STRUCTURE UNANIMITY BASED MULTIPLE DISCRIPTION SUBBAND CODING

Canhui Cai[*] *and* *Jing Chen*

Institute of Information Science and Technology, Huaqiao University, Quanzhou, China 362011
[*]Email:cheai@pub1.qz.fj.cn

ABSTRACT

A new multiple description coding approach is presented in this paper. In this approach, each significant wavelet coefficient is decomposed into two coefficients. One is made from the bits in the odd positions, whereas, the other is made from the bits in the even positions. These two types of coefficients are then grouped into two sub-signals. Two descriptions of coded data are formed from these sub-signals and transmitted over different channels. Similar to the polyphase transform and selective quantization multiple description coding algorithm (PTSQ), main descriptions and protecting data for the other description are separately coded. Since two sub-signals share the same hierarchical tree structure, only coefficient values in the redundancy parts need to be coded, and coding efficiency is improved. Experimental results have shown that the performances of the proposed scheme are better than those of PTSQ.

1. INTRODUCTION

Multiple Description Coding (MDC) provides a very efficient framework to achieve robust communication over unreliable channels such as a lossy packet network [1]-[6]. The basic idea of MDC is to introduce correlation between two descriptions of a source, which are transmitted over different channels to the receiver. In the case of a channel erasure, the decoder is still able to retrieve some information about the lost piece of signals. When all the descriptions are available at the receiver (i.e., all the channels are received), the decoder can reconstruct the source with high fidelity. However, if only a subset of the descriptions is received (signals in one or more channels are lost), the quality of the reconstructed signal should still be acceptable. In this paper, we consider a special case of MDC with two descriptions in the context of significant coefficient decomposition and realization in Stack X-tree MDC [7][8].

Early information theory based research in MDC presented theoretical rate-distortion results on a memoryless MDC source [1],[2]. Vaishampayan proposed the first MDC scheme for image coding, called Multiple Description Scalar Quantizer (MDSQ) [3]. MDSQ produces two quantization indexes for each sample. When both indices are available, the original sample can be reconstructed with a small quantization error. When only one index is available, the quantization error becomes larger. A simple implementation of MDSQ is the A2 index assignment employing two quantizers whose decision regions shift by half of the quantizer interval with respect to each other. Multiple Description Transform Coding (MDTC) is introduced in [4] and rate-distortion theoretic results for sources with memory are presented in this context. Wang et al. proposed another MDTC scheme by using pair-wise correlating transforms to introduce dependencies between two descriptions transmitted over different channels [5]. Both MDSQ and MDTC are effective approaches to alleviate the effects of the transmission errors. However, the gain of robustness to channel errors is at the cost of relatively complicated system design. For example, the requirement for index assignments in MDSQ calls for complicated system design, while MDTC requires another correlating transform besides the conventional decorrelation transform. To simplify the system implementation, Jiang and Ortega proposed another MDC scheme, Polyphase Transform and Selective Quantiaztion (PTSQ), by separating Zerotrees into polyphase components [6]. It was reported that PTSQ was simple to implementation and achieved better results in lower redundancy rates.

The proposed system splits each significant DWT coefficient into two coefficients by separating the odd number and the even number location bits of the coefficient. For notational convenience, we call the coefficient made of odd bits the odd coefficient and that made of the even bits even coefficient. Odd coefficients and even coefficients are coded to form odd phase and even phase components, respectively. Each description is formed by one phase and a redundancy addition from the other phase. Then they are coded and transmitted over

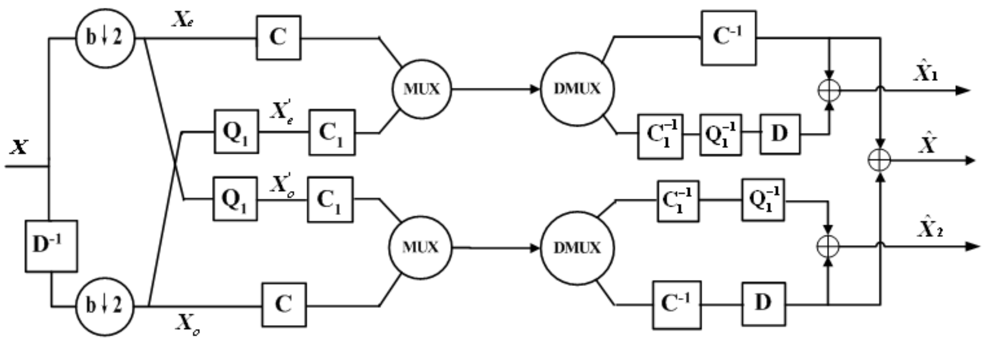

Figure 1. The proposed MDC system

two different channels. Till now, our approach sounds like PTSQ except the coefficients. However, there is different in redundancy coding. Zeros in the redundancy need not to be coded because both odd phase and even phase have identical zero-tree mapping.

The structure of the remaining sections of this paper is as follows. Section 2 describes the proposed MDC scheme, including the decomposition and reconstruction procedures. Section 3 shows some simulation results to illustrate the improved performances of the proposed algorithm. Section 4 gives some concluding remarks.

2. STRUCTURE UNANIMITY BASED MDC

2.1 Proposed MDC system scheme

The MDC coding system is shown in Fig. 1, where X is the outcome of a quantizer Q, which is not explicitly shown in the figure. Coefficient X and its shift are bitwise-down-sampled into even number position bits and odd number position bits, which are then grouped to form two-phase components X_e and X_o, respectively. The decomposition procedure is symbolized by $b\downarrow 2$ and D^{-1} is used to denote the logic shift in the figure. Each of these two-phase components is coded independently by a codec C and forms the primary part of the information in its corresponding channel. For the reconstruction of the second component in case of any lost channel, each channel also carries a coarser quantized version of the counterpart component as redundant information. A quantizer Q_1 is introduced to get a coarser quantization and C_1 is a codec for the redundant information. Generally, both X_e and X_o have the same zero mapping. In this light, C_1 codes only absolute value of redundancy, for zero mapping has coded in the primary part of the description. The encoded primary data and redundant data are combined for transmission. At the receiver, if data from both channels are available, primary information from both channels are employed for reconstruction. If only one channel data is available, the primary information and the redundant information from this channel are used for reconstruction.

2.2 The constitution of primary information

Let x be a significant coefficient with (n+1) bits:

$$x = b_n b_{n-1} \cdots b_1 b_0 = \sum_{k=0}^{n} b_k 2^k = \sum_{k=even} b_k 2^k + \sum_{k=odd} b_k 2^k \qquad (1)$$

Denote x_e and x_o the odd coefficient and the even coefficient, respectively. If n is an odd number, let $n = 2m-1$, then

$$x_o = b_{2m-1} \cdots b_1 = \sum_{k=0}^{m-1} b_{2k+1} 2^k, \qquad (2a)$$
$$x_e = b_{2m-2} \cdots b_0 = \sum_{k=0}^{m-1} b_{2k} 2^k.$$

Otherwise, n is an even number, let $n = 2m$, then

$$x_e = b_{2m} \cdots b_0 = \sum_{k=0}^{m} b_{2k} 2^k, \qquad (2b)$$
$$x_o = b_{2m-1} \cdots b_1 = \sum_{k=0}^{m-1} b_{2k+1} 2^k.$$

It should be noted that if x_e and x_o are transmitted and received with no lost channel then a multiple description coding stream is constituted. However, if one channel is lost, i.e., only one signal component is available, it is not known whether n is an odd or an even number. What is more, if b_n is dropped and $b_{n-1} = 0$ serious reconstruction error will happen. For instance, if x = 100000011, then x_e = 10001 and x_o = 0001. If only x_o is available, the reconstructed signal value will be $\hat{x}_0 = 1$. To avoid this situation, an MSB should be included in both x_e and x_o, and Eqns. (2a) and (2b) become

$$x_o = 1\ b_{2m-3} \cdots b_1, \text{ for n odd} \qquad (3a)$$
$$x_e = 1\ b_{2m-2} \cdots b_0$$

and

$$x_e = 1\ b_{2m-2} \cdots b_0, \text{ for n even} \qquad (3b)$$
$$x_o = 1\ b_{2m-1} \cdots b_1,$$

Equations (3a) and (3b) define the expressions for the odd and the even coefficients, respectively.

2.3 The constitution of redundant information

To make our discussion much simpler, we assume the stepsize of the quantizer Q_1 to be equal to two, and the quantization then becomes a logic shift to the right by one bit. Denote the shifted odd and the even coefficients x_e' and x_o', then

$$x'_o = 1\ b_{2m-3} \cdots b_3 , \quad \text{for n odd} \qquad (4a)$$
$$x'_e = 1\ b_{2m-2} \cdots b_2$$

and

$$x'_e = 1\ b_{2m-2} \cdots b_2 , \quad \text{for n even} \qquad (4b)$$
$$x'_o = 1\ b_{2m-1} \cdots b_3$$

Equations (3a), (3b), (4a) and (4b) show that any coding structure identifying the locations of significant coefficients in primary information also indicates the positions of the significant coefficients in the redundant information. Consequently, zero position mapping in the redundant data need not be transmitted, and only significant coefficients in redundant information need to be coded.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Experiments are performed on three popular 512×512 8-bit grayscale images: “Lena”, “Goldhill”, and “Barbara” to test the proposed algorithm. We used the 7/9 biorthogonal wavelet filters introduced along with a five level dyadic DWT in all our experiments [9].

Almost any one of the wavelet-based codec, such as the EZW, SPIHT and X-Tree approaches [7],[8],[10],[11], can be used to code the odd and the even coefficients. Among these coding schemes, the Stack X-Tree algorithm is the simplest one with high coding efficiency. We therefore employ this algorithm to realize the structure unanimity based MDC.

An X-tree is a generalization of a zerotree whose all descendants are insignificant but root node can be either significant or insignificant. The stack in fact is the nickname of a significant coefficient. For a given threshold, a DWT image is only scanned once, and X-tree maps of wavelet coefficients are produced and exported. Then significant coefficients with their signs are outputted one by one, where signs serve as separators of coefficients. Since all bits of a significant coefficient are outputted one after another with LSB going first and MSB last, which is similar to a stack, we call the significant coefficient a stack.

Consider that the Stack X-Tree is a non-embedded codec, the significant coefficient with odd n is shifted right for one bit, so that x_e and x_o have the same bits, and the LSB of the significant coefficients is sent with x_o. One more bit is sent with both x_e and x_o to indicate whether the n is odd. Though the preceding process will descend the coding efficiency and two descriptions will be somewhat unbalance, but the results are still acceptable.

The simulation results are summarized in Tables 1 - 3, where rate-distortion results from the proposed scheme and PTSQ scheme, including multiple description coding bit rate, redundancy rate, centre distortion and both side distortions, are tabulated for each of the images. Figure 2 shows the reconstructed images as obtained using the proposed method for “Lena” at bit rate 0.5 bpp.

Table 1. Simulation results for image “Lena”

MDC rate	ρ (%)	Available channel	PSNR (dB) Proposed	PSNR (dB) PTSQ
0.125	23.8	Both	30.05	30.05
		Channel1	26.60	25.77
		Channel2	27.88	26.21
0. 250	26.4	Both	32.96	32.97
		Channel1	29.31	28.69
		Channel2	30.65	28.80
0.500	26.9	Both	36.04	36.06
		Channel1	32.45	31.71
		Channel2	33.70	31.76
1.00	26.5	Both	39.05	39.09
		Channel1	35.45	34.80
		Channel2	36.52	34.81

Table 2. Simulation results for image “Barbara”

MDC Rate	ρ (%)	Available channel	PSNR (dB) Proposed	PSNR (dB) PTSQ
0.125	16.4	Both	24.34	24.35
		Channel1	21.83	21.54
		Channel2	22.63	21.70
0. 250	14.4	Both	27.11	27.11
		Channel1	23.21	23.30
		Channel2	24.68	23.27
0.500	17.3	Both	30.48	30.49
		Channel1	26.01	25.12
		Channel2	27.65	25.19
1.00	25.3	Both	34.58	34.60
		Channel1	29.72	28.47
		Channel2	31.18	28.52

Table 3. Simulation results for image “Goldhill”

MDC rate	ρ (%)	Available channel	PSNR (dB) Proposed	PSNR (dB) PTSQ
0.125	17.8	Both	27.94dB	27.94dB
		Channel1	25.25dB	24.93dB
		Channel2	26.21dB	24.95dB
0. 250	18.1	Both	29.93dB	29.95dB
		Channel1	26.91dB	26.70dB
		Channel2	28.01dB	26.72dB
0.500	17.2	Both	32.43dB	32.43 dB
		Channel1	28.94dB	28.47 dB
		Channel2	30.09dB	28.50 dB
1.00	18.9	Both	35.49dB	35.51 dB
		Channel1	31.39dB	30.95 dB
		Channel2	32.71dB	30.91 dB

From the experimental results listed, it can be seen that the proposed structure unanimity based multiple

(a) Both channels are available (36.04dB) (b) Only channel 1 is available (32.45dB) (c) Only channel 2 is available (33.70dB)

Figure 2. The simulation results of the proposed BSCD system for Lena (Bit rate = 0.5 bpp)

description coding scheme is some what bias, but side distortions from both descriptions outperform the polyphase transform and selective quantization method.

4. CONCLUDING REMARKS

This paper has outlined a new MDC scheme, called the structure unanimity based MDC scheme. The proposed algorithm splits a significant coefficient into one odd coefficient and one even coefficient, by separating odd bits and even bits in the coefficient. Two-phase components are produced from the odd and even coefficients. They are then encoded to form two descriptions and transmitted over different channels. Each description is composed by primary information and the protecting information for the other description. Code words for zero mapping in the redundant data are eliminated for the distribution similarity between primary data and protecting data. With the realization of the proposed MDC scheme by the stack X-tree codec, we have developed the new MDC system. Experimental results have shown that the implementation of the proposed system is simple but the coding results are very good.

5. REFERENCES

[1] A.A. El Gamal and T.M. Cover, “Achievable Rates for Multiple Descriptions,” IEEE Transactions on Information Theory, vol. 28, No. 6, pp. 851-857, Nov. 1982.

[2] L. Ozarow, “On a Source-Coding Problem with Two Channels and Three Receivers,” Bell Systems Technical Journal, Vol. 59, No. 10, pp. 1909-1921, Dec. 1980.

[3] V.A. Vaishampayan, “Design of Multiple Description Scalar Quantizers,” IEEE Transactions on Information Theory, vol. 39, no. 3, pp. 821-834, May 1993.

[4] J.-C. Battlo and V. Vaishampayan, “Asymptotic Performance of Multiple Description Transform Codes,” IEEE Transac-tions on Information Theory,” vol. 43, No. 2, pp. 703-707, March 1997.

[5] Y. Wang, M.T. Orchard and A.R. Reibman, “Multiple De-scription Image Coding for Noisy Channels by Pairing Trans-form Coefficients,” in the Proc. of the First IEEE Workshop on Multimedia Signal Processing, Princeton NJ, pp. 419-424, June 1997.

[6] W. Jiang, and A. Ortega, "Multiple Description Coding via Polyphase Transform and Selective Quantization," Proceedings of VCIP, pp.998-1008, 1999.

[7] C. Cai, S. K. Mitra, and R. Ding, "Smart Wavelet Image Coding: X-tree Approach," Signal Processing, Vol.82, No.2, Feb. 28, 2002, pp. 239-249.

[8] C Cai, T. Yu, S. K. Mitra, and R. Ding, "Stack X-tree Image Coding," Proceedings 2000 IEEE Asia Pacific Conference on Circuits and Systems, Tianjin, China, Dec. 4-6, 2000, pp. 727-730

[9] M. Antonini, M. Barlaud, P. Mathieu, and I. Daubechies, “Image coding using wavelet transform,” IEEE Trans. Image Processing, vol. 1, pp. 205-221, Apr. 1992.

[10] J. M. Shapiro, “Embedded image coding using zerotrees of wavelet coefficients,” IEEE Trans. Signal Processing, vol. 41, pp. 3445-3463, Dec. 1993.

[11] A. Said and W. A. Pearlman, “A new, fast, and efficient image codec based on set partitioning in hierarchical trees,” IEEE Trans. Circuits Syst. Video Technol., vol. 6, pp. 243-250, June 1996.