An Efficient Wavelet Based Multiple Description Coding for Image transmission over Wireless Channel

Santosh Kr. Mishra[1], Saif Ahmad[2], Dr. Rabindra Kumar Singh[3], Mohd Javed Khan[4]
[1, 2, 4] Department of Electronics & Communication Engineering
[3] Department of Electronics Engineering
[1, 2, 4] Integral University, Lucknow, Uttar Pradesh, INDIA
[3] KNIT, Sultanpur, Uttar Pradesh, INDIA

Abstract- *The multiple description coding (MDC) is an efficient way to solve the problem of unreliable channels by means of independent multiple descriptions. In this paper two-description image coding scheme in the wavelet domain is proposed. Here, The two-layered MDC method is implemented here. Firstly the low-frequency wavelet coefficients are divided into two groups and pair wise correlating transform (PCT) was applied on these groups to generate two new correlated groups. Now these two basic descriptions are coded and transmitted through two separate channels. Secondly by the adaptive down-sampling of high frequency wavelet sub bands we can get two enhanced descriptions. Finally the Wavelet Domain Interpolation is used for tree Reconstruction (WDIR) to conceal coefficients loss in spatial orientation tree of wavelet when one enhanced description lost during transmission. By the experimental results we can say that the proposed MDC scheme has good coding performance.*

Keywords- pair wise correlating transform; adaptive down-sampling; multiple description coding; spatial orientation tree.

I. INTRODUCTION

Recently multiple-description coding (MDC) has gained popularity as an effective method to cope with transmission errors when compressed media contents are delivered via error-prone channels or networks. The typical framework of MDC with two descriptions, and two side decoders and one central decoder is depicted in Fig. 1. An input signal $X(k)$ is compressed by MDC into Description 1 and Description 2. If both descriptions are received, then the central decoder can reconstruct the signal $X_0(k)$. But if either one is lost, the side decoder can still reconstruct the signal $X_1(k)$ or $X_2(k)$. Many works are also associated with the design of practical MDC systems, but most of the MDC schemes are implemented with only one method. The pair wise correlating transform (PCT) was used by Wang et al. to generate multiple correlated descriptions in the framework of standard DCT -based image coding [1]. Zhang et al. applied the quincunx sub-sampling directly in image domain to generate two correlated descriptions in JPEG 2000 [2]. Vaishampayan used an image MDC technique that applies MDSQ to the quantization of wavelet coefficients in JPEG 2000 [3]. MDC versions of many popular image coding techniques were also studied, such as SPIHT [4], sub-band coding [5], and wavelet coding [6].

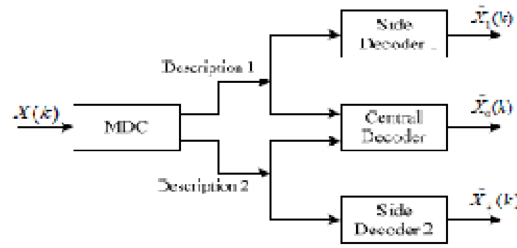

Figure 1. The typical framework of MDC with two descriptions and three decoders.

We proposed in this paper a MDC scheme combing PCT with the adaptive down-sampling based on wavelet. The PCT was used on the low-frequency wavelet coefficients [7], but it has a poor performance. The novelty of our technique is that we not only apply PCT on the low-frequency wavelet coefficients to generate the basic descriptions, but adaptive down-sampling is also used on the high-frequency wavelet coefficients of the highest-level decomposition to get two groups (i.e. the enhanced descriptions), whose coefficients can be the roots of spatial orientation trees according to the Set Partitioning in Hierarchical Trees (SPIHT) [8]. Although the side decoder can easily estimate one basic description from another with the controlled correlation when failure occurred during transmission, it is difficult to estimate one enhanced description from another using the conventional interpolation algorithm due to the feature of spatial orientation tree. To overcome this difficulty, we adopt the WDIR to conceal coefficients loss in Wavelet-Trees when one enhanced description lost during transmission. Similar ideas of WDIR have also been proven to be successful in wavelet domain in [9].

The rest of the paper is organized as follows. Section II discusses the conventional multiple-description transform coding (MDTC). The proposed MDC scheme and its implementation are introduced in Section III. Experimental results are given in Section IV. Finally, Section V concludes.

A. Basic Framework of MDTC

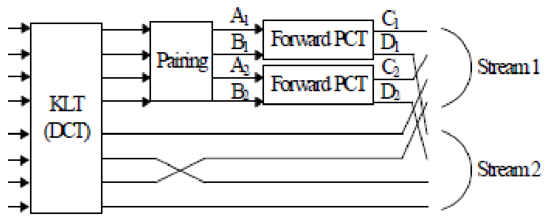

Figure 2. The generalized diagram of the MDTC.

The MDTC was first introduced by Wang in [1]. Fig. 2 shows the generalized diagram of conventional MDTC. Here, the important KLT or DCT coefficients are matched into pairs, a 2X 2 transform is applied to each pair, and one efficient coefficient from each output pair is assigned to each channel as the basic description. This structure maintains de correlation within each channel (by virtue of the independence among pairs), while providing a means to continuously control the correlation between the two descriptions. And the unimportant coefficients are simply divided into two enhanced descriptions. Then we can get coding stream 1 and 2.

B. The Adopted PCT

For sake of simplicity, we only analyze the situation of one pair of variables. An input pair of variables A and B are transformed into C and D, using (subject to detT= 1.)

$$\begin{bmatrix} C \\ D \end{bmatrix} = T \begin{bmatrix} A \\ B \end{bmatrix}$$

The transform matrix T controls the correlation between C and D. In our analysis, we assume A and B are two independent Gaussian variables with zero means and variances.

II. THE PROPOSED MDC SCHEME

According to the characteristics of wavelet image, we know that, the low-frequency subband is the most important factor on the reconstruction of high-quality images, and the other subbands have relatively small effect. Therefore, in order to reduce the redundancy, we only use the PCT on the low- frequency coefficients in wavelet domain to produce two basic descriptions. In above circumstance, the wavelet coefficients need to satisfy the feature of Gaussian distribution from Section II, and Mallat has theoretically proved that the wavelet coefficients of natural image meet the Gaussian distribution [10]. Then we apply the adaptive down-sampling on the high frequency coefficients of the highest-level decomposition to get two parts, which can be the roots of spatial orientation trees according to the Set Partitioning in Hierarchical Trees (SPIHT) [8], so that we can get two enhanced descriptions. Fig. 3 shows adaptive down-sampling on high-frequency bands and how our spatial orientation tree is defined in a hierarchical pyramid constructed with recursive four-coefficient splitting. In this paper, we do not intend to introduce any redundancy into these two enhanced descriptions because the adaptive down-sampling rest on the texture feature of the high frequency subbands. Here, we assume that there are L-level wavelet decompositions in our paper.

The transform matrix T controls the correlation between C and D. In our analysis, we assume A and B are two independent Gaussian variables with zero means and variances.

III. THE PROPOSED MDC SCHEME

According to the characteristics of wavelet image, we know that, the low-frequency subband is the most important factor on the reconstruction of high-quality images, and the other subbands have relatively small effect. Therefore, in order to reduce the redundancy, we only use the PCT on the low- frequency coefficients in wavelet domain to produce two basic descriptions. In above circumstance, the wavelet coefficients need to satisfy the feature of Gaussian distribution from Section II, and Mallat has theoretically proved that the wavelet coefficients of natural image meet the Gaussian distribution [10]. Then we apply the adaptive down-sampling on the high frequency coefficients of the highest-level decomposition to get two parts, which can be the roots of spatial orientation trees according to the Set Partitioning in Hierarchical Trees (SPIHT) [8], so that we can get two enhanced descriptions. Fig. 3 shows adaptive down-sampling on high-frequency bands and how our spatial orientation tree is defined in a hierarchical pyramid constructed with recursive four-coefficient splitting. In this paper, we do not intend to introduce any redundancy into these two enhanced descriptions because the adaptive down-sampling rest on the texture feature of the high frequency subbands. Here, we assume that there are L-level wavelet decompositions in our paper.

A. The Proposed Coding Algorithm

1) The PCT and coding on the low-frequency sub band:

We assume that the number of the low-frequency coefficients is N , the N coefficients are ordered to have decreasing variance. Then using a pairing algorithm, these N coefficients are split into $N/2$ pairs, A_m ,B_m ,m=1,2, …….N / 2, which are transformed using the optimal transform in Section 2, to yield C_m, D_m , m=1,2,…….,N/2. Putting the pixel coordinates of A_m and B_m (m □1, 2,……,N / 2) in the list *LIP*1 and *LIP*2 , are lists of insignificant pixels, which can be coded using the coding method of the LIP based on SPIHT algorithm [8]. So we can obtain the basic stream one and two.

1) The side decoding:

Here, we discuss the situation that only one description is received. If only one basic stream is received, then the conditional mean predictor described in (3) are used to recover a pair of original coefficients from each received variable. For the enhanced description, the missing coefficients are simply replaced by zeros because their loss does not cause a severe visual distortion. But if one enhanced description is also received, we need to interpolate the absent enhanced description from the received enhanced description.

This appears to be relatively easy for reconstruction of the three high-freq. sub bands (HL_L, LH_L, HH_L) of highest decomposable level because each missing pixel in these sub bands has the decoded values of its two or four connected neighbors. According to the adaptive down-sampling and characteristics of wavelet coefficients, we know that the HL frequency sub bands have more texture information of vertical direction, and the LH-frequency sub bands have more texture information of horizontal direction, and the HH-frequency have more texture information of diagonal direction.

2) The central decoding:

When two descriptions are simultaneously available at the decoder. If only two basic descriptions are received at the decoder, then the original coefficient pairs are obtained through the inverse of the PCT.

If the both enhanced descriptions are also received, then merge the two decoded adaptive down-sampling images directly. And if there is only one enhanced description is received, we can interpolate the absent enhanced description according Section 1) Then we get the reconstruction of original image with the inverse of DWT.

IV. EXPERIMENTAL RESULTS

Experiments are conducted and the results are presented in this section to evaluate the performance of the proposed image MDC scheme. We demonstrate our results on the standard

TABLE I. COMPARISON OF PSNR RESULTS FOR PROPOSED, MDSPIHT, AND WMDTC AT 0.5 BPP

Image	MD-SPIHT	WMDTC	Proposed
Lena	17.02	21-99	24.57
Sailboat	16.26	21.83	24.25
Baboon	17.10	22.05	24.72
Barbara	16.07	21.65	23.94

The unit of PSNR is dB

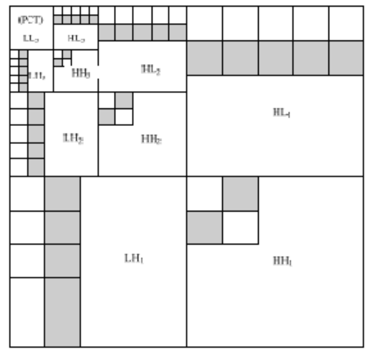

Figure 3. Example of the adaptive down-sampling on the high-frequency subbands and the parents-descendants dependencies in the spatial-orientation tree.

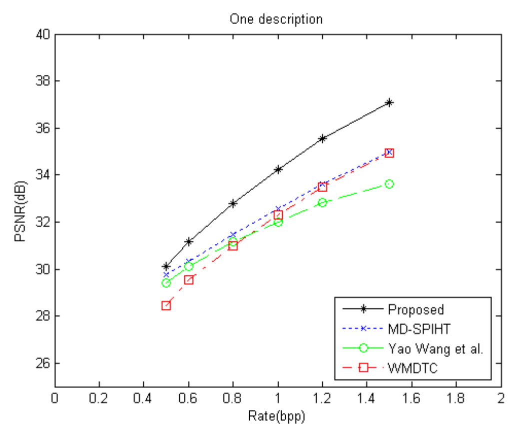

Figure 4. The PSNR and rate curves of side decoding.

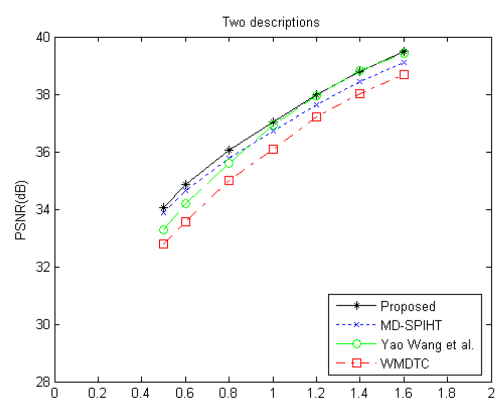

Figure 5. The PSNR and rate curves of central decoding

512 X 512 gray-scale image and use different levels of DWT decomposition to analyze the performance. Four test images (Lena, Sailboat, Baboon, Barbara) are used in Table I. And we set the number of level to 5 and compare our scheme with MD-SPIHT [4] in which the controlled amounts of redundancy are added to the original data during the compression process. We also compare the proposed method with WMDTC [7], which uses PCT on low-frequency subband only. Obviously, our scheme clearly surpasses MD-SPIHT and WMDTC when only one description is received. For further evaluation, several test images are applied in different MDC schemes. Some simulation results are presented in Fig. 4. It can be seen that the proposed method achieves a good trade-off between the coding efficiency and the reconstruction quality when only one description is available. Here, we compare our scheme with the MDC method of Yao Wang et al [1], who use PCT in JPEG algorithm, so much of the discrepancy between these results may be due to the choice of source coding algorithm. But the proposed scheme is more effective than MD-SPIHT and WMDTC. The last experiment is designed to evaluate the performance of the proposed image MDC when two descriptions are received. Fig. 5 shows that our results surpass those of WMDTC, MD-SPIHT and Yao Wang et al. at both low and high bit rate.

V. CONCLUSIONS

This paper proposes a new and effective MDC scheme on wavelet domain. The PCT and adaptive down-sampling are used on the low-frequency subband and high-frequency subbands separately in this scheme. So we can obtain the basic description and the enhanced description, which are coded respectively. And the unequal loss protection can be also used in different types of descriptions. The experimental results show that the proposed scheme outperforms the MDC method of Yao Wang et al, WMDTC and MD-SHIHT scheme in side decoding, and achieves a satisfactory quality in central decoding. There are some issues to be further investigated in the future. First, the proposed scheme only uses PCT on the low-frequency wavelet coefficients and it didn't introduce redundancy on the high-frequency coefficients. So we should consider how to use the PCT on the high-frequency coefficients. Second, the pairing algorithm before PCT should be improved. Finally, the reconstructed technique of ighfrequency coefficients should be further studied in side decoder.

REFERENCES

[1] Y. Wang, M. T. Orchard, and A. R. Reibman, "Multiple description coding for noisy channels by pairwise transforms coefficients," in Proc. Workshop on Multimedia Signal Processing, pp. 419-424, 1997.

[2] N. Zhang, Y. Lu, F. Wu, X. Wu, and B. Yin, "Efficient multipledescription image coding using directional lifting-based transform," IEEE Trans. On Circuits and System for Video Technology, vol. 18, no. 5, pp. 646-656, 2008.

[3] V. A. Vaishampayan, "Application of multiple description codes to image and video transmission over lossy networks," in Proc. International Workshop on Packet Video, pp. 55-60, Australia, 1996.

[4] A. C. Miguel, A. E. Mohr, and E. A. Riskin, "SPIHT for generalized multiple description coding," in Proc. International Conference on Image Processing, vol. 1, pp. 842-846, 1999.

[5] M. Srinivasan and R. Chellappa, "Multiple description subband coding," in Proc. International Conference on Image Processing, vol. 1, pp. 684-688, 1998.

[6] S. S. Channappayya, J. Lee, R. W. Heath, and A. C. Bovik, "Frame based multiple description image coding in the wavelet domain," in Proc. International Conference on Image Processing, vol. 3, pp. 920-923, 2005.

[7] J. Liu and Y. Yu, "Research on multiple descriptions transform coding algorithm based on wavelet," Computer Application, vol. 25, no. 2, pp. 317-319, 2005.

[8] Amir Said and William A. Pearlman, "A new, fast, and efficient image codec based on set partitioning in hierarchical trees," IEEE Trans. On Circuits and System for Video Technology, vol. 6, no. 3, pp. 243- 249, 1996.

[9] G. Ma, B. Guo, and Z. Feng. "An approach of wavelet domain interpolation for image reconstruction in transmission," ACTA ELECTRONICA SINICA, vol. 30, no. 4, pp. 552-555, 2002.

[10] Mallat S G, "A theory for multi-resolution signal decomposition: the wavelet representation," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 11, no. 7, pp. 674-693, 1989. Authorized