Wavelets Image Data Compression

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Abstract **- The fast development of multimedia computing has led to the demand of using digital images. The manipulation, storage and transmission of these images in their raw form is very expensive, it significantly slows the transmission and makes storage costly. Many techniques are now available and much effort is being expended in determining the optimum compression technique. Recently, compression techniques using Wavelet Transform (WT) have received great attention, because of their promising compression ratio, flexibility in representing images and its ability to take into account Human Visual System. In this paper we combine a wavelet transform with vector quantization, using a modified version of LBG algorithm using Partial Search Partial Distortion (PSPD) scheme, for coding the wavelet coefficients to speed up the scheme in codebook generation and the search required for nearest neighbour codevector of input image. The *Wavelet transform* is used to obtain a set of different frequency subbands of image; the image is decomposed using a pyramidal algorithm architecture. According to Shannon's rate distortion theory, the wavelet coefficients are vector quantized using Multiresolution codebooks. The proposed scheme can save 70 - 80 % of the Vector Quantization (VQ) encoding time compared to fully search VQ and reduced arithmetic complexity with out sacrificing performance.**

I. INTRODUCTION

Image data compression is the process of reducing the number of bits required to represent a digital image data while maintaining an acceptable fidelity or image quality. Due to the advent of multimedia computing, the demand for these images has increased rapidly, their storage and manipulation in their raw form is very expensive, and it significantly increases the transmission time and makes storage costly.

Data compression is possible because images are extremely data intensive, and contain a large amount of redundancy which can be removed by accomplishing some kind of transform, with a reversible linear phase to de-correlate the image data pixels.

There are two different techniques for image data compression namely; *'lossless'* and *'lossy'*, the lossless compression techniques are reversible or non destructive compression. It is guaranteed that the decompression image is identical to the original image.

This is an important requirement for some applications where high quality is demanded. Whereas, the lossy techniques allows the image quality degradation in each compression and decompression. The performance of any coder is determined by the bit rate achieved and the distortion introduced by the coder. For an image coder, the bit rate is measured as the average number of bits required to express one pixel of the image and the fidelity is measured in terms of PSNR (Peak Signal to Noise Ratio). The applications of image compression include television transmission, video conferencing, facsimile transmission, archiving of graphic images, medical images and drawing, computer communications, data base, etc.

In the last few years, using wavelet transforms has become one of the important technologies in image compression research. It involves viewing the image at different resolutions and decomposes the original image into various subimages.

Wavelet coders for images have been implemented by Antonini *et al* [1], they have proposed a scheme that takes into account the low sequence of the Human eye to the edges or high frequency components. The coefficients belonging to different subimages are encoded using different codebooks, thus reducing the distortion due to quantization. Higher number of bits are assigned to the subimages at low resolution, while higher resolution wavelet coefficients are encoded using lower number of bits. Lewis and Knowless [2] proposed to retain the low pass subband and send it fully and decided the number of bits to be assigned for other subbands.

The compression method, which is being used in this paper is based on applying a Vector quantization (VQ) which is designed by a modified version of LBG algorithm using Partial search Partial Distortion (PSPD)[3] on the wavelet coefficients resulting from wavelet transform of the trained images. This algorithm searches a part of vectors rather than a whole codebook. Where a window is centred around a set of vectors which have closest of significant feature vector. Using this approach we are able to get good results and this method is less complex & simple. The algorithm scheme is shown in figure(2).

II. WAVELETS

Wavelet theory [4] has provided a promising hope for image processing applications because of its flexibility in representing images and its ability in take into account Human Visual system characteristics. It is mainly used to de-correlate the image data, so the resulting coefficients can be efficiently coded. It also has good energy compaction capability which results in a high compression ratio. A wavelet transform decomposes an

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image into a set of different resolution sub-images, corresponding to the various frequency bands. This results in a multi-resolution/multi-frequency representation of images with localisation in both the spatial and frequency domains. This advantage is desirable in image compression, and it is not possible in Fourier and Discrete Cosine Transforms which give good localisation in one domain at the expense of other.

A wavelet transform can also be viewed as a special case of multi-rate filter bank with dyadic tree decomposition. It can be implemented by cascade of separable QMF filter banks using Daubechies'8 tap filter. The Quadrature Mirror Filter (QMF) pair of w_6 consists of a low pass filter $G = G(g(n))$, and $H = H(h(n))$, $n \in z$, where $h(n)$, $g(n)$ are Daubeche's 6-tap filter. Where the impulse response H, and G are mirror images, and related by:

$$g_n = (-1)^{1-n} h_{1-n}$$

The impulse response of the forward and inverse transform QMFs - denoted $(\hat{H},\hat{G})$ and (H,G) respectively are related by:

$$g_n = \hat{g}_{-n}$$

$$h_n = \hat{h}_{-n}$$

Figure(1) shows one level of the decomposition, which can be viewed as two one-dimensional decompositions; one along the vertical direction and the other along the horizontal direction. The process is then repeated on the coarser subimage up to the desired level[8].

III. QUANTIZATION

Applying the wavelet transform on images does not reduce the amount of the data to be compressed, it may remove some of redundancy, but that is not sufficient. A common way to reduce the number of bits required for compression is to quantise the coefficients and apply some lossless coding entropy such as Huffman or arithmetic coding

III.1. *Encoding of wavelet coefficients*:

The wavelet transform produces coefficients with statistics different from the original image. The low-band coefficients have a flat distribution, that approximates the distribution of luminance and chrominance values in the original image. The high-bands coefficients have a probability distribution that is similar to laplacian characters with mean zero. Moreover, the compression of wavelet coefficients based on the assumption that details at high resolution are less visible to human eye and therefore can be reconstructed with low precision, for this reason the low and high band coded separately. Different techniques involving Scale Quantization (SQ) [5] or Vector Quantization [1] [2] [6] can be used to encode the wavelet coefficients. According to Shannon's rate distortion theory better results are always obtained when vector's rather than scalars are encoded. Furthermore, a high compression ratio can be achieved by quantizing vectors with high dimension.

In this coder scheme the Wavelet Transform of the original image as I mentioned early is obtained by using the Daubeche's wavelet family (*DAUB6*) which is based on six coefficients [1] [7]. The process is repeated on the low-pass band to generate the next level of the decomposition.

III.2. *Principle of vector Quantization*

Vector quantization has proven to be a powerful tool for digital image compression. A vector quantizer (VQ) can be defined as a mapping **Q** of **K**-dimensional Euclidean space R^K into a finite sub set Y of R^k

$$Q: R \longrightarrow Y$$

Where $Y = (\bar{x}_i; i = 1,2,\ldots\ldots,N)$ Y is the set of reproduction vectors, and is called a VQ codebook or VQ table, N is the number of vectors in Y. In VQ, the first step is to decompose the input image (in our case the wavelet transform coefficients) into a set of k dimensions, where k is $n \ x \ n$ subblocks

2.1 Vector decomposition and organisation

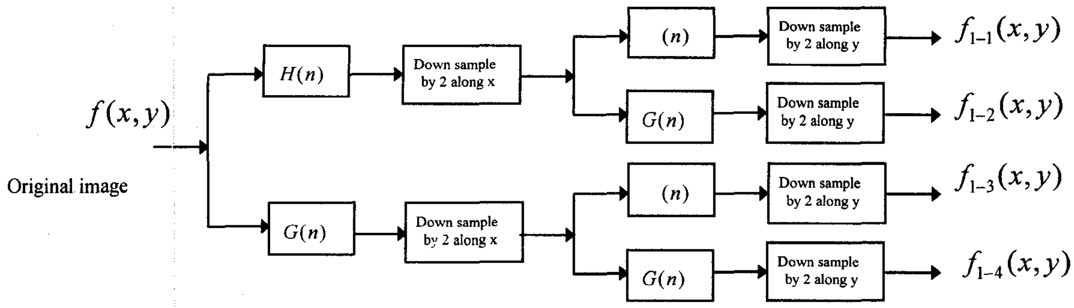
In this step the wavelet transform coefficients subbands are divided into several subblocks, usually in square. Each block containing k entities is considered as a k - dimensional vector, where k is 2^n ,and n is the subblocks dimension in the forward direction. In case of reconstruction it called vector organisation which is the reverse process of forward as show in figure(2) blocks.

2.2 Encoding/Decoding stage.

An identical codebook whose entries contain combination of pixels in a block exists in both coder and decoder before compression. At the encoder, each data input vector is matched or approximated with a closest codeword in the codebook, the address or index of that codeword is transmitted instead of the data vector itself, and this is where the compression is achieved. At the decoder, the image reconstruction is carried out with a simple look-up table technique in which the index is mapped back to the codeword, and the codeword is used to represent the original data vector after step of vector organisation and the inverse wavelet transform is taken.

A distortion measure d is used to assign the cost $d(x,\hat{x})$ of reproducing any vector x as reproduction $\hat{x}$. A quantizer is optimal if it minimizes the average distortion. The most conventional and computationally simplest measure is squared error distortion given by:

$$d(x,\hat{x}) = \|x-\hat{x}\|^2 = \sum_{i=0}^{k-1}(x_i - \hat{x}_i)^2$$



Figure(1) Block diagram of 2-D forward Wavelet Transform

In basic VQ scheme, a full search technique is used, where the Euclidean distance measure is calculated for all the code vectors in the codebook. This is one of the serious problems facing VQ. This becomes a limiting factor especially when the codebook size and vector dimension are large and the computations are to be implemented in real-time. The rate R of full search VQ codebook with vector dimension is defined to be:

$$R = \frac{log_2 N}{d}$$ bit per vector element Where N is codebook size, and d is vector dimension.

Using this definition, the size of the codebook rewritten as $N = 2^{Rd}$. This shows the size of the search grows exponentially wit the rate and vector dimension. Also there are major drawbacks with VQ, it is highly image dependent and there are a problem in designing a good codebook. Various VQ structures and design techniques have been developed. The method used almost exclusively for designing a codebook has been the algorithm known as the Linde -Buze -Gray (LBG) algorithm[8]. The LBG is time consuming because it is iterative method in building the codebook.

Recently, a new algorithm has been developed called the pairwise nearest neighbour (PNN) algorithm[9]. All of the algorithms have a local minimum problem. That is, the codebook guarantees local minimum distortion, but not global minimum distortion. These methods can improve the codebook, but they increase the complexity significantly. However, in this paper we used a modified version of LBG to built the codebook using a Partial search Partial distortion (PSPD) scheme [3] to save time and reduce computation complexity by restrict search to a small portion of the search space. The codebook is built up using the important feature of a block, then the (PSPD) technique is used to find the best match codevector from the Partial codebook. This algorithm yields a significant reduction of computation time without degradation of picture Quality.

IV. CODE BOOK CONSTRUCTION

The difficulty in designing a codebook is one reason why vector quantization was not seriously implemented in such applications as speech and image coding until the late 1970's. To cluster a training vector x in the case of LBG, we have to find its distance (distortion) from each of N codevectors obtained from previous iteration, and then compare these to get the best match codevector which is a time consuming in both codebook design and encoding phase. In the proposed algorithm calculating the distortion for clustering of training input vectors is used to reject a large number of code vectors from consideration without calculating their distortion from these input vectors. Moreover, the PSPD is used to get the best match codevector from remaining possible match codevectors of the codebook, which is built from the ascending sort of the codebook vector. But , it still has one problem in designing the codebook, it is the initial code vectors which are needed for the algorithm. We suggest a method to initialise the algorithm which known as the Pruning Method. This is based upon a statistical clustering technique, the first training vector taken as the first codevector in the codebook, its distortion evaluated with the next training vector. If the distortion is greater than the defined threshold, the centroid of both vectors is calculated and replaced in the training vector, the process continues with the next vectors. If the resulting distortion is not within the threshold, the training vector is added to the codebook. In most cases, in the experiment work, we get different length codebooks from the threshold method, so we need to get the exact codebook length, which has been given . Otherwise, splitting method is used, where the two vectors which have the lowest distortion are replaced by their centroid, the process repeated until the exact codebook length achieved.

As mentioned earlier, a separate codebook is constructed for each subband , the lowest band is scalar quantized, and the details subbands are encoded using different vector dimension lengths with different codebooks.

The performance of the proposed algorithm is evaluated using several standard 256 x 256 monochrome images with 256 grey levels. The performance is evaluated in the codebook design as well as image encoding. The metrics are in terms of execution time, bit rate coding, and Peak Signal- to Noise-Ratio (PSNR). All of our experiments were in Matlab on a Gateway 2000 PC with Pentium 166 CPU. Four images were employed; Montage, Lena, Pepper, and Cameraman, as our training for the codebook generation with different sizes and different vector dimensions. The vectors were of dimension 4x4 and three level wavelet Multiresolution was used. In the simulation, the wavelet coefficients of the Montage are used to design the codebooks, and then the resulting codebook used to encode the other images.

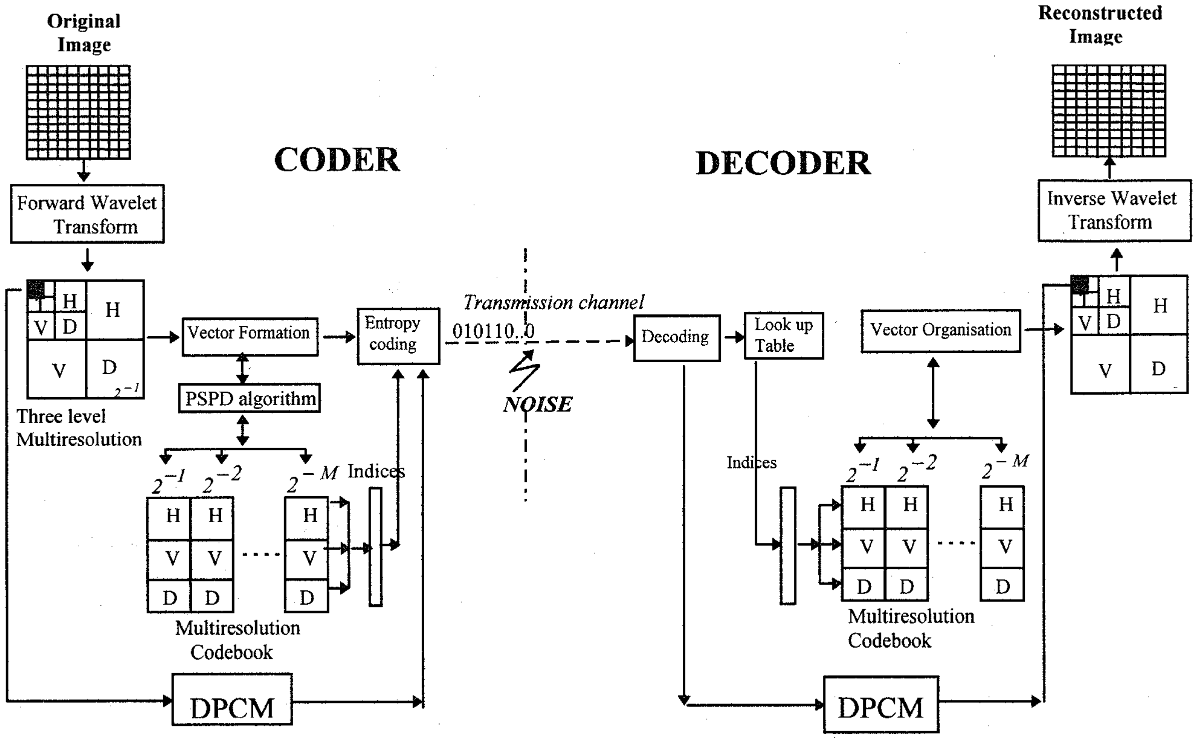


Figure.(2) Block diagram of coder scheme

V. CONCLUSION & RECOMMENDATION FOR FURTHER WORK

The quality of reconstructed images within the training set are yielded a compression ratio of 60 - 50 and the PSNR was 36 - 32 dB, as well as the out side the training set, with greatly reduced computation and execution time needed for codebook design and encoding phase. It reduces the computation complexity to $O(kf)$ arithmetic operations instead of $O(kN)$ in full search, where N is the number of codevectors, k is the vector dimension, and f is the window width, (where $f << N$). The proposed scheme can save 70 - 80% of the VQ encoding time compared to full search VQ. To increase the efficiency, fast algorithm for wavelet transform has to be incorporated. Developing Fast hardware architecture for wavelet transform and vector quantization are an area to be investigated.

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