

# Distributed Video Coding for Illumination Compensation of Multi-view Video

Seanae Park<sup>1</sup>, Donggyu Sim<sup>1</sup> and Byeungwoo Jeon<sup>2</sup>

<sup>1</sup> Department of Computer Engineering, Kwangwoon University  
Seoul, Korea

[email: {pseal118, dgsim}@kw.ac.kr]

<sup>2</sup> School of Information and Communication Engineering, Sungkyunkwan University  
Suwon, Gyeonggi-do, Korea

[email: bjeon@skku.edu]

\*Corresponding author: Donggyu Sim

*Received July 12, 2010; revised August 17, 2010; accepted September 12, 2010;  
published December 23, 2010*

---

## Abstract

In this paper, we propose an improved distributed multi-view video coding method that is robust to illumination changes among different views. The use of view dependency is not effective for multi-view video because each view has different intrinsic and extrinsic camera parameters. In this paper, a modified distributed multi-view coding method is presented that applies illumination compensation when generating side information. The proposed encoder codes DC values of discrete cosine transform (DCT) coefficients separately by entropy coding. The proposed decoder can generate more accurate side information by using the transmitted DC coefficients to compensate for illumination changes. Furthermore, AC coefficients are coded with conventional entropy or channel coders depending on the frequency band. We found that the proposed algorithm is about 0.1~0.5 dB better than conventional algorithms.

---

**Keywords:** Video coding, distributed video coding, multi-view video coding, illumination compensation, sub-band coding

## 1. Introduction

With the evolution of video processing techniques from analog to digital, users are being offered higher-quality video services. This provides consumers with more realistic experiences from diverse multimedia services. High-definition television (HDTV) services based on digital video compression and transmission are currently provided in many countries and have been rapidly replacing existing NTSC/PAL service. Terrestrial and satellite digital multimedia broadcasting (T-DMB and S-DMB) have been commercialized in Korea as mobile television services. With these technologies, we can easily enjoy higher-quality video without being restricted by location. However, these 2D single-view services cannot provide realistic 3D effects. Humans perceive 3D effects by observing two different views through two eyes. Thus, single-view video cannot produce 3D effects. Demand for digital multimedia services is changing from simple high-quality 2D services to 3D video services. In 2007, MPEG initiated a multi-view video coding (MVC) standardization to support these demands. The Joint Video Team (JVT) recently released an international standard for MVC, H.264/AVC amendment 4 [1]. MVC was designed by exploiting both temporal redundancy and inter-view redundancy. However, although this coding structure increases coding efficiency, the encoder is quite complex owing to the inter-view prediction needed to achieve the coding gain. Furthermore, a large amount of bandwidth among view encoders is required to exploit inter-view prediction.

Distributed video coding (DVC) approaches have been proposed to reduce the complexity of video encoders by migrating the computational load from the encoder side to the decoder side. This technology will be used for encoders having such characteristics as low-power and/or error resilience. Motion estimation is the most complex component of current encoders such as H.263, H.264/AVC, and MPEG 1/2/4. While conventional video codecs employ motion estimation at the encoder side, the theory developed by Slepian-Wolf [2] leads to a video codec in which temporal prediction is performed at the decoder side. Wyner and Ziv applied quantization to the Slepian-Wolf coder; the Wyner-Ziv (WZ) coder is considered to be a milestone and is a principal distributed video codec [2][3]. Inspired by this work, the DISCOVER project was conducted in Europe, and several DVC projects have been carried out [4][5].

X. Guo et al. applied this DVC technology to MVC [6]. F. Dufaux et al. also presented advanced MVC using DVC technologies [7]. The MVC technology standardized by MPEG [1] can improve the coding gain by exploiting inter-view prediction, which is quite complex. Several tools were proposed for improving the coding efficiency of MVC during the standardization process. Illumination compensation is one algorithm that can improve the coding efficiency. Differences in camera parameters and other factors cause illumination differences between adjacent views of the same object at a single time. An illumination compensation method was proposed to reduce bit-saving and to improve video quality by sending the difference value as an additional DC value [8].

A simple approach to applying DVC to MVC is to generate side information (SI) by both temporal and inter-view interpolation. The performance of DVC is strongly affected by the accuracy of the SI. However, the SI in distributed multi-view video coding (DMVC) can be influenced by camera parameters and illumination conditions. Illumination compensation was proposed to improve the coding efficiency of MVC, and the efficacy of the algorithm was proven with extensive experiments. In this paper, we propose a DMVC algorithm for a low-complexity multi-view system. In the proposed algorithm, illumination information is

coded separately, and the DMVC SI can be robustly estimated regardless of illumination changes. High-frequency components are known to be inappropriate for channel coding, so they are also coded with run-level entropy coding.

In Section 2, we introduce the fundamental DVC theory and conventional DMVC algorithms. In Section 3, the proposed DMVC method is presented. Experimental results and discussion are given in Section 4. Finally, Section 5 concludes the paper.

## 2. Conventional Distributed Multi-view Video Coding

Current MVC is based on inter-view prediction and requires considerable computational complexity at the encoder side. However, this computation load can be alleviated by adopting the DVC technique. In this paper, we propose a DMVC method that reduces the computational complexity of MVC by exploiting the characteristics of multi-view video. In this section, we introduce the fundamental concept of DVC and MVC.

### 2.1 Distributed Video Coding

DVC was proposed to reduce the computational complexity of a video encoder by using the statistical dependency between two or more pieces of data. Wyner and Ziv developed the fundamental framework for video coding based on Slepian and Wolf's work.

The Slepian-Wolf coding method is based on Shannon's information theory [2]. Assume that two random signals  $X$  and  $Y$  are independent, and their entropies can be represented by  $H(X)$  and  $H(Y)$ , respectively. Bit rates greater than the entropy are required to send information correctly; that is,  $R_x \geq H(X)$  and  $R_y \geq H(Y)$ . However, if  $X$  and  $Y$  are dependent,  $H(X) \geq H(X|Y)$ , and  $H(Y) \geq H(Y|X)$ ,  $H(X) + H(Y) \geq H(X, Y)$ . Using this fact, we can improve the coding efficiency for dependent signals. We need a certain bit rate for coding independent signals  $X$  and  $Y$ . However, coding two dependent signals requires a lower bit rate than that needed for independent signals. DVC exploits the statistical dependency between signals based on Shannon's theory [9][10]. Assume that we need to send information  $X$  from an encoder to a decoder, and  $Y$  is SI that depends on the signal  $X$ .  $Y$  is either known at the encoder side or not. Generally, DVC does not compute the SI  $Y$  at the encoder side; rather, it is generated by the decoder. While the Slepian-Wolf method is considered a lossless coding method, Wyner and Ziv employed quantization and dequantization for lossy video coding.

Signal  $X$  is quantized, and the quantized signal is coded with the Slepian-Wolf encoder. At the decoder side, the quantized signal is recovered with the Slepian-Wolf decoder with the SI  $Y$ . The recovered quantized signal is reconstructed using  $Y$ . This basic WZ coder has been combined with a channel coder. DVC with a channel coder consists of the following steps:

1. At the encoder side, a random signal is quantized; we call it  $X$ .
2. Parity bits are generated for the quantized random signal  $X$  and are transmitted to the decoder side.
3. At the decoder side, the coder generates SI that should be similar to  $Y$ .
4. The generated  $Y$  is corrected with the transmitted parity bits through channel decoding. The corrected signal  $X'$  should be similar to the original quantized signal  $X$ .

With fewer parity bits, we can reconstruct a more accurate  $X'$  that is similar to  $X$  from SI  $Y$ . For DVC based on channel coding, it is important to generate accurate SI that is more similar to that of the original signal  $X$ . In addition, the performance of a channel coder is also important for achieving good coding performance.

A DVC encoder does not have a motion estimation stage; it has only a channel coding method for WZ frames. However, the decoder has an SI generation module that corresponds to motion estimation in generic video coding. The motion estimation performance significantly influences a video codec's performance, and the accuracy of the SI is very important for improving DVC performance. For DVC, a channel decoder is used to correct errors between original frames and interpolated frames (SI). Thus, we need a large number of bits when the SI diverges considerably from the original frame. Much research has examined how to enhance the quality of SI [11][12][13][14][15][16][17][18].

## 2.2 Conventional DMVC Approaches

Fig. 1 shows a block diagram of conventional DVC; the DVC system generally encloses a conventional video codec [3]. Let  $X$  be information delivered by the DVC coder and  $K$  be the key information used as a reference signal to generate SI  $Y$  at the decoder side. For DVC, the generation of SI is critical to improving coding efficiency and robustness. At the decoder side, the approximated  $X$  is reconstructed using the generated SI  $Y$  and the parity information from the original signal  $X$ , delivered by the encoder. SI is generally a predicted frame that is estimated using two adjacent key frames. The key frames should be temporally close to the original signal.

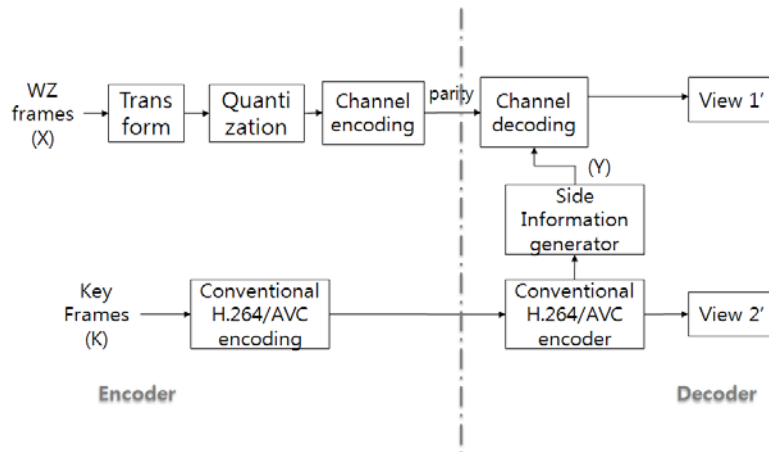
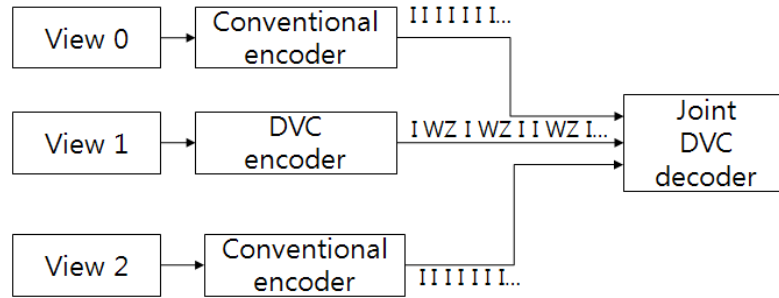


Fig. 1. Block diagram of conventional distributed video coding

This DVC method can be applied to MVC to alleviate the computational burden of the many predictions required by MVC. For some parts of a multi-view sequence, only parity information is delivered to a distributed multi-view (DMV) decoder. At the DMV decoder, the views are reconstructed with inter-view frames (SI), which are predicted using neighboring frames. Several SI generation methods have been proposed. As shown in Fig. 2, two views are encoded with a conventional video coder. The second view is coded with conventional intra-frame coding and a WZ coder. For instance, odd and even frames are coded with the conventional intra-frame and WZ coding, respectively. That is, only parity information is transmitted to the DMV decoder for the even frames of the second view [6][19][20].



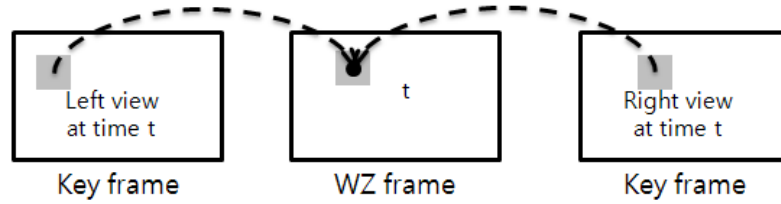
**Fig. 2.** Example of distributed multi-view video coding

By transmitting multiple views from a scene with MVC, we can watch the video from various user-selected viewpoints or in 3D with a 3D display. Single-view video coding exploits redundancy in the spatial and temporal domains. However, inter-view dependency is also used for MVC. Because an MVC system acquires multiple views of a scene simultaneously, similar spatial dependency exists in adjacent views. **Fig. 3** shows two adjacent input videos. The areas of spatial redundancy are indicated by black boxes.



**Fig. 3.** Spatial redundancy in two adjacent views

As mentioned above, the accuracy of SI is important for DVC. Based on the generic characteristics of multi-view video, SI can be generated using temporal or inter-view prediction. Methods of SI interpolation can be classified into three approaches: motion-compensated temporal interpolation (MCTI), homography-compensated inter-view interpolation (HCII), and disparity-compensated inter-view interpolation (DCII). In temporal interpolation, the current frame is synthesized with the previous and/or next frames. Left and/or right frames in the adjacent views are exploited to predict the current frame by inter-view interpolation. MCTI is generally used for DVC for single-view video coding. By using homography, an inter-view frame can be generated. However, HCII is not widely used because it requires many floating-point operations. In addition, it could suffer from the inaccuracy of camera parameters. DCII can be considered as an extension of MCTI. MCTI generates inter-view frames between temporally adjacent frames, whereas DCII generates inter-view frames with views from adjacent cameras, as shown in **Fig. 4**.



**Fig. 4.** Disparity-compensated inter-view interpolation (DCII)

### 2.3 Illumination Changes

In MVC, inter-view redundancy is very useful, so this clue could be used for disparity estimation in general MVC and for SI generation in DMVC. However, exploiting inter-view redundancy can be difficult, as shown in **Fig. 5**. Because of the unique intrinsic and extrinsic parameters of each camera, the two pictures could look different, reducing the usefulness of the redundancy.



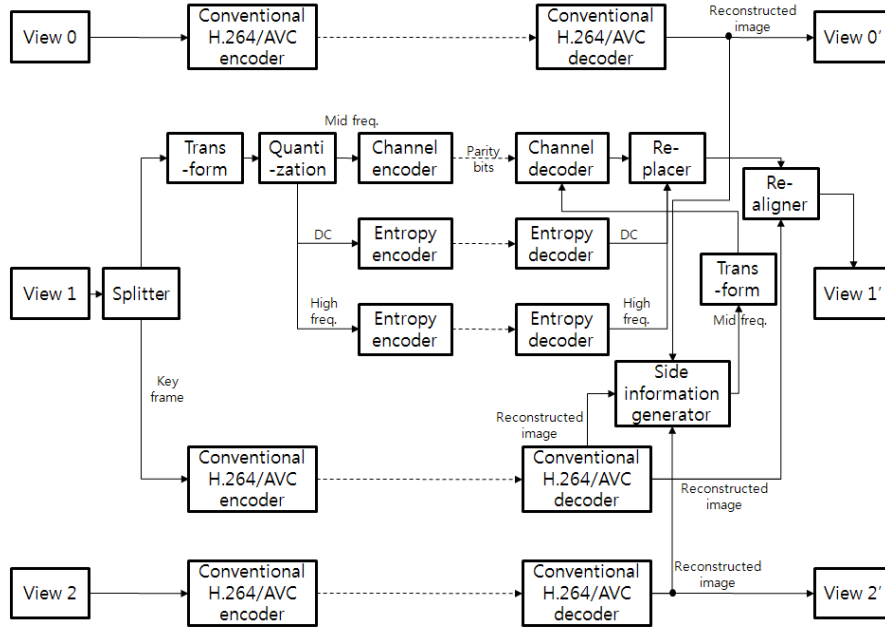
**Fig. 5.** Illumination difference between neighboring views

Illumination compensation can improve the peak signal-to-noise ratio (PSNR) of 0.5 dB for MVC [8]. In DCII, the accuracy of the SI is influenced by illumination changes. If the SI is inaccurate, error correction using the transmitted parity information is less effective. In this paper, we propose an inter-view prediction method based on illumination compensation for generating SI from neighboring views.

### 3. Proposed Illumination-Compensation-Based Distributed Multi-view Video Coding

**Fig. 6** shows a DVC-based multi-view coder for coding DCT coefficients with channel coding and entropy coding. Entropy coding is a lossless data compression scheme in which variable-length coding is typically used to assign a symbol to a codeword of minimal length to achieve the Shannon entropy bound for an ensemble. Channel coding is used to correct errors in a channel. Parity data are transmitted into a receiver, and errors in SI can be corrected by the channel decoder. Illumination compensation is performed by transmitting the DC coefficients and using them to generate accurate SI. In coding the rest of the AC coefficients, high-frequency components are coded with run-level coding, and mid-frequency components are coded with a channel coder such as a Turbo coder. The Turbo code is known to be the first practical code to closely approach the channel capacity and to provide outstanding error-correction performance. High-frequency components have a higher error rate than

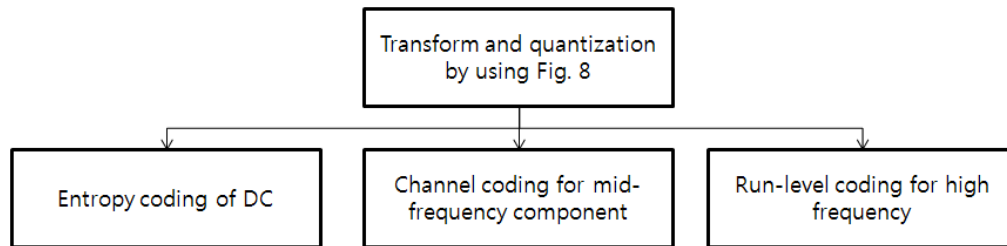
mid-frequency components. With a high error rate, many parity bits are needed to correct errors. Thus, the proposed algorithm employs conventional run-level coding for high-frequency components because the rate and quality can be adjusted easily. Furthermore, it does not lead to significant computational load at the encoder side.



**Fig. 6.** Block diagram of the proposed distributed video codec based on illumination compensation

### 3.1 Proposed Distributed Multi-view Encoder

Key views are coded by the conventional video coder, H.264/AVC. As shown in **Fig. 6**, view 0 and view 2 are key views, and all the frames in those views are encoded with the intra-prediction mode of H.264/AVC. Regarding the view 1, every other frame is coded by the H.264/AVC intra-frame coder; these are called key frames. The rest of the frames in the view are coded with the proposed DMVC.



**Fig. 7.** Encoding process of the proposed method

The proposed illumination-compensation-based DMVC is applied as shown in **Fig. 7**. As mentioned above, key frames are coded by the H.264/AVC intra-coder, and WZ frames are transformed by a discrete cosine transform (DCT). Then, the transform coefficients are quantized with a uniform quantizer. In the proposed method, we employ an  $8 \times 8$  fixed-point DCT with a precision of 10 bits. Because conventional DVC algorithms generally employ a fixed-point DCT, we also use the  $8 \times 8$  fixed-point DCT to remove transformation effects. The

quantization step size  $W_k$  for the  $k^{\text{th}}$  DCT coefficient is defined by:

$$W_k = 2|v_k|_{\max} / (2^{M_k} - 1), \quad k = 0, \dots, 63 \quad (1)$$

where  $|v_k|_{\max}$  indicates the highest absolute value among the DCT coefficients for each frequency component in a frame.  $|v_k|_{\max}$  should be transferred to the decoder for each frame. The quantization table ( $2^{M_k}$ ,  $k = 0 \sim 63$ ) is depicted in Fig. 8. While the conventional DVC algorithm employs a  $4 \times 4$  quantization table, the proposed algorithm uses an  $8 \times 8$  table because an  $8 \times 8$  transformation is used [20].

128	64	64	64	32	32	16	16
64	64	64	32	32	16	16	8
64	64	32	32	16	16	8	8
64	32	32	16	16	8	8	4
32	32	16	16	8	8	4	4
32	16	16	8	8	4	4	2
16	16	8	8	4	4	2	0
16	8	8	4	4	2	0	0

Fig. 8. Quantization matrix

As shown in Fig. 9, mid-frequency components (1~47) are coded with a channel coding method (that is, the Turbo coder). Next, only the parity bits are transferred to the decoder. Fifteen quantized high-frequency coefficients (48~63) are coded with a run-level entropy coder. First, the quantized coefficients are predicted from those of the collocated block in the previous frame. Then, these prediction residuals are coded by applying a variable-length coder based on CAVLC in H.264/AVC. The high-frequency components are coded with an entropy coding method used for intra-block (not inter-block) coding in H.264/AVC. Note that DCT coefficients for intra  $16 \times 16$  block are separated into AC and DC components in H.264/AVC.

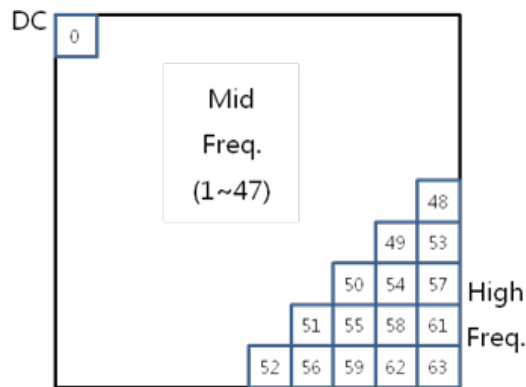
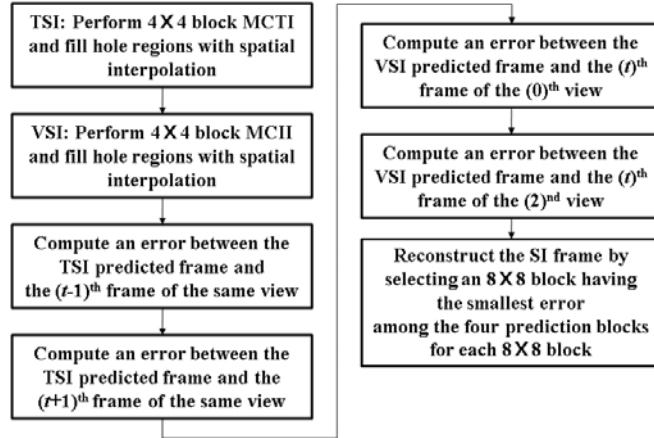


Fig. 9. DCT coefficients and their indexes in the DCT domain

### 3.2 Proposed Distributed Multi-view Decoder

In the proposed algorithm, not only parity data for the mid-frequency band but also DC and high-frequency coefficients are transferred into the distributed video decoder, whereas the conventional WZ coder transmits only parity bits for all the quantized DCT coefficients. The proposed illumination-compensation-based distributed video decoder consists of three steps. The first step is to generate SI, which is predicted by considering illumination changes. The second step is to replace the received DC coefficients with the reconstructed SI and channel decoding. The DC value transmitted from the encoder is placed as the DC component in the DCT domain of the reconstructed SI. Then, mid-frequency components are corrected by the channel decoder with the transferred parity data. The third step is to update high-frequency coefficients to reconstruct the final frame. The redundancy between two pictures is generally high at low frequency and low at high frequency. Therefore, prediction errors for high frequencies are higher than those for low frequencies. The SI is also an estimated signal, so it has large errors at high frequency. In DVC, the number of parity bits needed is proportional to the error, which affects the capacity for correction. Thus, we employ entropy coding for high frequencies.

As mentioned in Section 2, SI can be generated by either temporal prediction or inter-view prediction. In the proposed algorithm, we adaptively select one of the two approaches, MCTI or DCII, for each macroblock.



**Fig. 10.** Flowchart for the proposed side information generation

**Fig. 10** shows the flowchart for SI generation, which can be divided into three main steps. First, the temporally predicted frame is generated from the temporally succeeding and preceding key frames. This is based on MCTI, and motion estimation and compensation are conducted in 4×4 blocks. After prediction from the two frames, holes appear unpredictably. These holes are filled with neighboring pixels based on bilinear interpolation. **Fig. 11** shows an SI frame after the MCTI step, which has many hole regions. Then, an inter-view prediction frame is generated from two adjacent key frames in the key views. For prediction, we use a DC offset for an invariant distance measure defined by:

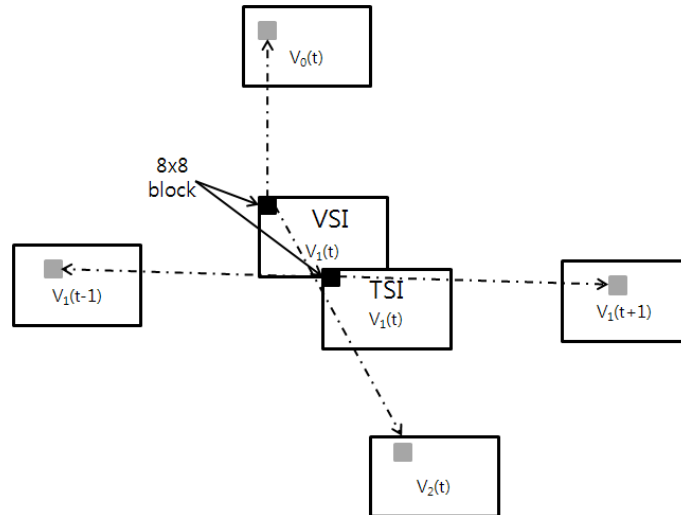
$$ICSAD^{(m,n)}(x,y) = \sum_{i=m}^{m+S-1} \sum_{j=n}^{n+T+1} \left\| (V_0(i,j) - M_{0(m,n)}) - (V_2(i+x, j+y) - M_{2(m,n)}) \right\| \quad (2)$$

where  $S$  and  $T$  represent block sizes, and  $M_{(m,n)}$  is the average of the pixel values in a block. Based on the *ICSAD*, we can remove the DC offset effect caused by illumination changes. Again, several holes can be seen in the predicted frame. The holes should be filled by bilinear interpolation.



**Fig. 11.** SI frame after MCTI step, which has multiple holes

In the last step, the SI frame is generated by adaptively selecting between temporal side information (TSI) and view side information (VSI) block by block, as shown in **Fig. 12**. The TSI and VSI images are divided into  $8 \times 8$  blocks. Then, we need to identify which blocks correspond to the  $8 \times 8$  TSI block in the previous  $(t-1)$  and next  $(t+1)$  key frames. In the same manner, for the  $8 \times 8$  VSI block, we must identify the blocks having the minimum sum of the absolute differences between the left and right views. Among the four corresponding blocks, the best matching block having the minimum distance is selected for the final SI.



**Fig. 12.** Reconstruction of SI with VSI and TSI

#### 4. Experimental Results and Analysis

We compared the proposed algorithm with that of Dufaux et al. [7]. We used the Ballroom, Exit, Race 1, and Akko-kayo sequences for this evaluation. The characteristics of the sequences are listed in **Table 1**. The Ballroom, Exit, and Race 1 sequences consisted of eight

views. However, we employed only the zeroth, the first, and the second views for our experiment. The Akko-kayo sequence was acquired with a 2D array camera arrangement. For this sequence, we also used the zeroth, the first, and the second views.

**Table 1.** Test sequences

Sequences	Image Property	Camera Arrangement
Ballroom, Exit	640x480, 25fps (rectified)	8 cameras with 20cm spacing; 1D/parallel
Race 1	640x480, 30fps (non-rectified)	8 cameras with 20cm spacing; 1D/parallel
Akko-kayo	640x480, 30fps (non-rectified)	100 cameras with 5cm horizontal and 20 cm vertical spacing; 2D array

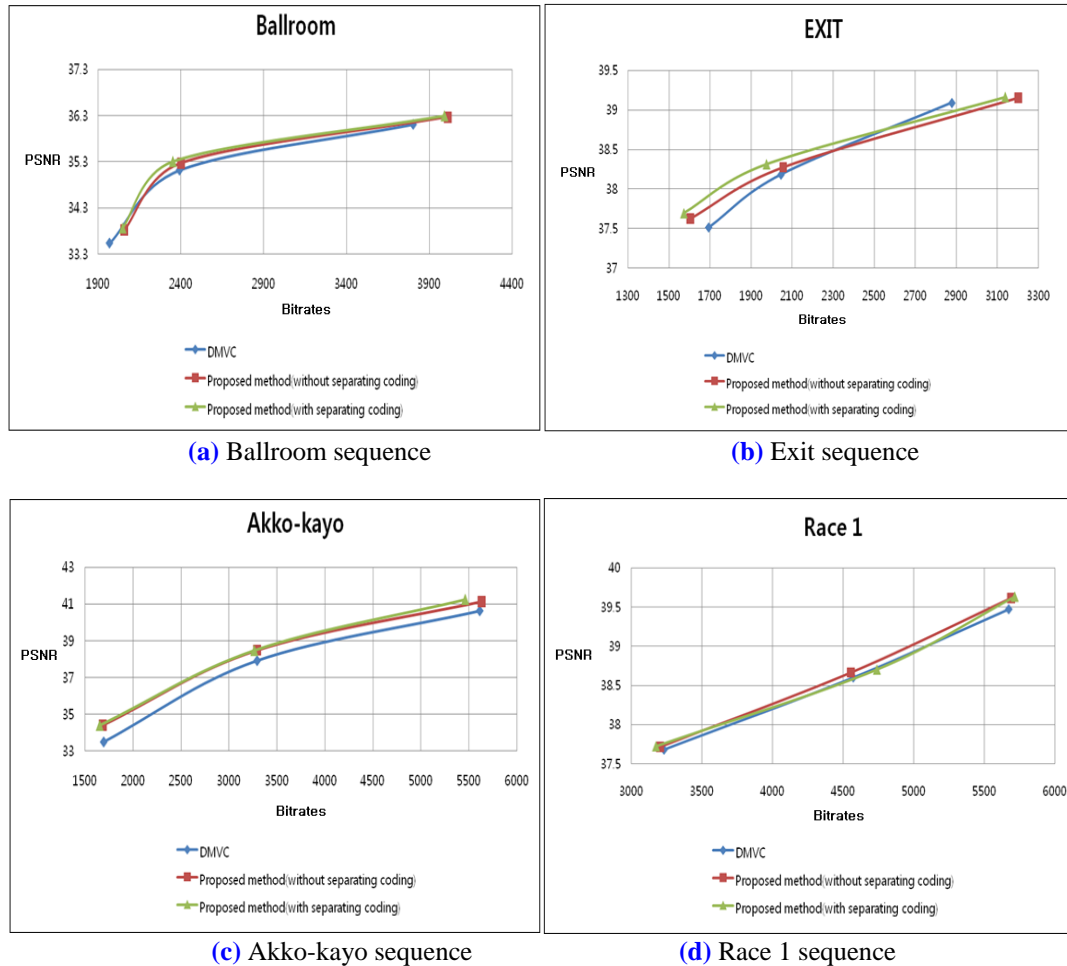
In our test, we used the conventional H.264/AVC intra-frame coding for key frames and key views. Note that the profile of H.264/AVC is set to the baseline. The conventional algorithm [7] and the proposed algorithm are based on WZ DVC and use an  $8 \times 8$  fixed-point DCT followed by a uniform quantization with  $2^{M_k}$  levels. The conventional and proposed algorithms employ the same Turbo coder and the same SI generation method, which is shown in Fig. 10. Note that the proposed algorithm was designed to improve the coding gain for multi-view videos by exploiting illumination mismatches. The proposed algorithm was implemented on the conventional DMVC [7], which is known to be efficient for multi-view video.

**Table 2.** RD performance of the conventional DMVC [7] and the proposed method

Sequence	QP	Conventional DMVC [7]		Proposed method	
		Average Rate (kbps)	Average PSNR (dB)	Average Rate (kbps)	Average PSNR (dB)
Ballroom	34	1969.83	33.53	2050.25	33.86
	31	2392.61	35.11	2352.83	35.30
	29	3803.34	36.1	3992.05	36.29
Exit	31	1694.48	37.51	1572.21	37.69
	29	2046.63	38.18	1974.66	38.31
	26	2878.74	39.09	3138.34	39.16
Race 1	28	3232.49	37.68	3175.46	37.72
	26	4572.3	38.6	4739.22	38.70
	24	5672.32	39.47	5715.16	39.63
Akko-kayo	36	1695.93	33.51	1653.56	34.40
	29	3294.74	37.92	3265.37	38.48
	24	5613.96	40.62	5464.17	41.25

Table 2 shows the rate distortion (RD) performance of the proposed and the conventional DMVCs for the test sequences in terms of quantization parameter (QP) values. As shown in Table 2, the proposed algorithm has a better PSNR than the conventional algorithm. However, additional information for the DC values increases the bit rates somewhat. Fig. 13 shows the RD curves for the test sequences. The proposed method without separate coding uses an entropy coder to encode only DC values, and the proposed method with separate coding employs a run-length coder to encode not only DC but also several AC values. As shown in Fig. 13, the RD performance of the proposed algorithm is superior to that of the conventional

algorithm for many QP values. The RD performance of the proposed method with separate coding is also better than that of the proposed method without separate coding at most QP values for the test sequences. We can say that channel coding is not suitable for representing high-frequency components.



**Fig. 13.** Comparison of RD performance of the conventional DMVC [7] and the proposed method

**Table 3** shows the average PSNR of the SI generated by the conventional [7] and the proposed algorithms. As shown in **Table 3**, the PSNR of the SI is higher than that of the conventional algorithm, because the proposed algorithm uses illumination compensation. In addition, **Table 3** also shows the percentages of view and temporal predictions for the conventional and proposed algorithms. View prediction is more frequently selected by the proposed algorithm because illumination mismatches occur between two adjacent views. We found that the percentage of view prediction increases depending on the proposed illumination compensation.

**Table 4** shows the RD performance of the conventional and proposed algorithms when they use only view prediction. The RD performance of both algorithms is degraded because temporal prediction is removed. However, the RD performance of the proposed algorithm is better than that of the conventional algorithm because the latter does not consider illumination differences between adjacent views. The Akko-kayo sequence has a moderate illumination

mismatch, and we found that some coding gain was achieved. We can say that our method is more robust than the conventional method.

**Table 3.** PSNR and percentages of prediction method selected to generate side information

	QP	Conventional DMVC [7]			Proposed method		
		Average PSNR (dB)	View prediction (%)	Temporal prediction (%)	Average PSNR (dB)	View prediction (%)	Temporal prediction (%)
Ball Room	34	28.9	6.0	94.0	29.2	7.0	93.0
	31	29.5			30.3		
	29	30.8			31.3		
Exit	31	32.2	9.8	90.2	33.6	23.2	76.8
	29	33.7			34.7		
	26	34.2			35.2		
Race 1	28	32.6	5.2	94.8	33.1	16.6	83.4
	26	31.5			32.7		
	24	33.5			34.6		
Akko-kayo	36	29.2	7.8	92.2	30.6	19.5	80.6
	29	32.4			33.0		
	24	34.5			35.9		

**Table 4.** RD performance of the conventional and proposed algorithms with only view prediction.

Sequence	QP	Conventional DMVC [7]		Proposed method	
		Average Rate (kbps)	Average PSNR (dB)	Average Rate (kbps)	Average PSNR (dB)
Ballroom	34	1983.29	32.74	2057.83	33.10
	31	2409.97	34.74	2400.85	35.00
	29	3818.04	35.9	4012.11	36.17
Exit	31	1697.78	37.04	1604.3	37.41
	29	2051.09	37.54	2056.94	38.12
	26	2881.07	38.44	3202.39	39.15
Race 1	28	3240.74	37.01	3204.3	37.47
	26	4579.13	37.9	4556.94	38.66
	24	5677.07	39.09	5692.39	39.61
Akko-kayo	36	1704.02	33.09	1687.31	34.01
	29	3300.8	36.94	3295.03	37.01
	24	5627.16	40.07	5633.16	40.87

## 5. Conclusions

In this paper, we proposed a distributed multi-view video coding method employing illumination compensation for multi-view video coding. In multi-view video, the illumination could differ in adjacent views owing to the use of different cameras and different illumination and viewing conditions. In addition, we employed run-level coding for high-frequency components and a channel coder for mid-frequency components. In this paper, the view

prediction and temporal prediction performance is improved by using illumination compensation. The proposed algorithm uses not only view prediction but also temporal prediction. Further research will focus on the development of an adaptive side information generation method for multi-view videos.

## References

- [1] Joint Video Team (JVT) of ITU-T VCEG and ISO/IEC MPEG, "Draft ITU-T recommendation H.264 and ISO/IEC 14496-10 AVC," Oct. 2009.
- [2] J. D. Slepian and J. K. Wolf, "Noiseless coding of correlated information sources," *Trans. on IEEE Information Theory*, vol. 19, no. 4, pp. 471-480, July 1973. [Article \(CrossRef Link\)](#)
- [3] Bernd Girod, Anne Aaron, Shantanu Rane and David Rebollo-Monedero, "Distributed video coding," in *Proc. of IEEE*, vol. 93, no. 1, pp.71-83, Jan. 2005. [Article \(CrossRef Link\)](#)
- [4] F. Pereira, L. Torres, C. Guillemot, T. Ebrahimi, R. Leonardi and S. Klomp, "Distributed coding: selecting the most promising application scenarios," *Signal Processing: Image Communication*, vol. 23, no. 5, pp. 339-352, June 2008. [Article \(CrossRef Link\)](#)
- [5] R. Puri and K. Ramchandran, "PRISM: An uplink-friendly multimedia coding paradigm," in *Proc. of IEEE Conf. on Acoustics, Speech and Signal Processing*, vol. 4, no. 4, pp. 856-859, Apr. 2003. [Article \(CrossRef Link\)](#)
- [6] X. Guo, Y. Lu, F. Wu, W. Gao and S. Li, "Distributed multi-view video coding," in *Proc. of SPIE Visual Communications and Image Processing*, vol. 6077, 60770T.1-60770T.8, Jan. 2006. [Article \(CrossRef Link\)](#)
- [7] F. Dufaux, M. Ouaret and T. Ebrahimi, "Recent advances in multi-view distributed video coding," in *Proc. of SPIE Mobile Multimedia/Image Processing for Military and Security Applications*, vol. 6157, pp. 1-11, Apr. 2007. [Article \(CrossRef Link\)](#)
- [8] J.-H. Hur, S. Cho and Y.-L. Lee, "Adaptive local illumination change compensation method for H.264/AVC-based multi-view video coding," *Trans. on IEEE Circuits Systems and Video Technology*, vol. 17, no. 11, pp. 1496-1505, Nov. 2007. [Article \(CrossRef Link\)](#)
- [9] C. E. Shannon, "A mathematical theory of communication," *ACM SIGMOBILE Mobile Computing and Communications Review*, vol. 5, no. 1, pp. 3-55, Jan. 2001. [Article \(CrossRef Link\)](#)
- [10] A. D. Wyner, "Recent results in the Shannon theory," *Trans. on IEEE Information Theory*, vol. 20, no. 1, pp. 2-10, Janu. 1974. [Article \(CrossRef Link\)](#)
- [11] B. Ko, J. Sim and B. Jeon, "Wyner-Ziv video coding with side matching for improved side information," *LNCIS*, vol. 4872, pp. 816-825, Dec. 2007. [Article \(CrossRef Link\)](#)
- [12] A. Aaron and B. Girod, "Compression with side information using turbo codes," in *Proc. of IEEE Conf. on Data Compression*, pp. 252-261, Apr. 2002. [Article \(CrossRef Link\)](#)
- [13] A.B.B. Adlikari, W.A.C. Fernando, W.A.R.T. Weerakkody and H. K. Arachchi, "A sequential motion compensation refinement technique for distributed video coding of Wyner-ziv frames," in *Proc. of the IEEE Conf. on Image Processing*, pp. 597-600, October 2006. [Article \(CrossRef Link\)](#)
- [14] S. Ye, M. Ouaret, F. Dufaux and T. Ebrahimi, "Improved side information generation for distributed video coding by exploiting spatial and temporal correlations," *EURASIP Journal on Image and Video Processing*, vol. 2009, Article ID 683510, Dec. 2008. [Article \(CrossRef Link\)](#)
- [15] T. N. Dinh, G. S. Lee, J. Y. Chang and H. J. Cho, "Side information generation using extra information in distributed video coding," in *Proc. of the Symp. on Signal Processing and Information Technology*, pp. 138-143, Dec. 2007. [Article \(CrossRef Link\)](#)
- [16] G.-I. Lee, B.-W. Jeon, R.-H. Park and S.-H. Lee, "Hierarchical motion compensated frame rate up-conversion based on the Gaussian/Laplacian pyramid," in *Proc. of IEEE International Conf. on Consumer Electronics*, pp. 350-351, June 2003. [Article \(CrossRef Link\)](#)
- [17] K. Y. Min, S. N. Park and D. G. Sim, "Side information generation using adaptive search range for distributed video coding," in *Proc. of the Conf. on Pacific-rim Symposium on Image and Video Technology*, vol. 4872, pp 854-857, Aug. 2009. [Article \(CrossRef Link\)](#)

- [18] X. Artigas, E. Angeli and L. Torres, "Side information generation for multi-view distributed video coding using a fusion approach," in *Proc. of the 7<sup>th</sup> Nordic Signal Processing Symposium*, pp.250-253, June 2003. [Article \(CrossRef Link\)](#)
- [19] C. Yeo and K. Ramchandran, "Robust distributed multi-view video compression for wireless camera networks," in *Proc. of IEEE international Conf. on Image Processing*, vol. 3, pp. 21-24, Sept. 2007.
- [20] A. Aaron, S. Rane, E. Setton and B. Girod, "Transform-domain Wyner-Ziv codec for video," in *Proc. of the SPIE Visual Communications and International Processing*, pp. 520-528, Jan. 2004. [Article \(CrossRef Link\)](#)



**Seanae Park** received the B.S. degrees in Computer Engineering from Kwangwoon University, Korea in 2004. She also received M.S.degree at the Intelligent Image Communication Lab of the same University in 2006. She is now studying for image processing. Particularly she researchs for the newest Video Coding, Multi-view Video Coding and distributed video coding.



**Donggyu Sim** received the B.S. and M.S. degrees in Electronics Engineering from Sogang University, Seoul, Korea, in 1993 and 1995, respectively. He also received Ph. D. degree at the Image processing lab. of the same University in 1999. He was with the Hyundai Electronics Co., Ltd from 1999 to 2000, where was involved in MPEG-7 standardization. He was a senior research engineer at Varo Vision Co., Ltd., working on MPEG-4 wireless applications from 2000 to 2002. He worked for the Image Computing Systems Lab. (ICSL) at the University of Washington as a senior research engineer from 2002 to 2005. I researched on the ultrasound image analysis and parametric video coding. He joined the Department of Computer Engineering at Kwangwoon University, Seoul, Korea, in 2005 as an Associate Professor. He was elevated to an IEEE Senior Member in 2004. His current research interests are image processing, computer vision, and video communication.



**Byeungwoo Jeon** received the B.S. degree (Magna Cum Laude) in 1985 and the M.S. degree in 1987 from the Department of Electronics Engineering, Seoul National University, Seoul, Korea, and the Ph.D. degree from the School of Electrical Engineering, Purdue University, West Lafayette, USA, in 1992. For 1993-1997, he was in the Signal Processing Lab. Samsung Electronics, Korea, where he worked for R&D of video compression algorithms, design of digital broadcasting satellite receivers, and other MPEG-related research for multimedia applications. Since September 1997, he has been with the faculty of the School of Information and Communication Engineering, Sungkyunkwan University, Korea, where he is currently a professor. His research interests include multimedia signal processing, video compression, statistical pattern recognition, and remote sensing. He has also served as a Project Manager of Digital TV and Broadcasting in the Korean Ministry of Information and Communications for 2004-2006 where he has supervised all digital TV-related R&D in Korea.