A NOVEL FPCM BASED VECTOR QUANTIZER CODEBOOK DESIGN FOR IMAGE COMPRESSION IN THE WAVELET PACKET DOMAIN

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ABSTRACT

This paper presents a novel Vector Quantizer codebook design using Fuzzy Possibilistic C Means (FPCM) clustering technique for image compression using Wavelet Packet. The idea is to achieve higher compression ratio based on clustering the wavelet coefficients of each Wavelet Packet Tree (WPT) bands. The methodology applied here is to apply WPT to the whole image. The sub blocks are decomposed into two level Wavelet Packet Tree where the coefficients of LL band's(approximation and details), LH band's(approximation), HL band's(approximation), HH band's (approximation) are clustered using FPCM. The centroids of each cluster is arranged in the form of a codebook and indexed. The index values are coded and then transmitted across. The image is reconstructed using the inverse WPT followed by rearranging and the subsequent encoder. The results show that the psycho-visual fidelity criteria (both subjective and objective measures) of the proposed FPCM technique do better than the other existing methods.

KEYWORDS

Image Compression, Discrete Wavelet Transform, Fuzzy Possibilistic C Means, Vector quantization, Wavelet Packet Tree

1. INTRODUCTION

Image compression is an indispensable coding operation that is able to minimize the data volume for many applications such as storage of images in a database, TV and facsimile transmission, video conferencing. Compression of images involves taking advantage of the redundancy in data present within an image. Vector quantization is often used when high compression ratios are required.

In the last decade, many lossy compression techniques are evolved. VQ is one of the techniques. In VQ, the transformed image has to be coded into vectors. Each of these vectors is then approximated and replaced by the index of one of the elements of the codebook. The only useful information in this is the index for each of the blocks of the original image, thus reducing the transmission bit rate ([1],[2],[3],[4]).

There are many approaches to code book design. The two most common approaches are to use some subset of a lattice to force a highly structured codebook or to apply a clustering algorithm such as the Lloyd (Forgey, Isodata, k-means) algorithm. The generalized Lloyd algorithm

(GLA), which is sometimes referred to as the Linde-Buzo-Gray (LBG) algorithm, iteratively tunes and improve seed vectors step by step until the local minimum is achieved.

In Tree Structured VQ, the codeword is selected by a sequence of binary minimum distortion decisions comparing the input vector to stored vector reproductions at each available node. The encoder produces binary symbols to represent its sequence of decisions from the root node of the tree through the terminal node. This binary sequence or path map is the final codeword [5].

A Structured VQ scheme which can achieve very low encoding and high storage complexity is Multistage Vector Quantization (MVQ). MVQ divides the encoding task into several stages ([6],[7],[8]), where the first stage performs a relatively crude quantization of the input vector. Then a second stage quantizer operates on the error vector between the original and the quantized first stage. The quantized error vector provides a refinement to the first approximation. At the decoder, the reproduction vectors produced by the first and second stages will be added together. MVQ is sometimes referred to as residual VQ but those words better apply to a variation on multistage VQ that effectively uses the same codebook but allows a non greedy search. ([9],[10],[11]).

Set Partitioning in Hierarchical Tree (SPIHT) belongs to the next generation of wavelet encoders, employing more sophisticated coding. In fact, SPIHT exploits the properties of the wavelet transformed images to increase its efficiency. The SPIHT algorithm uses a partitioning of the tree in a manner that tends to keep insignificant coefficients together in larger subsets[12].

Pyramid vector quantization (PVQ) uses the lattice points [13] of a pyramidal shape in multidimensional space as the quantizer codebook. PVQ was introduced by Fischer [14] as a fast an efficient method of quantizing Laplacian-like data, such as generated by transforms or subband filters in an image compression system. It combines the robustness of fixed-rate codes with the performance of entropy-coded scalar quantization. PVQ takes its name from the geometric shape of the points in its codebook. It is designed for Laplacian random variables, whose equiprobable contours form multidimensional pyramids.

The role of FPCM in the field of vector quantization has not been reported earlier in Wavelet Packet Domain. It has been extensively used in the field of segmentation. Therefore in this paper it is proposed to use this technique for vector quantizer codebook generation and to analyze its impact in the field of image compression. The implementation consists of three steps. First, image is decomposed into a set of sub bands with different resolution corresponding to different frequency bands. The output of LL(all sub bands),LH band's approximation sub band, HL band's approximation sub band, HH band's approximation sub band are fed to Vector quantization. The proposed clustering technique is used for the codebook design. It iteratively improves the codebook by ultimately optimizing the encoder for the decoder (using a minimum distortion) and the decoder for the encoder (replacing the old codebook by generalized "centroids"). Image quality is compared using mean squared error and PSNR along with subjective visual appearance measure.

This paper is organized as follows: Section II discusses the preliminary concepts about the techniques used in this paper. Section III discusses about the proposed work in detail and Section IV discuss about Result analysis. Finally in Section V conclusion and future enhancement are given.

2. PRELIMINARIES

2.1. Wavelet Packet and Wavelet Packet Tree

The fast wavelet transform decompose a function into a series of logarithmically related frequency bands. That is, the low frequencies are grouped into narrow bands, while the higher frequencies are grouped into wider bands. This is commonly called as constant Q filters[15].

DWT [16],[17] decompositions in a regular wavelet analysis may be lower. It may cause serious problem where the important information is located in high frequencies. The frequency resolution of the decomposition filter may not be enough to extract necessary information from the decomposed component of the signal. In order to achieve necessary information wavelet packet tree (Coifman and Wickerhauser [1992]) is used to decomposed the signal further.

The wavelet packet analysis is similar to the DWT with the only difference that in addition to the decomposition of only the wavelet approximation component at each level, a wavelet detail component is also further decomposed to obtain its own approximation and detail[18].

Each component in this wavelet packet tree can be viewed as a filtered component with a bandwidth of a filter decreasing with increasing level of decomposition and the whole tree can be viewed as a filter bank. The time resolution of the WP components is good at the top of the tree but at an expense of poor frequency resolution whereas the frequency resolution is good at the bottom of the tree but at an expense of poor time resolution. Thus with the use of wavelet packet analysis, the frequency resolution of the decomposed component with high frequency content can be increased. As a result, the wavelet packet analysis provides better control of frequency resolution for the decomposition of the signal.

Wavelet packet decomposition gives a lot of bases from which can be look for the best representation with respect to design objectives. The wavelet packet tree for 3-level decomposition is shown in Figure 1. In this paper Shannon entropy criteria is used to construct the best tree. Shannon entropy criteria find the information content of signal.

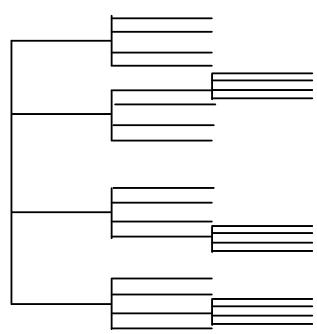

Figure 1.Wavelet packet tree

2.2 FPCM Clustering algorithm

FPCM algorithm was proposed by N.R.Pal, K.Pal, and J.C.Bezdek, it includes both possibility(typicality) and membership values[19,20]. It is a combination of a fuzzy partition and a possibilistic partition is presented. The idea behind is that the membership value of the fuzzy partition is important to be able to assign a hard label to classify an input vector, but at the same time, it is very useful to use the typicality (possibility) value to move the centers around the input vectors space, avoiding undesirable effects due to the presence of outliers. The distortion function to be minimized is

$$J_h(U,C,T;X) = \sum_{k=1}^{n}\sum_{i=1}^{m}(u_{ik}^{h} + t_{ik}^{h2}) \| x_k - c_i \|^2$$

with following constraints

$$\sum_{i=1}^{m} u_{ik} = 1 \quad \forall k = 1...n \quad \text{and} \quad \sum_{k=1}^{n} t_{ik} = 1 \quad \forall i = 1...m$$

where

X_k - input vectors
C_i - cluster centers
U_{ik} - is the matrix where the degree of membership is established by the input vector to the cluster.
T_{ik} - is the matrix where the degree of typicality is established by the input vector to the cluster.
Let T = [t_{ik}], then, the constraint shown above requires each row of T to sum up to 1 but its columns are free up to the requirement that each column contains at least one non-zero entry, thus, there is a possibility of input vectors not belonging to any cluster.

It is believed that memberships (or relative typicalities) and possibilities (or absolute typicalities) are both important for correct interpretation of data substructure. When it is necessary to crisply label a data point, membership is a plausible choice as it is natural to assign a point to the cluster whose prototype is closest to the point. On the other hand, while estimating the centroids, typicality is an important means for alleviating the undesirable effects of outliers. The above clustering technique is not used in the field of image compression so far in wavelet packet tree domain.

3. PROPOSED METHOD

The proposed method combines the concept of Wavelet Packetization and FPCM based quantization in order to achieve high compression ratios with minimum loss of quality. The illustration for the proposed method is given in figure 2. First the original image is decomposed into two level wavelet packet tree Decomposition(WPT). The Significant coefficients(nodes 1,2,3,4,5,6,7,8,9,13,17) are taken for the Quantization, whereas the insignificant ones are made zero and discarded. The significant coefficients are the coefficients that are more packets with more energy. They are identified by computing the energy function.

Entropy $(S) = = -\Sigma S_i^{\,2} \log(S_i^{\,2})$

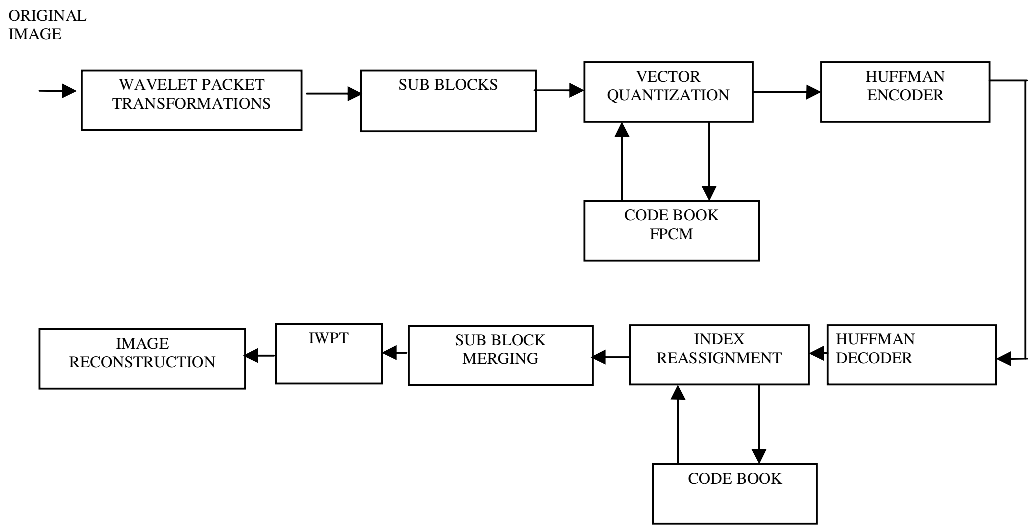

Figure 2. Wavelet Packet Tree based clustering for image compression.

In the quantization process, first a codebook of size 256 is randomly initialized. It is then trained with significant coefficients using the proposed FPCM technique. The objective function of the proposed FPCM technique is given by

$$J_{m,n}(U,T,V) = \sum_{i=1}^{c}\sum_{k=1}^{n}(u_{ik}^{m} + t_{ik}^{n})\ \| x_k - v_i \|^2$$

where

$$u_{ik} = \left[\sum_{j=1}^{c}\left[\frac{\| x_k - v_i \|^2}{\| x_j - v_i \|^2}\right]^{\frac{2}{m-1}}\right]^{-1}$$

$$t_{ik} = \left[\sum_{j=1}^{n}\left[\frac{\| x_k - v_i \|^2}{\| x_j - v_i \|^2}\right]^{\frac{2}{n-1}}\right]^{-1}$$

Code vectors (cluster) centroids V_i are computed using the formula,

$$V_i = \left(\sum_{k=1}^{n}\left(u_{ik}^{h} + t_{ik}^{h2}\right)x_k \Big/ \sum_{k=1}^{n}\left(u_{ik}^{h} + t_{ik}^{h2}\right) \right)$$

Now, the significant coefficients are quantized using this codebook and indices are generated. The generated index values and codebook then encoded using Huffman encoder. The output of the encoder is the compressed version of the original image.

To reconstruct the original image, the reverse process is carried out. First the compressed data is subject to Huffman decoder followed by index reassignment using the codebook. Then it is subjected to sub block merging. Finally, inverse wavelet packet transformation is carried to reconstruct the image.

4. EXPERIMENTAL RESULTS

The performance of the proposed FPCM technique using Wavelet Packet Tree is analyzed for various test images. Trained test images of size 256 x 256 such as Zelda, Womandarkhair, Woman, Tracy, Bottom_left are taken as input. These images are tested with the existing LBG, K -Means, FCM (Fuzzy C Means), PCM (Possibilistic C Means) and the proposed FPCM (Fuzzy Possibilisitc C Means) techniques.

Table 1 shows the performance comparison of the proposed FPCM with the existing techniques. The test images size is 128 X 128. The codebook (cluster size) of size 256 is used for observation. It is evident that the proposed method gives better PSNR values around 30db with 80% space saving.

The performance comparisons of proposed method with existing methods are listed in Table 2. 256 X 256 is the image size taken as input. The code book size of 256 is taken for the analysis. From the table 2 it is evident that the proposed FPCM gives better PSNR(db) than all other existing techniques. Also from the figure 3 it is clear that the proposed technique preserved more visual information than the existing technique.

Table 1. Performance comparison of the proposed work with the existing techniques for cluster size 256 and a compression ratio of 5.3:1 for 128 x 128 image size

Image/ Techniques	**LBG**	**K means**	**FCM**	**PCM**	**FPCM**
	PSNR(db)				
Zelda	30.79	30.71	30.78	26.46	31.56
Womandarkhair	29.94	29.83	28.21	25.36	29.95
Woman	28.59	27.40	27.63	26.16	28.60
Tracy	25.35	29.17	22.55	25.35	29.27
Bottom_left	35.34	34.90	35.04	31.73	35.40

Table 2. Performance comparison of the proposed work with the existing techniques for cluster size 256 and a compression ratio of 5.3:1 for 256 x 256 image size

Image/ Techniques	**LBG**	**K means**	**FCM**	**PCM**	**FPCM**
	PSNR(db)				
Zelda	34.68	32.65	30.65	29.84	34.69
Womandarkhair	33.10	31.99	32.67	27.89	35.25
Woman	30.28	29.76	30.24	23.71	30.43
Tracy	33.04	32.78	22.82	27.42	33.14
Bottom_left	37.63	36.97	37.87	34.94	38.00

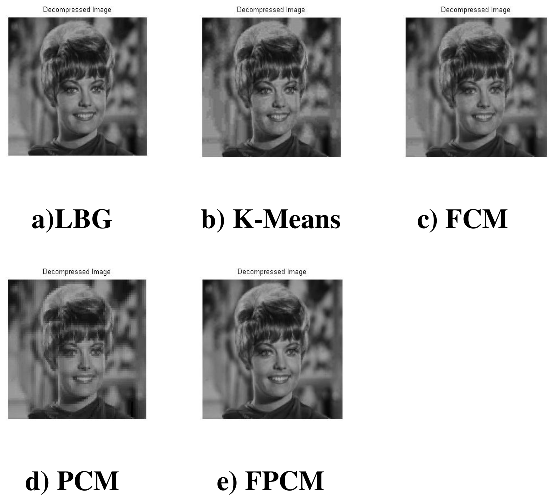

Figure 3(a,b,c,d,e): Reconstructed images of LBG,K-Means, FCM, PCM and Proposed FPCM techniques for 256 X 256 Zelda image (256 clusters) respectively.

5. CONCLUSION

In this paper, a novel idea of using FPCM technique for image compression is presented in wavelet packet tree. The proposed technique consists of four advantages which makes it very efficient in image coding. First the inter sub band self similarity of different sub band coefficients in the wavelet transform domain is taken. Second, FPCM clustering technique is used to compute the centroids of each sub band cluster. Third, VQ technique is employed to achieve higher compression ratios. Finally, Huffman coding is used for encoding. The analysis of the experimental results shows that the proposed technique provides better PSNR ratio than the existing other clustering techniques. This work may be extended to color & video coding in future.

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