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Min Wu, Anthony Vetro, Chang Wen Chen

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Abstract

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Min Wu[a], Anthony Vetro[b] and Chang Wen Chen[c]

[a] Dept. of ECE, University of Missouri-Columbia, Columbia, MO, USA
[b] Mitsubishi Electric Research Laboratory, Boston, MA, USA
[c] Dept. of ECE, Florida Institute of Technology, Melbourne, FL, USA

ABSTRACT

Multiple description coding (MDC) is a source coding technique that involves coding the source information into multiple descriptions. When these descriptions are transmitted over different channels in packet network or error-prone wireless environment, graceful degradation can be achieved even if part of descriptions are not received by the receiver. When MDC is applied to wavelet subband based image coding, it is possible to introduce correlation between the descriptions in each subband. In this paper, we consider using such a correlation as well as potentially error corrupted description as side information in the decoding to formulate the MDC decoding as a Wyner Ziv decoding problem. If only part of descriptions is lost, however, their correlation information is still available. Therefore, the proposed Wyner Ziv decoder can recover the description by using the correlation information and the error corrupted description as side information. High quality reconstruction can still be obtained by combining the decoded descriptions from Wyner Ziv decoder. The proposed scheme takes advantage of an efficient way to use the correlation information, thus makes the system more robust to channel error corruption. Experimental result shows that, comparing to conventional multiple description wavelet based image coding, the PSNR of the received and decoded image could be improved noticeably when coding at the same bit rate.

Keywords: Multiple description coding, Wyner-Ziv coding, wavelet based coding, MDSQ

1. INTRODUCTION

The transmission of multimedia data over packet network or error-prone wireless environment has motivated the research on multiple description coding (MDC). The source information is encoded into multiple descriptions which are transmitted over difference channels to the receiver. When all the descriptions are available at the receiver, a high quality reconstruction of the source can be obtained by combining all descriptions. However, in the absence of some of the descriptions at the receiver, the quality of reconstruction should still be acceptable. The quality of reconstruction usually degrades

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Athor information: (Send correspondence to)
Min Wu: E-mail: mwu@ee.missouri.edu, Telephone: 1 573 884 0097
Anthony Vetro: Email: avetro@merl.com 1 617 621 7591
Chang Wen Chen: Email: cchen@fit.edu Telphone: 1 321 674 8769

gracefully with the number of lost descriptions. Reconstructing a source with acceptable quality in the absence of one description at the receiver requires the two descriptions to be adequately correlated. The higher the correlation, the lower the difference between central and side distortion. Therefore, in MDC, source coding efficiency will be sacrificed and redundancy is increased. The tradeoff between the central and side distortion is controlled by the correlation between the descriptions.

In this paper, we consider two-channel two-description MDC. A source is described by two descriptions at the rates of R_1 and R_2. These two descriptions individually lead to reconstruction with side distortion D_1 and D_2, respectively. The two descriptions together yield a reconstruction with central distortion D_0. Rate-distortion theoretic results on MDC of memoryless source are presented in [1] and [2]. Ozarow gives an achievable region for two-description coding of one source. When the descriptions are individually good, a further inequalities gives $D_0 \geq min\{D_1, D_2\}/2$, so that the joint description is only slightly better than the better of the two individual descriptions. When the joint description is as good as possible, reconstruction is poor for individual description.

Many research efforts are aimed at developing efficient and reliable MDC scheme [3], [4]. Servetto proposed wavelet based multiple description image coding system, in which MDC is applied to wavelet subband to get better rate and redundancy allocation than block-based MDC approaches. Agnieszka applied SPIHT to multiple description coding system [5]. Redundancy in this system consists extra copies of zerotree in each description. Philip proposed the layered MDC [6]. Different layer descriptions are generated for different bandwidth channels. Unequal protection is applied to different layer of source information based on its importance in transmission.

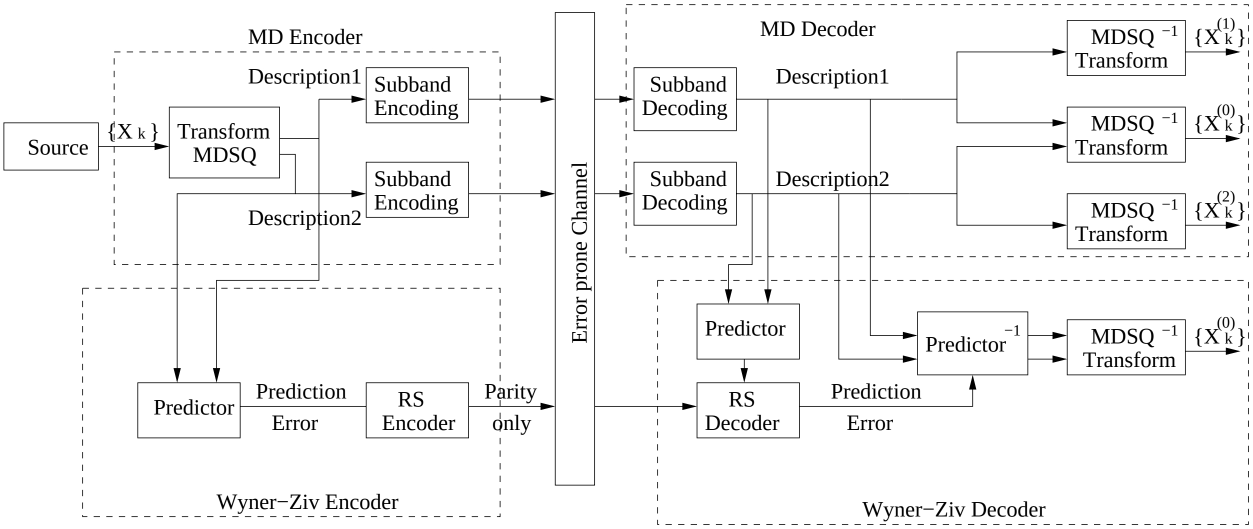

Figure 1: Block Diagram of proposed System

In this work, instead of adding redundancy of subband information, we consider exploiting correlation information between two descriptions. The proposed scheme is shown in Figure 1. The source is MD encoded into two descriptions which are transmitted through different channels. The correlation information is encoded by systematic RS encoder. Only the parity bits are transmitted through the channel. At the receiver, when all descriptions are available, the decoder yield high quality reconstruction by combining all the descriptions. When part of description are lost, however, their correlation information are still available at the receiver, the Wyner Ziv decoder can still recover the description by using the correlation information and the received noisy description as the side information. High quality reconstruction can still be obtained by combining the decoded descriptions that are the output of Wyner Ziv decoder. The proposed scheme takes advantage of the fact that the correlation information can be encoded in very efficient way. Thus the overall coding efficiency can be improved, and we are able to obtain more graceful degradation when transmitting over unreliable channels.

The rest of this paper is organized as follows. In section 2, we describe in detail our approach the proposed MDC scheme. Experimental results are presented in section 3 to confirm the improvement of PSNR of the proposed approach. Section 4 concludes this paper with a summary and some discussions.

2. THE PROPOSED APPROACH

In this section, we describe in detail the correlation properties between two descriptions. We also outline the strategy to use such correlations in decoding. In addition to the conventional MDC codec adopted in our scheme, we add Wyner Ziv codec in our system. We will show how to use Wyner Ziv coding to combat pack loss when transmitting over unreliable channel.

2.1. Background

In MDC system, the descriptions are generated in such a way that basic quality of reconstruction can be achieved by each individual description, the quality increases smoothly with the number of received descriptions. Vaishampayan proposed the first constructive approach towards a practical MD scheme by using multiple description scalar quantization (MDSQ) [7] to generate descriptions. A simple example of MDSQ is shown in Figure 2. S_1 and $_2$ represent two side quantizers with quantization index $i, j \in \{1, 2, ..., M\}$, while C represents central quantizer with quantization index $k \in \{1, 2, ..., N\}$. The cell of central quantizer is the intersections of cells of the two side quantizers. The mapping of central quantization index to a pair of side quantization indices is shown by a $M \times M$ matrix. The matrix entries represent the index of central quantizer. The row and column indices represent the two side quantization indices i and j respectively.

If both descriptions are available at the receiver, the central decoding can be performed by simple matrix lookup to get the central quantization index. With only access to one description at the receiver, the decoder uses received side quantization index in reconstruction. Since $N < M^2$, the side descriptions contain redundancy and therefore are correlated. The redundancy is controlled by choosing the number of diagonals covered by the index assignment. The correlation between the two indices i and j is inversely proportional to the number of diagonals used. There is a tradeoff between the correlation and the difference among side and central distortions. To illustrate this trade off, we use MDC algorithm in [3] to generate two descriptions of Lena image with 0.5 bpp each, and calculate the PSNR of reconstructed images by central and side decoder. Table 1 shows the results based on different number of diagonals. The correlation between descriptions decreases as the number of diagonals in index assignment matrix increases; while the side distortion increases as the central distortion decreases. A good trade-off between the central and side distortion will get a graceful degradation when part of descriptions is lost.

The optimal solution for the index assignment for MDSQ has been stated in [7]. In those recent subband based MDC schemes, the coding efficiency is improved, and bit allocation for redundancy is more flexible than block based MDC system. In those systems, the redundancy consists of repeats or forward error coding protections of low frequency subband information. In the MDC system, the correlation between descriptions can be computed from the matrix of the corresponding index

Table 1: Central and side distortion based on different correlation

Number of diagonals	PSNR of recon image by side decoder(dB)	PSNR of recon image by central decoder(dB)
2	35.4	38.4
3	32.4	39.0
5	26.7	39.3

assignment. We also observe that the correlation can be used in very efficient way. Therefore, careful consideration using the correlation information in the encoding and decoding will improve the overall coding efficiency.

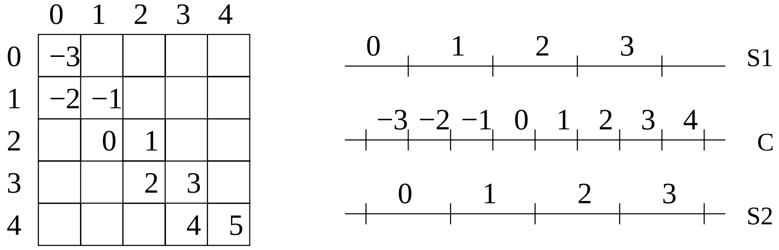

Figure 2: Multiple Description Scalar Quantizer

Wyner Ziv coding refers to lossy source coding with side information at the decoder. Figure 3 shows the basic structure of Wyner Ziv codec. Consider two statistically dependent discrete signals, X and Y. which are compressed using two independent encoders but decoded by a joint decoder. The well-known Slepian-Wolf Theory on distributed source coding states that even if the encoders are independent, the achievable rate region for probability of decoding error to approach zero is $R_x \leq H(X|Y)$, $R_y \leq H(Y|X)$, and $R_x + R_y \leq H(X, Y)$ [8]. The counterpart of this theorem for lossy source coding is pioneering work by Wyner and Ziv on source coding with side information [9]. Let X and Y be statistically dependent Gaussian random process, and let Y be known as side information for encoder X. Wyner and Ziv showed that the conditional Rate Mean Squared Error Distortion function for X is the same as the case when the side information Y is available only at the decoder, or at both encoder and decoder. Recently, Wyner-Ziv coding has been used in distributed source coding because the encoders can compress source, but do not have to communicate with each other to exploit the correlation. A joint decoding is performed at decoder with side information. In Wyner-Ziv video coding [10], [11]. The side information is an estimated frame by interpolation or motion estimation. The estimated frame can be viewed as noisy version of the reconstructed frame. The reconstruction is successful if the estimate error could be corrected by the syndrome decoder.

2.2. The Proposed Approach

In our proposed system, we use wavelet transform in our subband decomposition. Each subband is quantizer using MDSQ. Two descriptions are generated based on the two side quantizers. Each description is subband entropy encoded, and then transmitted over different channels. Since the two descriptions are highly correlated. At the encoder, we can use one description to predict the other description. The correlation between the two descriptions is represented by the prediction error. The

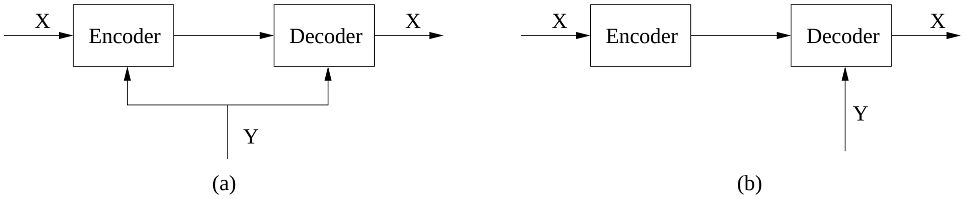

Figure 3: Wyner Ziv Coding

key feature of such correlation information is that the dynamic range of prediction error is small, which is decided by the number of entries in one column or row in the index assignment matrix. If the number of diagonal is two, the prediction error is only one bit per pixel in each subband. Therefore, the correlation information can be encoded in very efficient way. In our system, the prediction error of each subband is fed to a matrix row by row. Each column is encoded by a systematic Reed Solomon encoder. If one packet is lost, only one symbol in each column is lost. The lost symbol could be recovered by parity check bit. Prior to transmission, the systematic bits are discarded, and only the parity check bits form the Wyner Ziv bitstream which will be sent over the noisy channel to the receiver.

At the decoder, when both descriptions are available, the central decoder combines both descriptions to generate high quality reconstruction. If packet loss occurs during transmission, some of subbands are lost; however, their parity bits are assumed available. The partly received description can be viewed as noisy version of the error free description. Wyner Ziv decoder takes parity bits stream and the noisy version of the description as side information. The output from Wyner Ziv decoder will be an error free description if the channel errors can be corrected by RS decoder. The correct descriptions are then sent to central decoder to reconstruct the high quality image. If both part of descriptions and their corresponding correlation information are lost. The received description is sent to side decoder to yield an acceptable image construction.

In our system, the amount of redundancy is controlled by the coding rate of RS encoder. Careful analysis of the correlation properties of multiple descriptions shows that the MD coders are joint source and channel codes. To achieve optimal bit allocation of the redundancy for each subband, we adopt similar method in [12]. We use an algorithm to compute an optimal amount of redundancy assigned to wavelet coefficient subbands. The allocation algorithm is based on rate distortion trade off. For a given rate, the algorithm minimizes the expected distortion of the received data subject to a description loss model.

3. EXPERIMENTAL RESULTS

The proposed system works as follows. First, a given input image is decomposed into subbands, and then a uniform scalar quantizer is applied to each of the subband coefficients, thus, producing a quantized field. Two descriptions of this field are created, by mapping each quantized coefficient to a pair of numbers, using the index assignment component of a MD quantizer. The encoder is then split into two parts. The first part is traditional wavelet based subband MD scheme. All subband descriptions are entropy coded independently to each other. The encoded bits are then packaged and transmitted through error prone channel. The second part is Wyner Ziv encoder. Since the two descriptions of each subband are highly correlated, for each subband, we use one description to predict the other. The prediction error is then channel encoded by systematic RS encoder as shown in Figure 3. The coding rates for subband prediction error are determined by the algorithm in [12]. The systematic

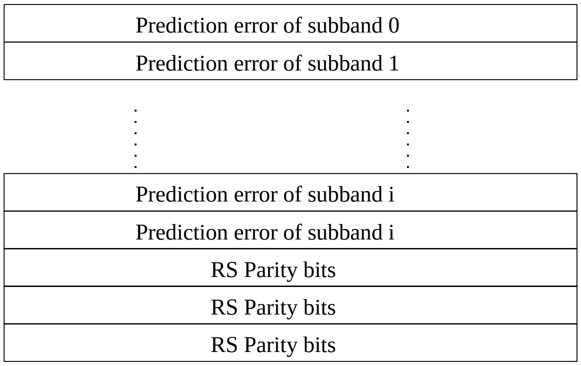

Figure 4: RS encoder of prediction error

bits are discarded. Only the parity bits form the Wyner Ziv bitstream, and are packaged and sent over the error prone channel.

In order to decode the received bitstream, three steps need to be performed. First, packets are collected and individual descriptions have to be entropy decoded. If both descriptions arrive at the receiver, then, prior to inverse quantization the two descriptions have to be recombined by inverting the index assignment. Secondly, If one description and parity bits are available, then, we assume part of one description is lost due to the packet loss. In this case, we use Wyner Ziv decoder to recover the packet loss. Some slices of subband may be lost after entropy decoding. We follow the same procedure in Wyner Ziv encoder, using one decoded description to predict the other. The prediction errors are then feed into the same matrix shown in Figure 3. The packet loss will cause the prediction error mismatch between the encoder and the decoder. If the mismatch can be corrected by RS decoder, we can recover the correct prediction error. The correct description could be recovered by inverse the prediction process. The two descriptions are then sent to central decoder to yield high quality reconstruction. Thirdly, if one of the descriptions and corresponding parity bits are lost, then the available description is dequantized using single channel inverse quantizer, and then the wavelet decoding process is performed. In this case, we yield the single channel image estimation.

To validate the robustness of the proposed system to packet loss, we tested the quality of reconstruction image based on different packet loss rates. The test is performed on Lena image and two descriptions are generated. Each description is 0.5 bpp. Figure 5 shows the reconstruction quality. When packet loss rate is less than 0.03, the proposed scheme is a little worse than Servetto's scheme because of the effects of side distortion. When packet loss rate is higher than 0.03, the PSNR of our scheme is consistently better than the scheme proposed by Servetto by 0.5-1 dB.

4. SUMMARY AND CONCLUSIONS

In this paper, we proposed a multiple description coding system with side information. We analyzed the correlation property between the descriptions in subband coding system. Instead of adding redundancy information of low frequency subband, we consider using the correlation of multiple description and partly received description in the decoding. We adopted the Wyner Ziv codec in our system. If only part of descriptions are lost, then, their correlation information is still available, the Wyner Ziv decoder can recover the description by using the correlation information and the received noisy description as side information. High quality reconstruction can still be obtained by combining the

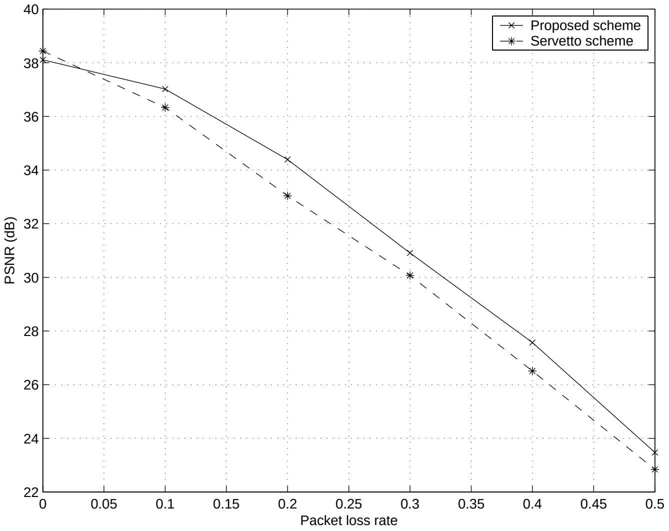

Figure 5: Reconstruction quality vs. packet loss rate

decoded descriptions from Wyner Ziv decoder. The proposed scheme takes advantage of an efficient way of using the correlation information, thus improves the overall coding efficiency, especially for error prone transmission of compressed images. Experimental result shows that, comparing to conventional multiple description wavelet based image coding, the PSNR of the received and decoded image could be improved noticeably when coding at the same bit rate.

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