed image with excellent PSNR values with the quality factor 10.

(a) **(b)**
Fig. 6.1: Original test images (a) Boat and (b) Baboon image

(a) **(b)**
Fig. 6.2: Results of Scalar Quantization when the quality

Factor is 10



(a) **(b)**
Fig. 6.3: Result of FBP algorithm when the qualityfactor is 10

(a) **(b)**
Fig. 6.4: Result of BPNN algorithm when the quality
Factor is 10

(a) **(b)**
Fig. 6.5: Result of IDE-LBG algorithm when the quality
Factor is 10

7. Conclusion

In this paper, we reported about the comparative study of vector quantization in the Image compression among various algorithms and the required codebook.It reduces the distortion with minimum computational time. In this comparative study, LBG algorithm consumes low computation time with low memory, without reducing a quality of resultant image when comparing with algorithms such as FBP, BPNN, and ENN.

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