A Codebook Generation Algorithm in Vector Quantization: A Survey

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Abstract -Vector Quantization is an essential and fundamental technique for lossy image compression; And Codebook generation is very important influence in Vector Quantization.In Vector Quantization the codebook generation algorithm is generally preferred to have minimum distortion between the original image and obtained the reconstructed image.In the past years, many improved algorithms of VQ codebook generation approaches have been developed. In this paper, we present a various techniques of codebook generation. The discussed schemes includes LBG, KPE, KEVR, KEVRW, The Proposed MSE based algorithm. Also discussed quality measures i.e. MSE and PSNR.

Keywords - *Image, Image Compression, Vector Quantization, Codebook Generation Algorithm.*

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I. INTRODUCTION

It's well known fact that today's world has emerged as global village where communication any time anywhere is essential. Internet has become the important for every sphere whether education, industry or entertainment. In every application of computer a digital image is used. This 2-dimentional array consists of images and videos which required huge bandwidth to get effective and efficient transmission of data. The users demand for bandwidth is ever increasing and thus it is essential to find the innovative ways to store and also transmit data. Compression of image could be one such solution to achieve better results. Doing so we reduce the amount of data required for such transmission without hampering the quality of transmission leading to compact image representation. The compression can be effectively achieved by reducing the data redundancies in coding, interpixel and psychovisual areas. By effectively handling such redundancies the number of bits representing the image is reduced through compression methods.The Compression of image can be classified into two types as lossless and lossy.

The original image can be reconstructed exactly in lossless image compression method while only some part of the original image can be recovered in lossy image compression technique. LZW coding, Huffman encoding and run length encoding are lossless image compression methods on the other hand transformation coding, vector quantization and fractal coding belongs to lossy image compression techniques [1].

Quantization is a process of mapping an infinite set of scalar or vector quantities by a finite set of scalar or vector quantities. Quantization has applications in the areas of signal processing, speech processing and Image processing. In speech coding, quantization is required to reduce the number of bits used to represent a sample of speech signal. When less number of bits is used to represent a sample the bit-rate, complexity and memory requirement gets reduced. Quantization results in the loss in the quality of a speech signal, which is undesirable. So a compromise must be made between the reduction in bit-rate and the quality of speech signal.

Two types of quantization techniques exist. They are scalar quantization and vector quantization. "Scalar quantization deals with the quantization of samples on a sample by sample basis", while "vector quantization deals with quantizing the samples in groups called vectors". Vector quantization increases the optimality of a quantizer at the cost of increased computational complexity and memory requirements.

II.VECTOR QUANTIZATION

The vector quantization is a classical quantization technique for signal processing and image compression which allows the modelling of probability density functions by the distribution of prototype vectors. Main use of vector quantization (VQ) is for data compression. It works by dividing a large set of values (vectors) into groups having approximately the same number of points closest to them. Each group is represented by its centroid value, as in k means algorithm and some other algorithms.

The density matching property for vector quantization is powerful, especially in the case for identifying the density of large and high dimensioned data. Since data points are represented by their index to the closest centroid, commonly occurring data have less error and rare data have higher error. Hence VQ is suitable for lossy data compression. It can also be used for lossy data correction and density estimation. The methodology of vector quantization is based on the competitive learning paradigm, hence it is closely related to the self-organizing map model. Vector quantization (VQ) is used for lossy data compression, lossy data correction and density estimation. Finally image decompression, or reconstruction, is achieved by carrying out the above steps in reverse and inverse order.[2]

A. Principle of vector quantization

Vector Quantization assist to project a continuous input space on a discrete output space, while minimizing the loss of information. To define zones in the space, the set of points contained in each zone being projected on a representative vector.

B. Vector quantization in image processing

The methodology used in vector quantization is also called "block quantization" or "pattern matchingquantization" is often used in lossy image compression.

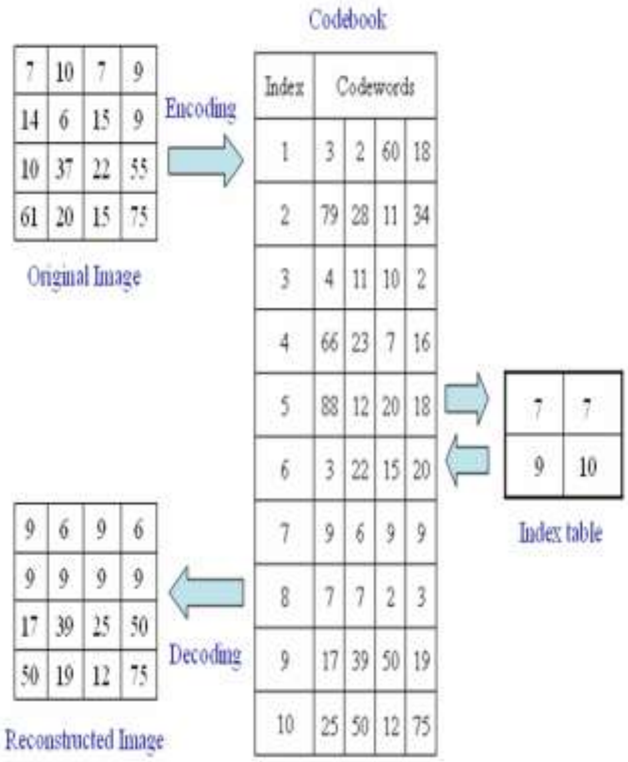

Figure 1.An Example of Encoder and Decoder in VQ

In VQ the given method the image is divided into non overlapping image blocks X = {x0, x1, x2...xm} of size 2 x 2 pixels each. Aclustering algorithm is used to create a codebook C= {Y1, Y2, Y3...Yn} for the given set of image blocks. The codebook C consists of a collection of representative image blocks called code words. 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 code words from the codebook and produces the quantized image, called as reconstructed image[3].

III. CODEBOOK GENERATION ALGORITHM

In this section existing codebook generation algorithms i.e. Linde-Buzo-Gray(LBG) Algorithm, Kekre's Propotionate Error(KPE),Kekre's Error Vector Rotation (KEVR),Kekre's Error Vector Rotation Using Walsh Sequence (KEVRW, and Proposed MSE based Algorithm are discussed. And also discussed the quality measures included in these algorithms.

A. The LBG Algorithm [3]

In 1980, Linde et al. proposed a Generalized Lloyd Algorithm (GLA) which is also called as Linde-Buzo-Gary (LBG)algorithm. The LBG Algorithm starts with the initialization of a codebook which has the random vectorsvector is calculated and then interchange with the code vector. This process runs until the distortion in the codebook between iterations reaches a predetermined number. Let X = (x1, x2….. xk) be a training vector and d(X, C) be the Euclidean distance between any two vectors.

Algorithm Steps:

Step 1: Divide the input image into non overlapping blocks and convert each block into vectors.

Step 2: Randomly generate an initial codebook CB0

Step 3: Initialize I = 0.

Step 4: Perform the following process for each training vector.

• Compute the Euclidean distance between all the training vectors belonging to this cluster and thecodewords in CBI.

$$d\,(X,C) = \sqrt{\sum_{t=0}^{k}(xt - ct)2} \ldots\ldots\ldots\ldots(1)$$

• Compute the centroid (code vector) for the clusters obtained in the above step.

Step 5: Increment I by one and repeat the step 4 for each code vector.

Step 6: Repeat the Step 3 to Step 5 till codebook of desire size is obtained.

B. The KPE Algorithm [4]

Here to generate two code vectors C1 & C2, proportionate error is added to the code vector. Magnitude of elements of the code vector decides the error ratio. Hereafter the procedure is same as that of LBG. While adding proportionate error a safe guard is also introduced so that neither v1 nor v2 go beyond the training vector space.

Algorithm

Step 1: Divide the image into non overlapping blocks and convert each block to vectors thus forming a training vector set.

Step 2: initialize i=1;

Step 3: Compute the centroid (codevector) of this training vector set.

Step 4: Add and subtract error vector ei from the codevector and generate two vector v1 and v2.

Step 5: Compute Euclidean distance between all the training vectors belonging to this cluster and the vectors v1 and v2 and split the cluster into two.

Step 6: Compute the centroid (codevector) for the clusters obtained in the above step 5.

Step 7: increment i by one and repeat step 4 to step 6 for each codevector.

Step 8: Repeat the Step 3 to Step 7 till codebook of desire size is obtained.

C. The KEVR Algorithm [5]

In Kekre's error vector rotation (KEVR) algorithm two vectors v1 and v2 are generated by adding and subtracting error vector to code vector.

First image is divided into non overlapping blocks and each block forms training vector set. Centroid is computed for training vector set and error vector ei is added or subtracted from the code vector and two vector v1 and v2 are generated. The Mean square error between training vector and codeword is computed and v1 and v2 splits in two clusters. This procedure is repeated for the new clusters. This procedure is repeated till codebook of desired size is obtained. KEVR introduces new orientation every time to split the clusters. But in KEVR the error vector sequence is the binary representation of numbers starting from 0 to k-1, so only one bit of error is changed in one iteration.

D. The KEVRW Algorithm [6]

In KEVRW algorithm image is divided into non overlapping blocks which forms training vector of dimension k. It is considered as one cluster and its centroid (mean) represents space first code vector. Then generate n Walsh sequences where codebook size of 2n is required by sampling Walsh function at center of interval. Then add and subtract first Walsh sequence to the first code vector to generate two code vectors. Then calculate Mean Square error between the training vectors in the cluster and the code vector to split the cluster into two. Update the cluster centroid. In the next iteration add and subtract next Walsh sequence to the cluster centroid. The procedure is repeated for each cluster till the codebook of desired size is obtained.

Walsh sequence is used to generate error vector. The Walsh sequences are symmetric in nature and half the number of digits change in successive Walsh sequences. So there is a fast change in cluster orientation. This gives effective clustering.

E. The Proposed MSE based codebook generation algorithm [7]

Codebook generation acts as important role in Vector Quantization (VQ). The codebook is used to encode the image blocks for image compression.

In this proposed algorithm two vectors v1 and v2 are generated by adding error vector to code vector. This error vector is generated using Haar sequence. From the Haar transformation matrix the positive and negative values are replaced respectively with 1's and -1's to obtain the Haar error vector matrix to be used in proposed MSE based HEVR codebook generation algorithm, where each row of Haar error matrix ei for ith row will be error vector to be added and subtracted from the centroid of cluster for dividing into two. Haar sequence consists of a brief positive impulse followed of a brief negative impulse. So there is fast change in cluster orientation. This gives effective clustering.

Step 1: Image is divided into non overlapping blocks.

Step 2: Each block is converted into training vector of dimension k. Initially all vectors are considered to be in one cluster.

Step 3: Its centroid represents first code vector.

Step 4: Generate Haar error vector.

Step 5: Then add and subtract all Haar sequence to the first code vector to generate two code vectors.

Step 6: To form the two clusters using Euclidean distance between the training vectors in the cluster and the code vectors.

Step 7: For newly generated centroids from first code vector MSE will calculated.

Step8: Centroids having minimum MSE will be considered for further processing.

Step 9: Repeat the steps from 5 to 8.

Step10: This process will continue as per the size of codebook.

F. Quality Measure

1. PSNR:PSNR is used to measure the quality of reconstruction of lossy and lossless compression (e.g., for image compression). The signal in this case is the original data, and the noise is the error introduced by compression. When comparing compression codecs, PSNR is an *approximation* to human perception of reconstruction quality. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. PSNR is most easily defined via the mean squared error.PSNR is measured in decibel(dB) [7]

PSNR= $10 \cdot \log_{10}(\frac{MAX_I^2}{MSE})$ ……. (1)

2. MSE: The *Mean Square Error (MSE)* and the *Peak Signal to Noise Ratio (PSNR)* are the two error metrics used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error.

MSE= $\frac{1}{MxN} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [x(i,j) - y(i,j)]^2$ ..(2)

V. CONCLUSION& FUTURE WORK

This paper takes a deep look into the vector quantization, and also study of the existing most significant and commonly used methodologies in vector quantization for image compression. In this paper different existing codebook generation algorithms are discussed. The discussed algorithm includes LBG, KPE, KEVR, KEVRW, MSE based Algorithm. All these algorithms are used to generate efficient codebook in vector quantization.

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