

# Review of Image Compression Techniques using Vector Quantization

Vinit Raut<sup>1</sup>, Pallavi Raut<sup>2</sup>, Sunita Naik<sup>3</sup>, Tatwadarshi Nagarhalli<sup>4</sup>

<sup>1,3,4</sup>Department of Computer Engineering, Viva Institute of Technology, Shirgaon, Virar

<sup>2</sup>Department of Electronics & Telecommunication Engg., SJCEM, Palghar

**Abstract**—This paper presents the review of various algorithms based on vector quantization for image compression. Implementation of Vector quantization for Image compression is divided into three parts i.e. Encoding process, Codebook design, Decoding process. Codebook generation in vector quantization is an important step so that the distortion between the original image and the reconstructed image is minimum. Many efficient algorithms have been developed to reduce the computations and for fast search. This paper discusses various algorithms for the generation of codebook and algorithms for fast search.

**Keywords**— CNN, DCT, Fast search, LBG, VQ

## I. INTRODUCTION

Vector quantization (VQ) is an effective method of data compression. The objective of image compression is to reduce redundant data of the image in order to store or [transmit](#) data efficiently. Image compression can be categorized as [lossy](#) or [lossless](#). Vector Quantization (VQ) is a simple and efficient approach for data compression. Vector quantization is often used to achieve high compression ratios. Lossy compression techniques are based on quantization. Quantization is irreversible process. Scalar quantization and Vector quantization are the important Lossy compression techniques. Quantizing each pixel separately is called scalar quantization. Vector quantization is an approach for quantizing group of pixels together.

Vector quantization is the process of dividing an image into vectors or blocks and each vector is mapped to the codeword's of a codebook to find its reconstructed vector. Each of these vectors is then approximated and replaced by the index of one of the elements of the codebook. Codebook generation, encoding procedure and decoding procedure are the major procedures in Vector Quantization. The goal of the codebook design procedure is to design the desired codebook that is to be used in the image encoding/decoding procedures.

In VQ an original image of size  $N \times N$  is divided into blocks of size  $n \times n$ . Therefore total numbers of blocks are  $n_b = (N/n) \times (N/n)$ .  $n_b$  is known as input vectors as  $X = (X_1, X_2, \dots, X_{n_b})$ ,  $C = (C_1, C_2, \dots, C_{n_c})$  is known as codebook in which  $n_c$  indicates the total number of codevectors. Vector quantization is the process of mapping each input vector to the one of the codevector from the codebook. Mapping is based upon the minimum distance criterion i.e by finding out Euclidian distance. The closest codeword [1] in the codebook for each image vector is to be determined. The compressed codes of VQ are the indices of the closest codewords in the codebook for all the image blocks.

One of the main issues of VQ encoding is to reduce the computational complexity from searching the best matched codeword in order to reduce the search time. Many efficient algorithms have been developed to reduce the computation load.

The paper is organized as follows: Section II gives various codebook generation algorithms. Section III describes various search algorithms and section IV gives the concluding remarks.

## II. CODEBOOK GENERATION ALGORITHMS

### A. LBG [2][3]

A LBG algorithm for codebook design is an iterative procedure. The procedure for a codebook generation is given as follows:

1: First step is to generate random codebook CB0.

2:  $i = 0$ .

3: Following process is applied for each input vector.

- Compute the Euclidean distances between the training vector and the codewords in C<sub>B<sub>i</sub></sub>. The Euclidean distance is defined as

$$d(X,C)=\sqrt{\sum_{t=1}^k(X_t - C_t)^2} \quad (1)$$

- Search the nearest codeword from C<sub>B<sub>i</sub></sub>.

4: Partition the codebook into N cells.

5: Compute the centroid to obtain the new codebook C<sub>B<sub>i</sub>+1</sub>.

6: Compute the average distortion for C<sub>B<sub>i</sub>+1</sub>. If it is changed by a small amount since the last iteration, and the procedure stops.

Otherwise,  $i = i + 1$  and go to Step 3.

LBG is an easy and rapid algorithm. In LBG algorithm the resulted codebook quality depends on the initial codebook. If the initial codebook is not proper then it produces a distortion in the reconstructed image.

This algorithm generates very large codebook. It requires large storage space for codebook. It takes a long time for the generation of the codebook. A complete design of this algorithm requires a large number of computations. Convergence time is very large.

#### B. PNN [4]

In Pairwise Nearest Neighbor method first codebook of size N is initialized, where each input vector is considered as its own codevector. In each step two codevectors are merged and this process is repeated till codebook reduces to size M. Main drawback of PNN is its slowness because implementation require a lot time. The Pairwise Nearest Neighbor (PNN) algorithm is an alternative method to the LBG algorithm for generating codebooks.

#### C. CNN-ART

Lin and Yu in 2003[5] proposed a centroid neural network adaptive resonance theory (CNN-ART) algorithm for the generation of codebook. The CNN-ART algorithm contains of an input layer and an output layer. The total number of neurons in the input layer is the same as the total number of dimension of the input vectors. Each neuron in the input layer has connections to the neurons in the output layer. Codewords from the codebook are equal to the total number of neurons in the output layer. Centroid of the first neuron will act as the first input training vector X<sub>1</sub> and after that then the next input vector is compared to the neuron. If the Euclidean distance between the neuron and the next vector is higher than a predefined threshold, the input vector forms the centroid of a new neuron. The procedure is repeated for all the training vectors.

#### D. LBG with DCT [6][7]

This paper uses a DCT (Discrete cosine Transform) and LBG to construct a codebook. In this the input image is divided into blocks or subimages and then DCT coefficients of blocks are calculated and quantized. Next step is generate a codebook using LBG in DCT domain. Applying LBG algorithm in the frequency domain reduces distortion in the reconstructed image. For each input vector a codeword is selected from the codebook. Index metrics indicates the corresponding block codeword. By using this algorithm improvement in the PSNR values as well as higher compression ratio is achieved.

### III. SEARCH ALGORITHMS

#### A. FSA [8]

Full search algorithm needs to compute the Euclidian distance between the input vector and all codewords from the codebook and then these distances are compared to find minimum distance. Therefore computational complexity of FSA limits the application of VQ in compression.

**B. Mean-distance-ordered Partial Codebook Search (MPS) [9]**

Ra and Kim proposed a fast mean-distance-ordered partial codebook search algorithm in 1993. The codevectors are sorted according to their mean. The search is continued for the codevector having minimum Euclidian distance to a given input vector. They used squared mean distance (SMD) to filter false candidate codewords.

The definition of Squared Mean distance (SMD) is

$$dSMD(X,C) = (\sum_{t=1}^k X_t - \sum_{t=1}^k C_t)^2 \tag{2}$$

In their scheme, if the codeword C whose

$$|\sum_{t=1}^k X_t - \sum_{t=1}^k C_t| > \sqrt{kd(X, C_{min})} \tag{3}$$

then it will not be the nearest neighbor for input vector X.

In other words, its Squared mean distance (SMD) is larger than the Euclidean distance,  $dSMD(X,C) \geq d(X,C_{min})$  is the Euclidean distance between X and the tentative matching codeword which has minimum  $|\sum_{t=1}^k X_t - \sum_{t=1}^k C_t|$  in the current stage.

**C. ENN [10]**

The equal average nearest neighbor (ENN) searching algorithm makes use of the mean of an input image vector to search the nearest codevector. This algorithm uses following inequality to reject the codevectors,

$$|m_x - m_{y_j}| \geq \sqrt{d_{min}/k} \tag{4}$$

If above inequality is satisfied then  $d(x, y_j) \geq d_{min}$ , then that codeword  $y_j$  is rejected. Mean of the vectors can be obtained by offline computation. This algorithm reduces the computation time as compared with the FSA.

**D. EENNS [11]**

EENNS algorithm uses the variance to reject the codevectors. It uses following inequality,

$$|V_x - V_{y_j}| \geq \sqrt{d_{min}} \tag{5}$$

If above inequality is satisfied then  $y_j$  will not be the nearest codevector.

If above variance inequality of EENNS or the mean inequality of ENNS is satisfied then  $d(x,y_j) \geq d_{min}$ , then reject the codevector  $Y_j$ .

**E. IENNS and IEENNS [12,13]**

Both improved ENNS (IENNS) and improved EENNS (IEENNS) algorithms are based on subvectors. In which k-dimensional input vector is divided into two  $k/2$ - dimensional subvectors.

$$X_f = (X_1, X_2, \dots, X_{k/2}) \text{ and } X_s = (X_{k/2+1}, X_{k/2+2}, \dots, X_k)$$

Similarly codevector  $y_j$  is also divided into two subvectors as,

$$Y_{jf} = (Y_{j1}, Y_{j2} \dots Y_{jk/2}) \text{ and}$$

$$Y_{js} = (Y_{jk/2+1}, Y_{jk/2+2} \dots Y_{jk})$$

The Sum and Variances for all subvectors of input vector  $X_i$  and codevector  $Y_j$  are calculated as given in equations (6) and (7) respectively.

$$S_x = \sum_{i=1}^k X_i \tag{6}$$

$$S_{xf} = \sum_{i=1}^{k/2} X_i \quad S_{xs} = \sum_{i=k/2}^k X_i$$

$$S_{Y_j} = \sum_{i=1}^k Y_{j,i}$$

$$\begin{aligned}
 SY_{j,f} &= \sum_{i=1}^{k/2} Y_{j,i} & SY_{j,s} &= \sum_{i=1}^{k/2} Y_{j,i} \\
 V_x &= \sqrt{\sum_{i=1}^k (X_i - S_x/k)^2} \\
 V_{Y_j} &= \sqrt{\sum_{i=1}^k (Y_{j,i} - S_{y,j}/k)^2} \\
 V_{xf} &= \sqrt{\sum_{i=1}^{k/2} (X_i - 2S_{xf}/k)^2} \\
 V_{xs} &= \sqrt{\sum_{i=1}^{k/2} (X_i - 2S_{xs}/k)^2} \\
 V_{Y_{j,f}} &= \sqrt{\sum_{i=1}^k (Y_{j,i} - 2S_{y,j,f}/k)^2} \\
 V_{Y_{j,s}} &= \sqrt{\sum_{i=1}^k (Y_{j,i} - 2S_{y,j,s}/k)^2}
 \end{aligned} \tag{7}$$

IEENNS uses following inequality to reject the codevectors.

$$\begin{aligned}
 (S_x - S_y)^2 &\geq kd_{mi} \\
 (S_{xf} - S_{yf})^2 &\geq (k/2)d_{min} \\
 (S_{xs} - S_{ys})^2 &\geq (k/2)d_{min}
 \end{aligned} \tag{8}$$

IEENNS uses following inequality to reject the codevectors.

$$\begin{aligned}
 (S_x - S_y)^2 + k(V_x - V_y)^2 &\geq kd_{min} \\
 (S_{xf} - S_{yf})^2 + (k/2)(V_{xf} - V_{yf})^2 &\geq (k/2)d_{min} \\
 (S_{xs} - S_{ys})^2 + (k/2)(V_{xs} - V_{ys})^2 &\geq (k/2)d_{min}
 \end{aligned} \tag{9}$$

#### IV. CONCLUSION

Various algorithms for Image compression using vector quantization are discussed here. One of the key point in the image compression using vector quantization is to design a codebook such that the distortion between the original image and the reconstructed image is the minimum. If the designed codebook is random then reconstructed image contains more distortion, therefore our main aim is to design a proper codebook for the given input image. Fast search algorithms reduces the searching time for codevector from the codebook. Further the performance of the vector quantized can be improved by combining the most suited methods of codebook generation and best suited fast search algorithm.

#### REFERENCES

- [1] LEE C.H., CHEN L.H.: "Fast closest codeword search algorithm for vector quantization", IEE Proc Vis. Image Signal Process., 1994, vol. 141(3), pp. 143-148.
- [2] B Y. Linde, A. Buzo, and R. M. Gray, "An algorithm for vector quantizer design," IEEE Trans. Communications", vol. -28, no. 1, pp. 84-95, 1980.
- [3] N. M. Nasrabadi, Y. Feng, "Image compression using address vector quantization", IEEE Trans. Comm. vol. 38 No. 12, pp. 2166-2173, 1990.
- [4] C. M. Huang and R. W. Harris, "A Comparison of Several Vector Quantization Codebook generation Approaches", IEEE Trans. Image Processing, vol. 2, no. 1, pp. 108-112, 1993.
- [5] T. C. Lin and P. T. Yu, "Centroid Neural Network Adaptive Resonance Theory for Vector Quantization, *Signal Processing*", vol. 83, pp. 649-654, 2003.

- [6] Mahmood Shabanifard and Mahrokh G. Shayesteh, "A New Image Compression Method Based on LBG Algorithm in DCT Domain", IEEE transactions, 2011.
- [7] Pallavi N. Save and Vishakha Kelkar, "An Improved Image Compression Method using LBG with DCT", IJERT Journal, Volume-3, Issue-06, June-2014.
- [8] C.M. Huang, Q. Bi, G.S. Stiles, & R.W. Harris, "Fast full search equivalent encoding algorithms for image compression using vector quantization", IEEE Transactions on Image Processing, vol. 1(3), 1992, 413–416.
- [9] S. W. Ra and J. K. Kim, "A Fast Mean-Distance-Ordered Partial Codebook Search Algorithm for Image Vector Quantization", IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing, vol. 40, no. 9, pp. 576-579, 1993.
- [10] QIAN S. E., "Fast vector quantization algorithms based on nearest partition set search", IEEE Transactions on Image Processing, 2006, 15, (8), pp. 2422–2430.
- [11] BAEK S.J., JEON B.K., SUNG K.M.: "A fast encoding algorithm for vector quantization", IEEE Signal Processing Letters, 1997, vol. 4(12), pp. 325–327.
- [12] C. Wang and C. Tung, "Fast search algorithm for vector quantization using dynamic subvectors", Optical Engineering, vol. 45(9), 097004, (September 26, 2006).
- [13] Pallavi N. Save and Vishakha Kelkar, "An Improved Image Compression Method using Vector Quantization for Color Images", International Conference on Communication Technology (ICCT-2015).