효율적인 분산 동영상 압축을 위한 채널 분할 기법

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CDV-DVC: Channel Division for Efficient Distributed Video Coding

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Abstract

This paper presents a Channel DiVision (CDV) scheme for transform-domain distributed video coding. In the proposed system, we employ the symmetric motion estimation to generate high quality side information for Wyner-Ziv (WZ) frames. Also, the decoder estimates the distortion of the side information, which is used to classify the transmitting channels for WZ frames. Each channel has a different expected noise. Then, the encoder allocates an appropriate number noise. Then, the encoder allocates an appropriate number present rate-distortion performance results and comparisons with existing state-of-the-art algorithms and H.264.

1. INTRODUCTION

Distributed video coding (DVC) is a video coding paradigm with target applications that require low-complexity encoding, e.g., wireless sensor networks and mobile encoding devices. One of the most common architectures is based on the work of Girod *et al.* [1]. They achieve low encoding complexity by generating the prediction of a video signal at the decoder. It is called side information, which is reconstructed at the decoder using parity bits. Based on this architecture, various DVC researches have been conducted. Early studies focused on finding the proper tools for DVC architectures from conventional video coding algorithms. The transform and adaptive quantization schemes have been adopted and various channel codes have been used. Although these efforts have enhanced the rate-distortion (R-D) performance of DVC, its practical use is still limited due to the delay of feedback channel and poor compression performance.

The poor compression performance of DVC is a serious problem, limiting its practical applications. An efficient way to increase the R-D performance is to minimize the error of side information, since it has strong impacts on the amount of parity bits. Therefore, efforts have been made to generate better side information [2, 3]. Meanwhile, some papers suggested that the R-D performance gets increased by zero bit allocation to sufficiently fine regions of side information [4, 5].

In this work, we introduce a novel concept of channel division to improve the performance of DVC. It is based on our previous work [5], but we improve the side information generation and the minimum rate estimation. To obtain higher quality side information, the proposed algorithm employs the symmetric motion estimation, which minimizes the forward and backward matching costs simultaneously. Moreover, we perform the hierarchical motion estimation and refinement with the distortion estimator. After the side information generation, the proposed algorithm classifies blocks into reliable blocks and unreliable blocks, which can be regarded as the channel division. Then, parity blocks are not transmitted for reliable blocks, as in the skip-mode, reducing the overall bitrate. Simulation results demonstrate that the proposed algorithm provides better R-D performance than the-state-of-the-art-algorithms [6].

2. Proposed Algorithm

Fig. 1 shows the block diagram of the proposed algorithm, which is based on our previous work [5]. First, an input sequence is split into two parts: key frames and WZ frames. The DVC performs frame interpolation at the decoder to create the side information frames using neighbor frames based on a group-of-pictures (GOP) structure. We adopt a rigid, fixed GOP size in this work. Then, each key frame is encoded and decoded using the traditional H.264/AVC intra coding scheme.

At the decoder, the side information $\widehat{W}$ generated

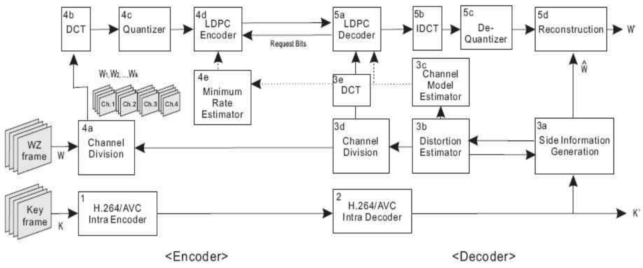

Fig. 1. The Proposed DVC algorithm.

for a WZ frame W based on the motion compensated interpolation from adjacent key frames. To improve the quality of $\widehat{W}$ we propose the hierarchical symmetric motion estimation. After constructing the side information, the decoder estimates the distortion of the side information and refines unreliable blocks with differently weighted motion estimation. Then, the refined $\widehat{W}$ is divided into multiple sub-frames $\widehat{W}'$s with different expected distortions. The decoder transmits the channel division information to the encoder through a feedback channel. Meanwhile, based on the estimated distortions, we analyze the noise characteristics of each channel.

At the encoder, the WZ frame W is divided into multiple sub-frames $\widehat{W}'$s using the channel division information. Then, each sub-frame is transformed and quantized into bit planes. The parity bits for the bit planes are generated by the low density parity check (LDPC) coder. We assign a different amount of parity bits to each sub-frame W_i, which is interpolated at the decoder with a different expected distortion. Since the blocks of the most reliable channel has a sufficient fidelity, we can save the parity bits for that region as a skip-mode.

A. Generation of Side Information

How to generate the side information at the decoder influences significantly the rate-distortion performance of the Wyner-Ziv video codec. Thus, extensive research efforts have been made for the frame interpolation scheme at the decoder. In the direct prediction [2], to motion compensate a block of Wyner-Ziv frame, the motion vector of the co-located block in the backward reference frame X_b to the forward reference frame X_f is estimated and scaled by a factor of 2. Ascenso *et al.* [3] proposed a spatial motion smoothing algorithm, which can alleviate the distortions in the side information using the weighted vector median filter. We improve Ascenso's algorithm using the symmetric motion estimation module [5].

Fig. 2 illustrates the proposed side information generation scheme. A motion field closer to the true motion is estimated between the backward and the forward reference frames. To avoid incorrect results due to uni-directional motion estimation, we find

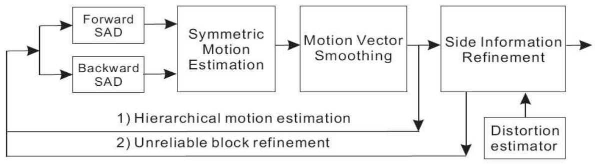

Fig. 2. The proposed scheme for side information generation.

the symmetric motion vector for a block that minimizes the sum of the forward sum of absolute differences (SAD) and the backward SAD. Then, the spatial motion smoothing based on a weighted vector median filter is applied to the motion field to remove outliers. In this work, we estimate motions using variable block sizes and refine the motions of unreliable blocks.

Hierarchical motion estimation: The motion estimation is performed hierarchically using block sizes 16x16, 8x8, and 4x4. When smoothing the motion vectors, a resulting motion vector is influenced by its upper level blocks and its neighbor blocks at the same level. The motion vectors at the bottom-level are amended in the same way to be closer to the true motion field.

Side information refinement: The side information refinement module utilizes the estimated distortion costs, which are based on three criteria: the bilateral term, the side matching term, and the motion vector term [5]. By comparing the distortion index of a block against a threshold, we determine multiple sub-frames with different expected distortions. The worst channel, consisting of unreliable blocks, need to be refined. To this end, we add the bilateral term and the side matching term into the cost function and minimize it with weighting factors.

B. Channel Division and Modeling

Using the distortion indices, we classify blocks in a side information frame into *k* categories. In other words, we divide the virtual channel into *k* sub-channels. Channel 1 is the least noisy channel, while channel 4 is the noisiest channel. In the case of channel 1, it is not necessary to transmit parity bits, since it only wastes the limited bit budget. On the other hand, for the other channels, the bit allocation is carried out adaptively according the amounts of channel noises.

The proposed algorithm uses the Laplacian distribution to model channel noises The Laplacian distribution parameter is estimated at the decoder based on the temporal and spatial variations of the noise statistics [5].

3. Experimental Results

We evaluate the performance of the proposed algorithm using two test sequences *Mother & Daughter*, *Foreman*, which have the QCIF@15Hz format with a GOP length of 2. Key frames are encoded with the H.264/AVC intra coder (main profile), and the quantization parameter (QP) for each R-D point is chosen so that the average quality of the WZ frames is similar to the quality of

	Mother & daughter		Foreman	
	QP=28	QP=20	QP=28	QP=20
Direct Prediction [6]	34.54	35.31	32.49	33.64
Ascenso [7]	35.12	36.04	33.56	34.78
Proposed	35.65	36.53	33.75	34.92

Table 1. Objective quality comparison for interpolated SI.

the key frames. For comparison, a similar *I-B-I-B* GOP structure is adopted for the H.264/AVC interframe coding with no motion.

Table 1 compares the side information generation results, which are obtained by the direct prediction algorithm [2], the smoothing algorithm [3] and the proposed algorithm. We see that the proposed algorithm significantly outperforms the other algorithms. For example, the proposed algorithm improves the quality up to 1.22dB for the *Mother & Daughter* sequence. On average, the proposed algorithm yields about 0.4 dB better PSNR performance on the test sequences than the smoothing algorithm [3].

Next, Fig. 3 evaluates the R-D performance of the proposed CDV-DVC algorithm in comparison with the state-of-the-art DVC algorithm DISCOVER [6] and the H.264 standard. Compared to DISCOVER, the proposed algorithm improves PSNR performances up to 0.7 dB for the *Mother & Daughter* sequences. However, the proposed algorithm is inferior to DISCOVER on the *Foreman* sequence. This is because, for the fast moving *Foreman* sequence, the computed side information is not well correlated with the original signal and the linear motion assumption is violated in fast moving regions. However, we observe that the proposed algorithm improves the R-D performance on average by allocating bits adaptively according to the characteristics of the side information, especially on slow motion sequences.

4. Conclusions

In this work, we proposed an efficient DVC algorithm using the symmetric motion estimation with refinement module and the channel division. The proposed algorithm divides the virtual noisy channel from the encoder to the decoder into multiple channels, analyzes the noise characteristics of each channel, and uses an adaptive LDPC coding tailored to the noise characteristics. Experimental results demonstrated that the proposed algorithm provides better PSNR performance than the state-of-the-art algorithm, especially on slow motion sequences.

The notion of channel division is novel and promising. Future research issues include the development of more accurate reliability estimation of blocks in side information frames.

5. References

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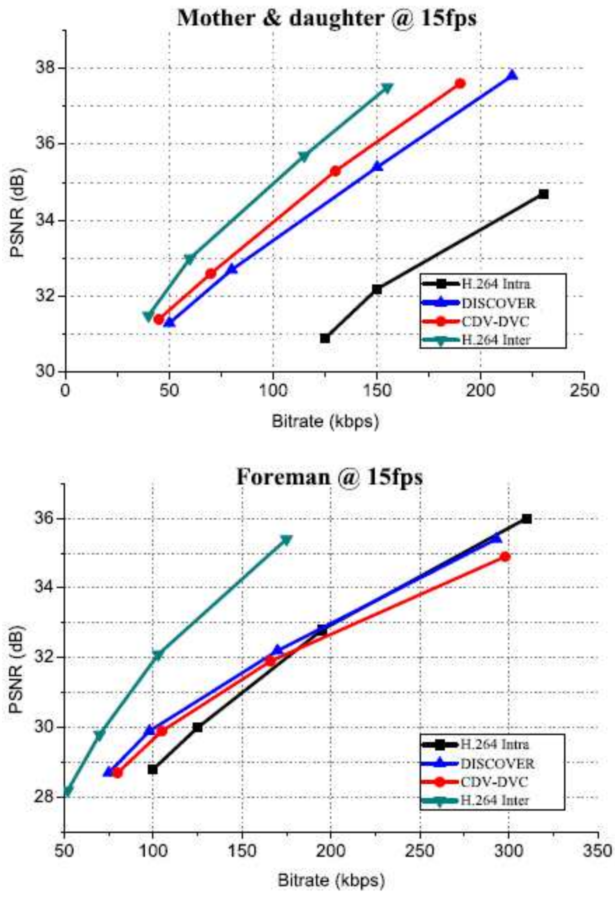

Fig. 3. R-D performance comparison of the proposed CDV-DVC system for the QCIF sequences.