

SCALABLE MPEG VIDEO CODING WITH IMPROVED B-FRAME PREDICTION

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ABSTRACT

Recently, there is a great interest in video codecs that implement the functionality of spatial scalability. Unfortunately, those MPEG-2 and MPEG-4 coders which exhibit such a functionality produce much more bits than corresponding single layer coders. This bitrate overhead can be reduced by application of spatio-temporal scalability as proposed by the authors. The base layer bitstream corresponds to pictures with reduced both spatial and temporal resolution while the enhancement layer bitstream is used to transmit the information needed to retrieve images with full spatial and temporal resolution. Full compatibility with the MPEG standards is ensured in the base layer where temporal resolution reduction is obtained by B-frame data partitioning, i.e. by placing each second frame (B-frame) in the enhancement layer only. Improved prediction of B-frames in the enhancement layer is proposed in this paper. The idea is to combine temporal forward and backward prediction with spatial interpolation. Experimental results prove clear improvement of the MPEG-2-compatible scalable coding efficiency for the scheme proposed.

1. INTRODUCTION

Development of communication networks with different transmission bitrates as well as a demand for better protection of video transmission in error-prone environments has stimulated research on spatially scalable or hierarchical video coders. Such coders produce two bitstreams: a base layer bitstream which represents low resolution pictures and an enhancement layer bitstream which provides additional data needed for reproduction of pictures with full resolution. An important feature is that the base layer bitstream can be decoded independently from the enhancement layer.

The functionality of spatial scalability is already provided in the MPEG-2 [1,2] and MPEG-4 [3] video compression standards. Unfortunately, standard implementations of spatial scalability are mostly related to unacceptably high bitrate overheads as compared to single-layer encoding of video.

Especially, many attempts to improve spatially scalable coding of video have exploited subband/wavelet decomposition into four spatial subbands (Fig. 1) [4-9]. The subband LL of lowest frequencies constitutes a base layer while the other three subbands are jointly transmitted in an enhancement layer. Unfortunately, in most of such coders, it is difficult to allocate appropriate number of bits to the base layer and to the enhancement layer.

A practical requirement is that the bitstream of the base layer does not exceed the bitstream of the enhancement layer. In order to meet this requirement, spatio-temporal scalability has been already

proposed by the authors [10,11]. In this proposal, a base layer corresponds to the bitstream of the pictures with reduced both spatial and temporal resolutions. Therefore, in the base layer, the bitrate is decreased as compared to encoding with spatial scalability only. Such a solution yields the base layer bitrate being even less than that of the enhancement layer. The enhancement layer is used to transmit the information needed for restoration of the full spatial and temporal resolution.

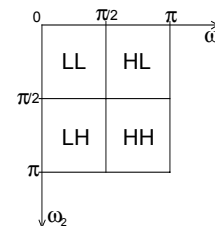


Figure 1. Subband decomposition

Two basic versions of the system have been already proposed. The first variant is based on 3-D subband/wavelet decomposition [10] while the other one employs B-frame data partitioning [10-12]. For both variants high level of compatibility with the MPEG video coding standards is ensured. In particular, the low-resolution base layer bitstream is fully compatible with the MPEG-2 standard. From the point of view of the compression efficiency, both versions outperform the MPEG-2 hierarchical coder.

The goal of this paper is to propose a modification of the coder with B-frame data partitioning. We are going to show that this modified coder provides the functionality of spatial scalability with very low bitrate overhead.

2. SPATIO-TEMPORAL SCALABILITY WITH B-FRAME DATA PARTITIONING

Let us assume that the number of B-frames between two consecutive I- or P-frames is odd. Temporal resolution reduction is achieved by partitioning of the stream of B-frames: each second frame is included into the enhancement layer only. Therefore there exist two types of B-frames: BE-frames which exist in the enhancement layer only and BR-frames which exist both in the base and enhancement layers (Table 1). The base layer represents the subband LL from I-, P- and BR-frames, and the enhancement layer represents BE-frames, subbands LH, HL, HH from I-, P-frames and hierarchical enhancement of the BR-frames.

Base layer coder is implemented as a motion-compensated hybrid MPEG-2 coder. In the enhancement layer coder, motion is estimated for full-resolution images and full-frame motion compensation is performed. Therefore all subbands have to be

synthesized into full frames. After motion compensation spatial subbands are produced again. The prediction errors are calculated and encoded for three subbands (HL, LH, and HH) of I- and P-frames.

Table 1. Frames of different types in both layers.

Base	I	BR	P	BR	P	BR	P		
Enhancement	I	BE	BR	BE	P	BE	BR	BE	P

Motion vectors MV are transmitted for the base layer. Another motion vectors are estimated for the enhancement layer. In the enhancement layer, difference values MV_e are transmitted.

In the enhancement layer coder, the subband LL used for frame synthesis is more finely quantized than this transmitted in the base layer. It corresponds to a sum of information contained in the base layer and in the bitstream ΔLL transmitted in the enhancement layer. The bitstream ΔLL contains bitplanes correcting the transform coefficients transmitted in the base layer.

3. IMPROVED B-FRAME ENCODING

A somewhat different scheme is proposed for the B-frames.

Improved prediction is used for the BR-frames, which are the B-frames represented in both layers. Each macroblock in a full-resolution BR-frame can be predicted from the following reference frames (Fig.2):

- previous reference frame RP (I- or P-frame),
- next reference frame RN (I- or P-frame),
- current reference frame RC (BR-frame).

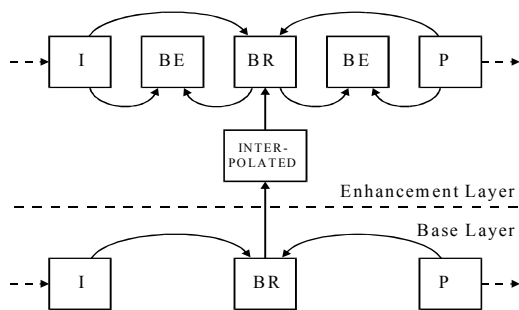


Figure 2. Improved prediction of B-frames.

The data from the previous and next reference frames RP and RN are motion-compensated, and data from the current reference frame are upsampled in the two-dimensional space domain. The best suited reference frame or average of two or three reference frames is chosen according to the criterion of smallest prediction error.

The improvement on standard MPEG-2 prediction within a single layer consists in another decision strategy. The best prediction/interpolation is chosen from all three possible reference frames: previous, future and interpolated (Fig. 3).

Experimental results with television test sequences prove that a current reference frame, i.e. a low-resolution BR-frame, is used in prediction of significant portion of macroblocks, sometimes even

for more than 50% of all macroblocks in BR-frames (Fig. 5). Application of the improved prediction leads to lower bitrates and higher PSNR as compared to standard prediction (Fig. 4).

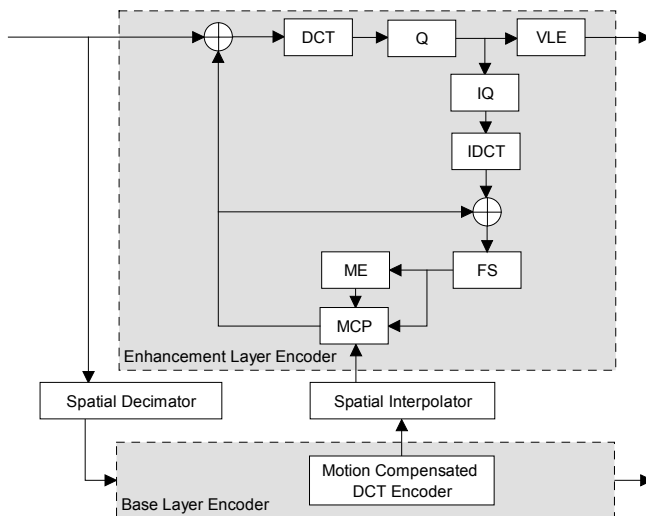


Figure 3. BR-frame prediction in the enhancement layer.

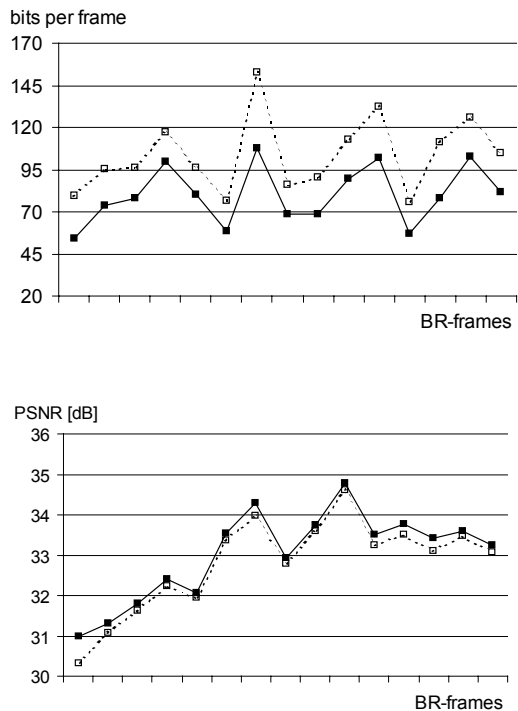


Figure 4. Bitrate and PSNR for improved and standard prediction of BR-frames: solid line – improved prediction, dotted line – standard prediction used in an MPEG-2 hierarchical coder.

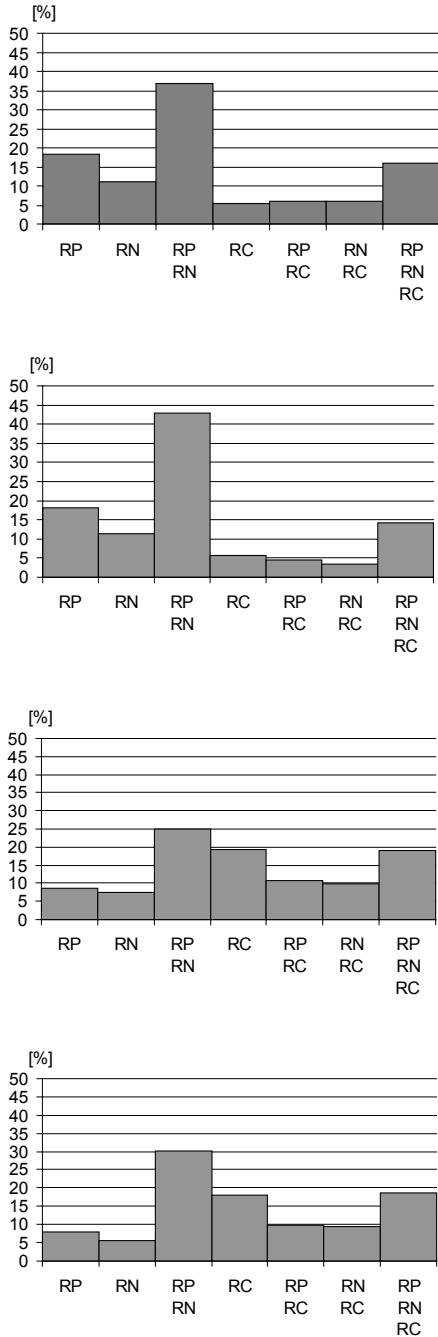


Figure 5. Percentage of macroblocks predicted using individual reference frames or their averages. From the top to the bottom: the test sequence *Flower garden* (15 frames) encoded for 5,24 and 8,76 Mbps and the test sequence *Funfair* (15 frames) encoded for 5,03 and 8,48 Mbps.

The difference from the MPEG-2 spatially scalable profile consists in choosing the best prediction using all three reference frames simultaneously.

The explanation of the results is that improved prediction replaces I-macroblocks with macroblocks predicted using current reference frame RC (Fig. 6). Of course, much less bits are needed to encode the latter macroblocks than macroblocks of type I.

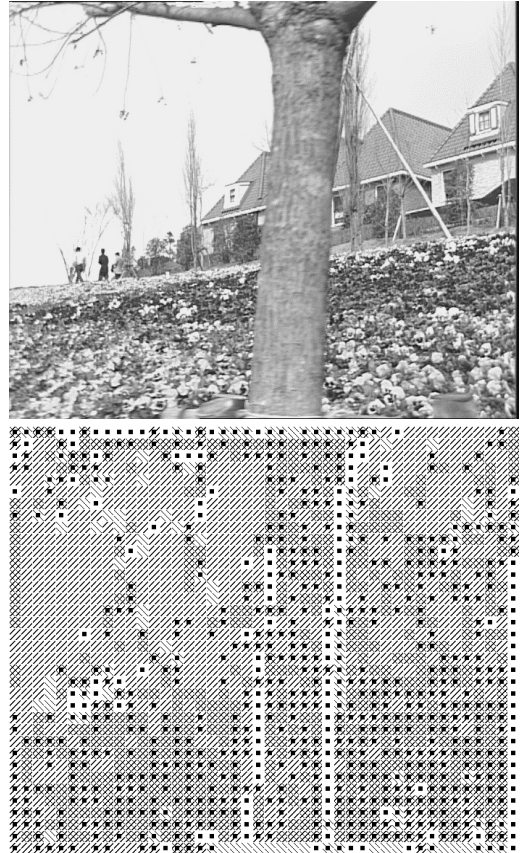


Figure 6. A frame from the test sequence *Flower garden* and various types of macroblocks in the corresponding BR-frame: slash signs denote forward prediction, backslash signs denote backward prediction and square signs denote interpolation.

4. EXPERIMENTAL RESULTS

The experimental results for progressive 720×576 , 50 Hz test sequences „Flower garden” and „Funfair” are given in Table 2.

The experimental results from Table 2 prove high efficiency of the coder. With the same bitrate as by MPEG-2 non-scalable profile, the scalable coder proposed reaches almost the same quality. The codec proposed significantly outperforms spatially scalable MPEG-2 [1] coders which generate bitrate overheads mostly exceeding 50%.

Table 2. Experimental results.

		Test sequence			
		<i>Flower Garden</i>		<i>Funfair</i>	
Single Layer (MPEG-2)	Bitsream [Mb]	5.24	8.76	5.03	8.48
	Average luminance PSNR [dB]	30.63	33.75	31.38	34.07
Proposed scalable coder	Bitsream [Mb]	5.34	8.74	5.04	8.48
	Average luminance PSNR [dB]	30.44	33.41	30.81	34.16
	Base layer bitstream [Mb]	2.21	3.00	2.11	2.70
	Base layer bitstream [%]	41	34	41	31

5. CONCLUSIONS

The experimental results show that the proposed scheme of B-frame encoding is very efficient. Actually it is not based on subband/wavelet decomposition but rather on some modification of classic hierarchical coder already standardized in the MPEG-2 standard. Nevertheless this B-frame coder can be efficiently embedded into the proposed video coder with the functionality of spatio-temporal scalability.

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REFERENCES

- [1] ISO/IEC International Standard 13818, *Information Technology - Generic Coding of Moving Pictures and Associated Audio Information*.
- [2] B. Haskell, A. Puri, A. N. Netravali, *Digital Video: An Introduction to MPEG-2*, New York: Chapman & Hall, 1997.
- [3] International Organization For Standardization, "MPEG-4 Video Verification Model", ISO/IEC JTC1/SC29/WG11, Stockholm, 1998.
- [4] T. Tsunashima, J. Stampleman, V. Bove, "A scalable motion-compensated subband image coder," *IEEE Trans. on Communication*, vol. 42, pp. 1894-1901, 1994.
- [5] F. Bosveld, "Hierarchical video compression using SBC," Ph.D. dissertation, Delft University of Technology, Delft 1996.
- [6] H.Gharavi, W.Y.Ng, "H.263 Compatible Video Coding and Transmission," in *Proc. First International Workshop on Wireless Image/Video Communication*, pp. 115-120, Loughborough 1996.
- [7] Senbel, H. Abdel-Wahab, "Scalable and robust image compression using quadrees," *Signal Processing: Image Communication*, vol. 14, pp. 425-441, 1999.
- [8] Shen, E. Delp, "Wavelet based rate scalable video compression," *IEEE Trans. Circuits Syst. Video Technology*, vol. 9, pp. 109-122, February 1999.
- [9] U. Benzler, "Scalable multi-resolution video coding using a combined subband-DCT approach", *Picture Coding Symposium 1999*, pp. 17-20.
- [10] M. Domański, A. Łuczak, S. Maćkowiak, R. Świerczyński, "Hybrid coding of video with spatio-temporal scalability using subband decomposition," in *Signal Processing IX: Theories and Applications*, pp. 53-56, Rhodes, September 1998.
- [11] M. Domański, A. Łuczak, S. Maćkowiak, R. Świerczyński, Ulrich Benzler "Spatio-Temporal Scalable Video Codecs with MPEG-Compatible Base Layer", *Picture Coding Symposium 1999*, pp. 45-48.
- [12] M. Domański, A. Łuczak, S. Maćkowiak, „Spatio-temporal scalability for MPEG video coding”, *IEEE Trans. Circuits Systems for Video Technology*, to be published.