A Hybrid Approach to Compress Still Images using Wavelets and Vector Quantization

S. Vimala, P. Usha Rani, J. Anitha Joseph

Abstract- This paper presents a hybrid technique for compression using Wavelet and Vector Quantization (VQ). Wavelet is a technique for representing the image into various degrees of resolution. The input image of size 256 *256 pixels is divided into 4 sub-bands named LL, HL, LH, HH by applying Discrete Wavelet Transform. Vector Quantization is then applied for the lower sub band (LL). The size of lower sub-band is 128*128 pixels. VQ is a lossy image compression technique used to have improved coding efficiency. In the proposed study, the different types of wavelets such as Haar Wavelet, Coiflet Wavelet, Symlet Wavelet, Daubechies Wavelet and Bioorthogonal Wavelet are applied to the input images and the respective lower bands are then subjected to Vector Quantization in the Encoding process. The compressed image is then transmitted or stored in the form of Codebook and the Index Map, which are the outcomes of VQ. In the decoding phase, an image of size 128 x 128 pixels is reconstructed from the stored/transmitted Codebook and Index map. The reconstructed image is then subjected to Inverse DWT to get an output image of size 256 x 256 pixels. Standard images such as Lena, Baboon, Boats, Bridge and Cameraman are used to test the performance of the proposed method. With all the wavelets, the proposed technique leads to better compression ratio without losing the visual effect.

Keywords: image compression, wavelet, vector quantization, haar, coiflet, symlet, daubechies, bioorthogonal.

I. INTRODUCTION

Digital images take a large amount of storage and bandwidth while being transmitted over the internet. By using compression techniques, the redundant pixels are removed effectively to reduce the required storage and bandwidth. The images are compressed exploiting the inter pixel redundancy feature of images. There are two types of compression techniques: Lossy and Lossless compression.

With lossless techniques, the original image can be recovered accurately from the compressed image [1]. Lossy compression leads to loss of information [2] without affecting the visual effect of the compressed images.

This paper presents a hybrid technique of combining Wavelet and Vector Quantization to compress gray scale images. The initial step of the proposed method is applying Discrete Wavelet Transform over the input image [3]. The output will be four sub-bands namely LL, HL, LH and HH. The lower sub-band LL contains the high frequency details of the image and this LL sub-band is then compressed using a lossy compression technique called Vector Quantization.

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In VQ, quantization is performed on a set of scalar values (coefficients). One of the most widely used techniques for lossy compression is Vector Quantization, which is used for reducing the bit rate effectively, less than one bit per pixel (bpp) [4]. In Vector Quantization, the data to be encoded are divided into blocks which are size 4 x 4 pixels. Each image is encoded by vector by vector. VQ comprises of three stages: 1. Codebook Generation, 2. Image Encoding and Image Decoding. The compression model of the proposed method is given in Fig. 1[5].

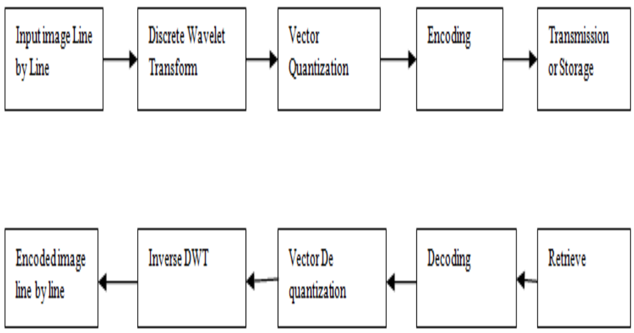

Fig. 1. Wavelet Based Image Compression and Decompression using VQ

Need for Wavelet:

Often signals we wish to process are in the time-domain, but in order to process them more easily other information, such as frequency, is required [6]. Wavelet analysis can be used to divide the information of an image into approximation and detail sub signals. The approximation sub signal shows the general trend of pixel values, and three detail sub signals show the vertical, horizontal and diagonal details or changes in the image [6]. It is enough to retain the detail sub signals alone for the image thus leading to compression.

Wavelet: Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions [7]. A wavelet means a small wave (the sinusoids used in Fourier analysis are big waves) and in brief, a wavelet is an oscillation that decays quickly.

[8] Wavelets are applied in Signal Processing, Data Compression, Smoothing and image denoising, Fingerprint verification, DNA Analysis, Speech Recognition, Computer Graphics and Multifractal Analysis. The original image is given as input to the Wavelet Transform and the outcomes of the wavelet are four sub bands namely LL, HL, LH and HH.

LL - Low frequency sub band.

HL - High frequency sub band.

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LH - High frequency sub band of the vertical details of the image.
HH - High frequency sub-band of the diagonal details of the image.

To get the fine details of the image, the image can be decomposed into many levels. A first level of decomposition of image is given in Fig.2.

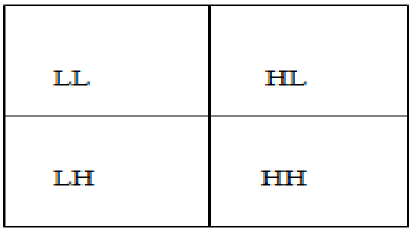

Fig. 2. First level Wavelet Decomposition

There are different types [9] of wavelets such as Haar Wavelet, Coieflet Wavelet, Symlet Wavelet, Daubechies Wavelet and Biorthogonal wavelet. In this paper, the input images are transformed using all the aforementioned wavelets and the LL bands of all these wavelets become the input image for Vector Quantization.

Vector quantization (VQ) is an efficient image coding technique achieving low bit rates i.e. lower than one bit per pixel (bpp) [10]. In VQ, the image to be compressed is divided into non-over lapping square blocks of size 4 x 4 pixels which are converted into vectors with dimensions 1 x k, where, k=16. By increasing the block size, quantization process is more efficient [11]. Also VQ variants can give high compression ratios with competitive Peak Signal to Noise Ratio (PSNR) [12].

VQ consists of two steps: Encoding and Decoding. In the encoding process, each input image vector is mapped onto a single value which is the index of the closest code vector in the codebook according to the nearest neighbor rule [12]. In the decoding phase, the index is replaced with the corresponding codevector to form the reconstructed image [13]. The image thus reconstructed will be an approximation of the original image but not exactly the same. Hence VQ is said to be, it is suitable for lossy image compression technique [3]. The process of VQ is depicted in Fig. 3.

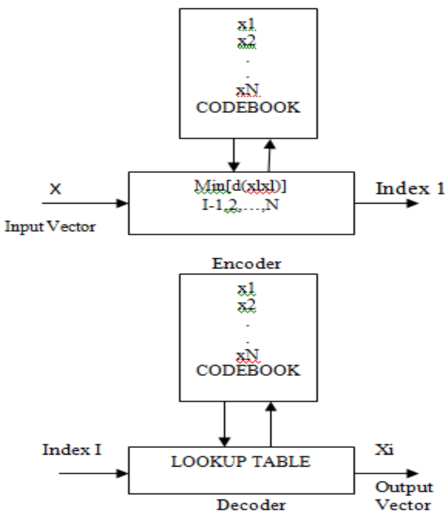

Fig. 3.Block diagram of VQ

II. PROPOSED WORK

Discrete Wavelet Transform (DWT) is applied over the input image. The LL band becomes the input image I (128 x 128) for VQ. The image I is divided into N blocks of size 4 x 4 pixels using (1).

$$N= (n*n)/16 \tag{1}$$

Where ***n*** is the size of the image. Each block is converted in to training vectors to form the Training Set (TS). Training vectors at every P^{th} position are selected to form the Codebook (CB), where P is computed using (2).

$$P=N/M \tag{2}$$

Where N is the size of the training set and M is the size of codebook.

$$d\,(X_{ij}, Y_j) = \sum_{j=1}^{16} abs(X_{ij} - Y_j) \tag{3}$$

Where 1 <= i <= M, X_i is the i^{th} codevector and Y is the current training vector.

The index of the code vector with which the minimum distance is computed is identified for that input vector. The collection of such indices for the entire TS is called the Index Map (IM). As a result of the encoding process, the compressed image in the form of IM and CB is either stored or transmitted. In the decoding stage, every index is coded with the respective code vector to reconstruct the compressed image.
The difference between the original and the reconstructed image is Mean Square Error (MSE) is calculated using (4).

$$MSE=\frac{1}{N}\sum_{i=1}^{N}(I - I') \tag{4}$$

The quality of the reconstructed image called the Peak Signal to Noise Ratio (PSNR) is computed using (5).

$$PSNR=10Log\ (Image\ size/\ MSE) \tag{5}$$

Encoding Algorithm
Step1: Apply DWT over the input image.
Step2: The lower band LL is subjected to VQ
Step2.1: Codebook CB and IM are generated
Step3: The set {CB, IM} is stored/ transmitted.

Decoding Algorithm
Step1:The indices in the IM are replaced with the respective codevectors to reconstruct the image RI.
Step2: RI is passed as the lower band LL to Inverse DWT.

III. RESULTS AND DISCUSSION

The proposed method is tested with some standard grayscale images: Cameraman, Lena, Boat, Bridge, Pepper and Barbara of size 256 x 256 pixels. The input images are shown in Fig. 4. The work is implemented using Matlab 7.0 on Windows Operating system. The hardware used is the Intel Core i5 processor with 4 GB RAM. The simulated results in terms of PSNR and bpp are given in Table.I.

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Fig. 4.Input images

Table.I. Results in terms of PSNR and bpp of the Reconstructed Image.

CB Size		128					
Images		Camer a Man	Lena	Boat	Bridge	Pepp er	Bar bara
Haar	PSNR	19.18	18.60	19.03	19.58	19.26	19.38
	Bpp	0.37	0.37	0.37	0.37	0.37	0.37
Coif 2	PSNR	19.12	18.57	19.08	19.49	19.24	19.30
	Bpp	0.37	0.37	0.37	0.37	0.37	0.37
Sym 2	PSNR	19.16	18.58	19.04	19.55	19.28	19.37
	Bpp	0.37	0.37	0.37	0.37	0.37	0.37
Db4	PSNR	19.12	18.60	19.00	19.50	19.25	19.31
	Bpp	0.37	0.37	0.37	0.37	0.37	0.37
Bior 1.1	PSNR	19.18	18.60	19.03	19.58	19.26	19.38
	Bpp	0.37	0.37	0.37	0.37	0.37	0.37

In Table I, the results generated with the proposed method in terms of PSNR and bpp are given. The PSNR obtained with Haar Wavelet and Bio orthogonal Wavelets are better when compared to that of other Wavelets. But the difference is very less. But the bpp obtained is only 0.37. The images compressed using various wavelets are given in Fig. 5. The reconstructed image obtained with the proposed method is compared with that of the reconstructed images of and are given in Fig. 6. The images in the existing method are compressed only using VQ where the bpp obtained are 0.59, 0 0.69, 1.88 and 2.63. But the bpp obtained with the proposed method is only 0.37. For visual comparison, the images obtained by the proposed method are more effective when compared to that of the existing methods using VQ even though the PSNR is high when compared to that of the proposed method.

Fig. 5: Reconstructed images compressed using various Wavelet and VQ

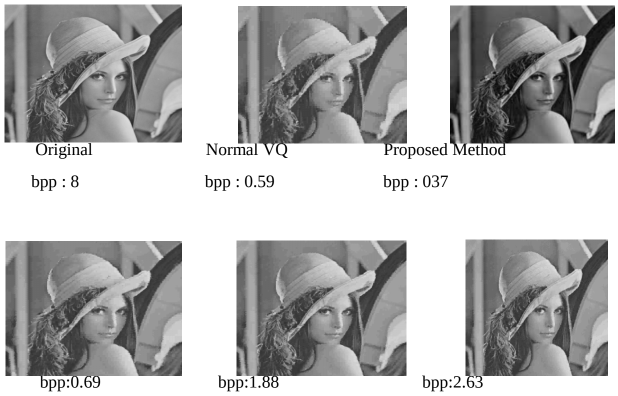

Fig. 6: Reconstructed images with the existing and proposed methods.

IV. CONCLUSION

Normal Vector Quantization, when incorporated with Wavelet Transform achieves better coding efficiency when compared to that of exiting VQ techniques. A bpp of 0.37 is obtained with the proposed method. Generally, when the bpp is reduced, the quality of the reconstructed image will also be reduced. But with the proposed method, the wavelet is used to extract the fine details of the image. VQ is then applied to further reduce the bit rate. In the decoding stage, the vector quantized image is subjected to inverse wavelet transform. The images compressed with the proposed method look better when compared to that of other vector quantized images. The proposed method is well suited for Human Visual System which can be very well used in hand-held devices.

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