MULTIPLE DESCRIPTION SHIFTED LATTICE VECTOR QUANTIZATION FOR PROGRESSIVE WAVELET IMAGE CODING

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ABSTRACT

Multiple description (MD) coding is a promising alternative for robust transmission of information over non-prioritized and unpredictable networks. Furthermore, practical variable-bandwidth channels also require fine grain scalability of the descriptions (bit streams). In this paper, according to the geometrical structure and the special relationship of lattice vector quantizers, a MD quantizer called shifted lattice vector quantization (SLVQ) is employed in MD image coding to realize progressive transmission over unreliable channels. In view of the characteristics of wavelet coefficients in different frequency subbands, besides an appropriate construction of wavelet coefficient vectors, the algorithm of modified zerotree coding is also applied to improve compression performance. Experimental results validate the effectiveness of the proposed scheme with better performance than the other schemes based on MD scalar quantization for progressive transmission.

Index Terms—lattice vector quantization, multiple description coding, image coding, wavelet transform

1. INTRODUCTION

Network congestion and delay sensibility pose great challenges for multimedia communication system design. This creates a need for coding approaches combining high compression efficiency and robustness. Multiple description (MD) coding has emerged as an attractive framework for robust transmission over unreliable channels. It can effectively combat packet loss without any retransmission thus satisfying the demand of real time services and relieving the network congestion [1]. Multiple description coding encodes the source message into several bit streams (descriptions) carrying different information which can then be transmitted over separate channels. If only one channel works, the only description can be individually decoded to guarantee a minimum fidelity in the reconstruction at the receiver. When more channels work, the descriptions from these channels can be combined to yield a higher fidelity reconstruction.

The MD quantization algorithms mainly include MD scalar quantization (MDSQ) [2-5] and MD lattice vector quantization (MDLVQ) [6-8]. In [5], Vaishampayan presented MD scalar quantizers for communication systems that use diversity to overcome channel impairments for the first time. In [3], a scheme is proposed based on multiple description uniform scalar quantization (MDUSQ) for robust and progressive transmission of images over unreliable channels, which outperforms the embedded MDC algorithm based on the polyphase transform proposed in [4]. However, another type of embedded scalar quantizers for MDC systems (EMDSQ) in [2] is claimed that it provides constantly better rate-distortion performances on the central channel for all the rates.

In this paper, a novel MD image coder is designed for progressive transmission over unreliable channels. There are mainly two significant improvements in the proposed scheme. On one hand, according to the geometrical structure and the special relationship of lattice vector quantizers (LVQ), a MD quantizer called shifted lattice vector quantization (SLVQ) is constructed to produce two balanced descriptions as suggested in [8]. On the other hand, enlightened by EZW [9], in view of the characteristics of wavelet coefficients in different frequency subbands, a modified zerotree coding is applied for vectors of the lattice A_2 in order to improve compression performance. It is noted that in our scheme SLVQ is adopted instead of SVS-MDLVQ (developed by Servetto, Vaishampayan and Sloane [6]) and [7] is also developed based on SVS-MDLVQ. The main reason is that in SVS-MDLVQ only one LVQ on the central channel is difficult to match two zerotree coders on two channels, while in SLVQ two LVQs respectively on both channels make it easy to cooperate

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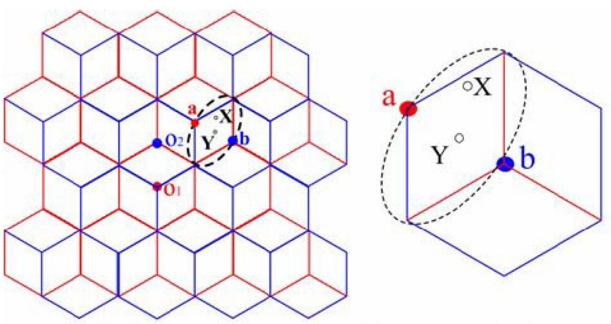
with two zerotree coders for two descriptions (shown in Fig.5).

The rest of this paper is organized as follows. In Section 2, MD shifted lattice vector quantization (MDSLVQ) is given in detail. In Section 3, the zerotree coding is modified for vectors in the lattice A_2. In Section 4, the scheme of MD image coder for progressive transmission is presented. In Section 5, experimental results are compared with EMDSQ [2] and MDUSQ [3]. We conclude the paper in Section 6.

2. MDSLVQ

Generally, lattice vector quantization is based on a certain geometrical structure of lattice, for example, the lattice A_2 is hexagonal lattice [11]. Here, we make use of the geometrical relationship between the same lattice vector quantizers to construct our MD quantizer.

Fig.1 illustrates the construction of MDSLVQ for two channels.



(a) SLVQ **(b) a example from (a)**

Fig.1. The construction of MDSLVQ

As suggested in [8], SLVQ can be constructed by the two lattice vector quantizers called LVQ_1 and LVQ_2 for two channels in Fig.1. The two lattice vector quantizers can be produced by the general method [10, 11], but they have certain geometrical relationship in SLVQ, that is, LVQ_2 can be regarded as the shifted LVQ_1 when the origin O_1 is moved up to the origin O_2 and the shifted vector is $(0,1/\sqrt{3})$. We can find that for LVQ_1 and LVQ_2 the hexagonal lattices can spread the whole space while for SLVQ the diamond lattices with different directions also can extend all the space like normal LVQ. As a result, the principle of MDSLVQ can be obtained as follows. The input source can be quantized coarsely by LVQ_1 and LVQ_2 respectively to get two descriptions which can be transmitted on two channels. If only one channel works, the reconstructive value is the lattice point in LVQ_1 or LVQ_2. If both channels work, the fine reconstruction is the centroid of the diamond lattice in SLVQ.

For example, an input two-dimensional vector X is quantized by LVQ_1 and LVQ_2 to get two lattice points respectively a and b. If only channel 1 or 2 works, the reconstructive value is just a or b. But if both channels work, the reconstruction is Y which is the centroid of diamond lattice (enclosed in ellipse illustrated in Fig.1 (a) and (b)).

It is necessary to note that the origin O_1 of LVQ_1 is also used as the origin O of SLVQ but the origin O_2 of LVQ_2 is not so. This will lead to the unbalance of LVQ_1 and LVQ_2 which will turn to the unbalance of two descriptions obtained. The main reason is that the origins of LVQ_1 and LVQ_2 are not symmetrical according to the origin of SLVQ. As the result, the origin of SLVQ can be set on the centroid of the diamond lattice (enclosed in ellipse in Fig.2) to realize the symmetry of O_1 and O_2 which turns to the balance of two descriptions.

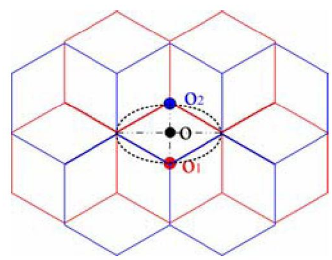


Fig.2. MDSLVQ for two balanced channels

3. MODIFIED ZEROTREE CODING

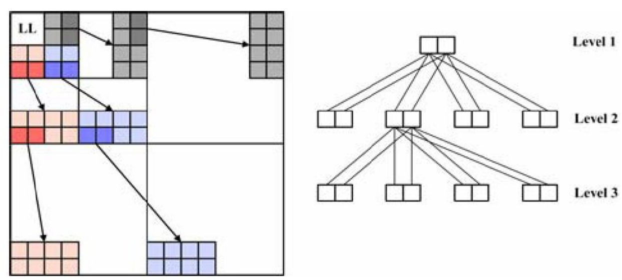


Fig.3. The tree structure of wavelet coefficients

Fig.3 shows the tree structure of wavelet coefficients in different frequency subbands in the modified algorithm. Due to the lattice vector quantizer based on the lattice A_2, two-dimensional vectors as tree nodes are considered in the modified zerotree coding. The zerotree here is also a quad-tree of which all nodes are equal to or smaller than the root just like its concept in EZW [9].

The first step in the proposed zerotree coding is to get threshold which is also the step size of lattice vector quantization [7]. In the modified algorithm, the step size can be computed to satisfy the case in which the significant wavelet coefficients have only six pairs (1, 0), (1, 1), (0, 1), (-1, 0), (-1, -1) and (0, -1) and the insignificant ones is (0, 0) just shown in Fig. 4(b). The idea to obtain such threshold comes from the fast algorithm of lattice vector quantization [10]. In [10], the lattice vector quantization based on the lattice A_2 maps a 2D vector to 3D space firstly, then rounds off each dimensional value of 3D vector to an integer, and then modifies the 3D integer vector to make all three values from each dimension to add up to zero, lastly maps again the 3D vector to 2D vector which is just the quantized vector. So if the maximum among three dimensional values is chosen as the step size of lattice vector quantization, that is, the threshold in modified zerotree coding, the insignificant pair (0, 0) and six significant ones can be achieved in Fig. 4 (a). Additionally, the lattice A_2 can be spanned by the vectors (1, 0) and $(-1/2, \sqrt{3}/2)$ [11], so if we use these two vectors as base vectors, we can utilize Fig.4 (b) instead of Fig.4 (a).

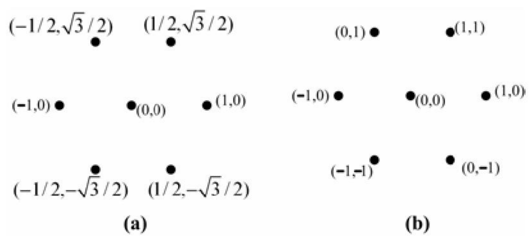


Fig.4. The significant and insignificant wavelet coefficients

Just like the conventional algorithm EZW, the modified zerotree coding also has two passes. In the first pass, the dominant pass, the quantized wavelet image is scanned (the details in Section 4) and the symbols are produced for every 2D vector. If the quantized pair is (1, 0), (1, 1) or (0, 1), it will be regarded as positive significant coefficients and a symbol ‘p’ is outputted. If the quantized pair is (-1, 0), (-1, -1) or (0, -1), it will be negative significant coefficients denoted by a symbol ‘n’. If (0, 0) is the quantized pair and all of its children nodes (shown in Fig.3) are also (0, 0), it is the root of zerotree and a symbol ‘t’ is obtained. However, if the quantized pair is (0, 0) and not all of its children nodes are (0, 0), it is the isolated zero and denoted by ‘z’. In second pass, the subordinate pass, only to the significant quantized pairs which have been denoted by ‘p’ or ‘n’, three symbols ‘a’, ‘b’ and ‘c’ are used as the division of (1, 0), (1, 1) and (0, 1) in the case of positive pairs or of (-1, 0), (-1, -1) and (0, -1) in the case of negative pairs.

After the two passes, the significant pairs denoted by ‘p’ and ‘n’ can be reconstructed to a 2D vector which is subtracted from the original 2D vector before lattice vector quantization. At the same time, the insignificant pairs denoted by ‘t’ and ‘z’ will be kept unchangeable, that is, (0, 0). Then the next threshold will be computed by the reconstructed wavelet coefficients and the zerotree coding is used in succession. As a result, a loop is formed (enclosed in the broken line in Fig.5).

4. PROGRESSIVE MD CODING SCHEME

Our scheme can be depicted in Fig.5 and the encoding and decoding methods are explained as follows.

In MD encoding procedure, the image source is transformed by DWT, then each frequency subband is scanned in different direction in view of corresponding directional correlation. Fig. 6 shows our scheme for vector construction: HL is scanned to form vectors along vertical direction, LH is scanned in horizontal direction and HH is scanned in zigzag way. In addition, spiral scan is also applied in LL subband considering the strong correlation among neighboring coefficients.

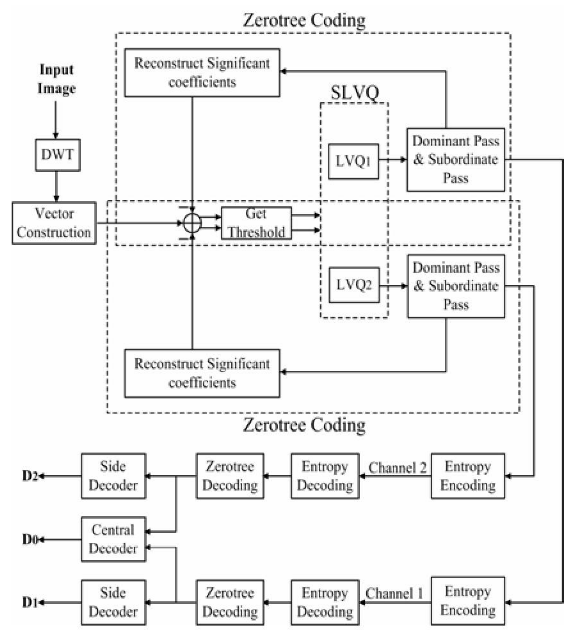


Fig.5. Block diagram of our scheme

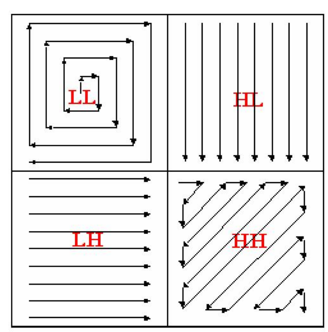


Fig. 6. Vector construction in different subbands

After vector construction, shifted lattice vector quantization and zerotree coding are applied to the reordered wavelet coefficients. The details are in Section 2 and 3. Then after entropy encoding two descriptions are transmitted over two channels. It need be explained that the entropy encoding is used for the bit stream from two pass of zerotree coding, but the threshold which nearly can be neglected is coded by fixed length bits.

In decoding procedure, after entropy decoding, the bit streams are processed by zerotree decoding. It is noted that for each loop or each threshold, the zerotree decoding is lossless. Consequently, if the two channels work, the fine reconstruction is just the centroid of the diamond lattice in SLVQ. If only one channel works, the lattice point of the hexagonal lattice can be regarded as coarse reconstruction.

5. EXPERIMENTAL RESULTS

The standard image Lena(512×512) is chosen to validate the performance of the proposed scheme MDSLVQ. Fig.7 and Fig. 8 show the side and central distortion-rate performance of the proposed scheme against EMDSQ [2] and MDUSQ [3] respectively.

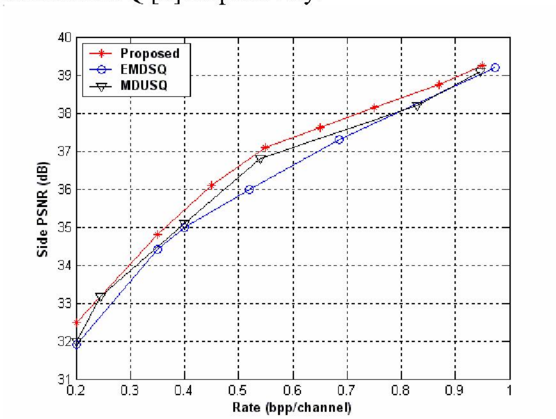


Fig. 7. PSNR results from only one channel

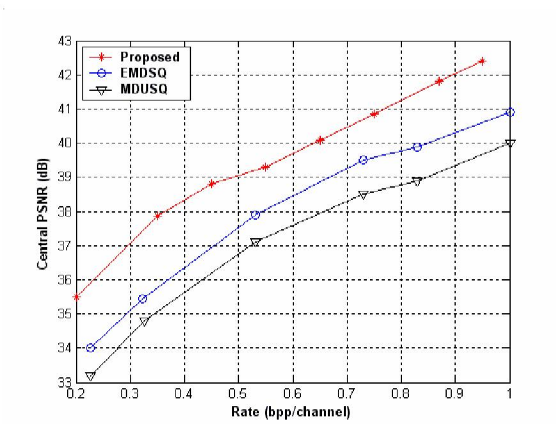


Fig. 8. PSNR results from both channels

From the figures, we can find that our proposed MDSLVQ consistently outperforms the other schemes in both central and side distortion simultaneously at the progressive bit rate over a wide range from 0.2bpp to 1bpp per channel, with about 0.2~0.5dB improvement for side PSNR values in Fig.7 and about 1~1.5dB for central PSNR values in Fig.8.

6. CONCLUSIONS

In this paper, a novel MD scheme for progressive wavelet image coding has been presented based on shifted lattice vector quantization. The SLVQ takes advantages of geometrical structure and keeps better redundancy between quantized wavelet coefficients to construct progressive MD descriptions. The modified zerotree coding reorders the wavelet coefficients efficiently to improve the compression performance. From the experimental results, the proposed scheme has demonstrated better rate-distortion performance to the other MD schemes [2] and [3] for progressive wavelet image coding.

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