



VECTOR QUANTIZATION AND LZW BASED LOSSY IMAGE COMPRESSION

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Abstract: This research paper presents a combined approach to Lossy image compression algorithm, based on wavelet transform, Global thresholding, Vector quantization and Source coding like Huffman coding and LZW coding. In this image compression algorithm, discrete wavelet transform (DWT) is applied on input image, which decomposes the input image into a sequence of wavelet coefficients. Global thresholding is used to modify the wavelet coefficients image. Resultant coefficients after thresholding are quantized using vector quantization technique and later, VQ indices are coded using LZW coding to increase the compression ratio. Main goal of proposed work is to lower the execution and transmission time with maintaining higher values of CR and PSNR for various images. Proposed algorithm is applied on various images and results are analyzed using performance CR, PSNR, MSE and SSIM for image quality and its performance has been compared with the already existing methods.

Keywords: Discrete wavelet transform (DWT); Vector quantization (VQ); Image compression (IC), Peak signal to noise ratio (PSNR); Mean square error (MSE).

I. INTRODUCTION

Image compression (IC) has been a remarkable a real challenging field and had been for many years due to its unremittingly increasing necessity in transfer and storage of data. [2] The motto of IC is to reduce the amount of data required to represent a digital image. Thus, IC is quite necessary. There are two ways of image compressions: (1) Lossless IC and (2) Lossy IC (LIC). LIC methods are suitable in case where the exact recovery of an image is not expected [1].

Discrete cosine transform (DCT), Vector Quantization (VQ) [13] and Discrete Wavelet Transform (DWT) are widely used methods for image compression. DCT presents blocky artifacts in the reconstructed image, which are not necessary and pleasing to the eyes. In STFT once window is selected, it remains uniform for all frequencies. So, it gives a constant resolution at all frequencies. Compared to other conventional techniques, wavelet based compression gives enhanced performance.

Wavelet transform allow multi-resolution analysis of an image, using these technique different frequencies can be analyzed with different resolutions. It provides a time-frequency representation of the signal. [6] In any wavelet based image compression scheme, the attainable compression ratio not only depends on the efficiency of the coding scheme; but dependent on the choice of appropriate wavelet filters. Compression ratios also depend on different filters even for the same image and coding scheme. It is an engineering compromise to carry out the choice of appropriate filters for our compression scheme.

The main application of IC is to overcome the problem of storage requirement with maintaining image quality up to acceptable [2]. Wavelet Transform and Vector quantization (VQ) is one of the popular IC techniques for its simplicity at receiver and it can reduce the number of bit requirement in image along with achieving enhanced quality of image. [1]

LIC algorithm gives higher CR with better picture quality. It also overcomes the problems of low resolution and high computational complexity for different satellite and medical images. In Vector Quantization, by selecting proper value of cluster size and codebook, proposed work can improve the performance of lossy image compression algorithm. In vector quantization, algorithm performance improved but processing time also increased if we increase codebook size and cluster size [1]. This research paper presents vector quantization based algorithm which have a more improvement on lossy image compression.

The presented algorithm gives better performance, which is applicable to all kind of images. [1] The proposed algorithm for lossy image compression is appropriate to digital images which are used in criminal investigations, medical imaging, etc. [1]

II. PROPOSED APPROACH:

This work represents an effective Lossy image compression algorithm to minimize the number of bit requirement in image with the combination of the wavelet transform [10], Global Thresholding (GT), Vector quantization and Source coding like Huffman coding and LZW coding.

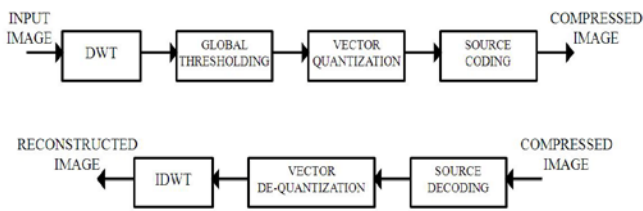


Figure 1.1 Block diagram of the proposed algorithm

Figure 1.1 presents the description of the proposed work. In this proposed work, first DWT is applied on input image [7], which decomposes the image into the coefficients of wavelet. [11] In WT, inter-pixel redundancy is reduced to achieve higher image compression.

Mother Wavelet is defined as a single basis function which is generated using wavelet coefficients. It is only a primary form of generating other necessary window functions. It is fractioned by a multiple of (1/a) and origin is shifted by a value of b as given below.

$$\Psi_{a,b} = \left(\frac{1}{\sqrt{|a|}}\right) \Psi((t - b)/a) \dots (1)$$

Where, variables a and b are any two real numbers which are not same. 'a' represents the dilations and 'b' represents the translations which are relative to the time axis. The variable 'a' reduces $\Psi(t)$ in the time axis for the values of a less than 1 and increases when a is greater than 1, therefore 'a' is considered as the fraction variable. Analytically, when time t is shifted by an amount (t - b), it causes a translation in the time axis.

Image compression using DWT is accomplished by obtaining two separate 1-D transform. Input image is low pass and high pass filtered along row or x-axis, then it is down sampled by two along the row or x-axis. As a result, FL (low frequency) image and FH (high frequency) image is generated. Then FL and FH image is low pass and high pass filtered along column or y-axis, after this operation it is down sampled by two along the x and y axis. As a result, FLH, FLL, FHH and FHL image is generated. In Discrete Wavelet Transform, redundancy between neighboring is reduced. It is a reversible process. In the proposed work, best wavelet has been selected for generating wavelet co-efficient based on performance of various wavelet filters and their order. Results of proposed algorithm have been tested using performance parameters like CR, PSNR and SSIM. As compared to DCT, wavelet transform gives better energy compaction [1]. Due to higher energy compaction of wavelet, most of the energy in wavelet is represented by only few coefficients, which gives higher compression ratio as compared to other transform like DCT and FT.

In thresholding and vector quantization, psychovisual redundancy is reduced to achieve higher image compression. Generally, image contains many of the wavelet coefficients that are clustered near to zero. GT is applied to change these coefficients in such a way the coefficients of wavelet which contain long strings of zeros. [11] In any GT wavelet coefficients whose absolute value falls below the selected threshold is set to zero and all the wavelet coefficients above threshold are retained. [8] The main goal of global thresholding

is to introduce many zeros without losing the larger amount of detail as compared to other existing thresholding techniques. GT is applicable to alter the wavelet coefficients to another sequence and it is irreversible. Resultant coefficients after thresholding are quantized using vector quantization technique. VQ is highly strong and conventional quantization technique for Lossy image compression [1]. VQ is irreversible process and reduces the psycho-visual redundancies.

In VQ $M \times N$ pixels, where M and N is number of pixels in X and Y dimensions of input Image respectively and it is power of 2. Then resize the input image into $C \times D$ blocks. Where C and D are number of pixels in X and Y dimensions of Blocks and both are power of 2. The Euclidean distance of all code words in the code book is calculated by this vector. This calculation has been equated in Eq. (1). [13] Then the closest CW (codeword) is found, and the index value of this CW is assigned to the entire block. At the end, get table of index that can have 32×32 indices [1]. In the reconstruction phase, we can use this table of index to calculate the CW from the codebook. Then, reproduce the vectors of block and restore the image according to equation mentioned below.

$$d(B, C_i) = \sqrt{\sum_{j=0}^{k-1} (B_j - C_{i,j})^2} \dots (2) [1]$$

Where, d = Euclidean distance, B is block's vector, C_i is the i^{th} index codeword in the codebook, k is the dimension of vectors. [13]

After this, VQ generates N training vectors. Where, $N = ((M \times M) / C \times D)$. Then fix the codebook size to n. [9] where, n is power of 2. At the end calculate $P = N/n$ and choose each P^{th} training vector as a code word vector until the required size of codebook is reached. [1] After VQ discrete values are source encoded using Huffman codes or LZW codes. [12]. Proposed work implements the mapping of the set of VQ coefficients to the set of symbols so that the total bits requirement per symbol could be minimized. [1] The encoding process is carried out based on the probability of the quantized coefficients. In this proposed work, Huffman or LZW encoding is used, which reduces the coding redundancy as compared to other existing source coding techniques. Substantial decrease of number of bits can be seen by optimization of the LZW codes. [4]

In image decompression, the reconstruction of the input image is carried out from the compressed image. First source decoding namely Huffman decoding and LZW decoding is applied on compressed image. The resultant image after source decoding is vector de-quantization, which is irreversible operation, so it introduces loss in reconstructed Image. Vector de-quantization output coefficients are applied to inverse DWT for reconstruction of input image, which is represented in spatial domain. DWT is reversible operation, so it does not loss information in image.

III. MEASURES OF IMAGE COMPRESSION TECHNIQUE:

Measurement has been carried out based on standard measuring criteria like CR, MSE and SSIM. These parameters are defined as follows:

A. Compression Ratio:

$$CR = \frac{n1}{n2} \dots (3)$$

B. Mean Square Error:

$$MSE = \frac{1}{M \times N} \sum_{x=1}^M \sum_{y=1}^N [f(x,y) - f'(x,y)]^2 \dots (4)$$

C. Structural Similarity Index Measurement [3]:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \dots (5)$$

Where, C1 and C2 are constant and equal to unity.

In case of same images, SSIM remains as 1. Accordingly, if the value of SSIM comes closer to 1, it would typically specify better image quality. [3]

IV. SIMULATION RESULTS:

This research paper presents a proposed work is carried out based on Haar wavelet and VQ techniques. Images for test are considered from the example of cameraman (256 X 256) and Lena (256 X 256) by applying LZW coding. The observation result is as shown in figure 1.2 and figure 1.3. The measurement parameters are PSNR, CR, MSE and SSIM for various size of cluster and codebook of VQ.

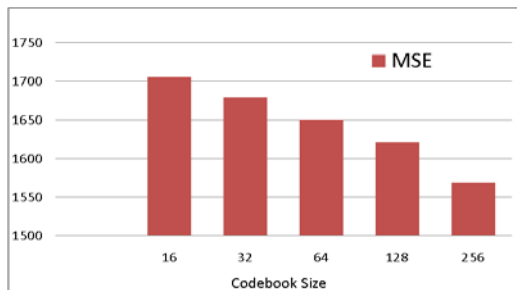


Figure 1.2: MSE for Cluster size (4x4) and various size of codebook for CAMERAMAN image

Figure 1.2 represents the MSE by using cluster size (4x4) and various size of codebook for CAMERAMAN image. These results are for various codebook size of Vector Quantization, Haar wavelet, decomposition Level-1 and LZW coding techniques. From these results, it is concluded that as codebook size increases, MSE decreases, so as a result reconstructed image quality is improved.

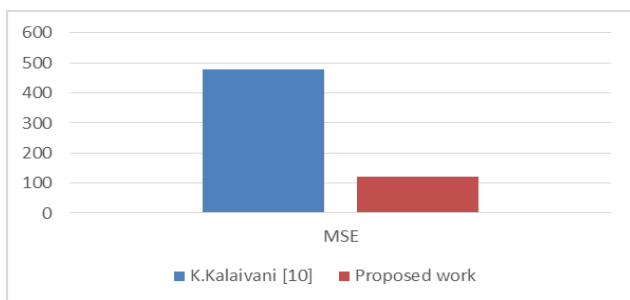


Figure 1.3: comparisons of proposed work with reference paper using MSE for Lena image

Figure 1.3 represents the comparisons of proposed work with reference paper using MSE for Lena Image. Results of the

proposed work are simulated using the Vector Quantization and LZW coding techniques. From these results it is observed that proposed work gives better performance as compared to the existing works done by K. Kalaivani [10] in terms of both PSNR and CR.

V. CONCLUSION:

This paper compares the performance of proposed work with already existing methods using various parameters like CR, PSNR, MSE, and SSIM. The major focus is to implement the IC algorithms intended for the lossy image compression which is applicable to variety of images. The proposed work has attained outstanding enhancement in the performance as compared to existing techniques. The CR is significantly improved, but it is found that the PSNR is reduced, this eventually conclude that the purpose of proposed work for that area of IC which requires improved quality of images.. Future work on this image compression may include the implementation of an effective codebook and the wavelet based tree structure, the computation time can be reduced more.

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