Scalable Multiresolution Video Coding using Subband Decomposition

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Abstract

A subband approach to scalable multiresolution video coding is presented. In a first step of experiments this scheme is applied to the coding of I–frames, where bit rate savings up to 21.1% compared with MPEG–2 spatial scalability are achieved. In a next step it will be used for inter–frame coding of P– and B–frames.

1. Introduction

Scalable video source coding requires that parts of the encoded and transmitted data can be decoded separately by a base layer decoder to reconstruct low resolution images. In combination with unequal error protection it can be used for graceful degradation in case of transmission errors. Due to reduced requirements in terms of processing power and memory capacity, low resolution images can be decoded by a low–complexity decoder in a mobile receiver.

In MPEG–2 this functionality is provided by the spatial scalable profile [1] (MPEG–2 SSP), where a pyramid coding scheme is used. Low resolution images are derived by low pass filtering and subsequent subsampling of the input signal. The low resolution images are encoded separately, and the resulting bitstream represents the base layer of the scalable system. To regain parts of the base layer information for the high resolution, the reconstructed low resolution images are upsampled and additionally used to predict the high resolution images, see Fig. 1. The resulting prediction error is encoded in the enhancement layer with a sample rate of the video input signal. Therefore, the total number of encoded samples is increased by the number of samples encoded in the base layer. This disadvantage of an increased sample rate cannot fully be compensated by providing an additional prediction signal for the high resolution images. Thus, an overall performance can be observed which is only slightly better than 'simulcast' where the two resolutions are coded independently [2].

In the proposed scheme the input signal is decomposed by a 4–band analysis filter bank (AF), see Fig. 2. Due to the critically sampled subband decomposition, the total number of encoded samples is equal to the number of video input samples. Hence, the disadvantage of an increased sample rate is avoided.

High quality format conversion of interlaced video signals requires the generation of an intermediate deinterlaced signal [1] [4]. In [4] it is shown that this intermediate deinterlaced signal can be coded at the

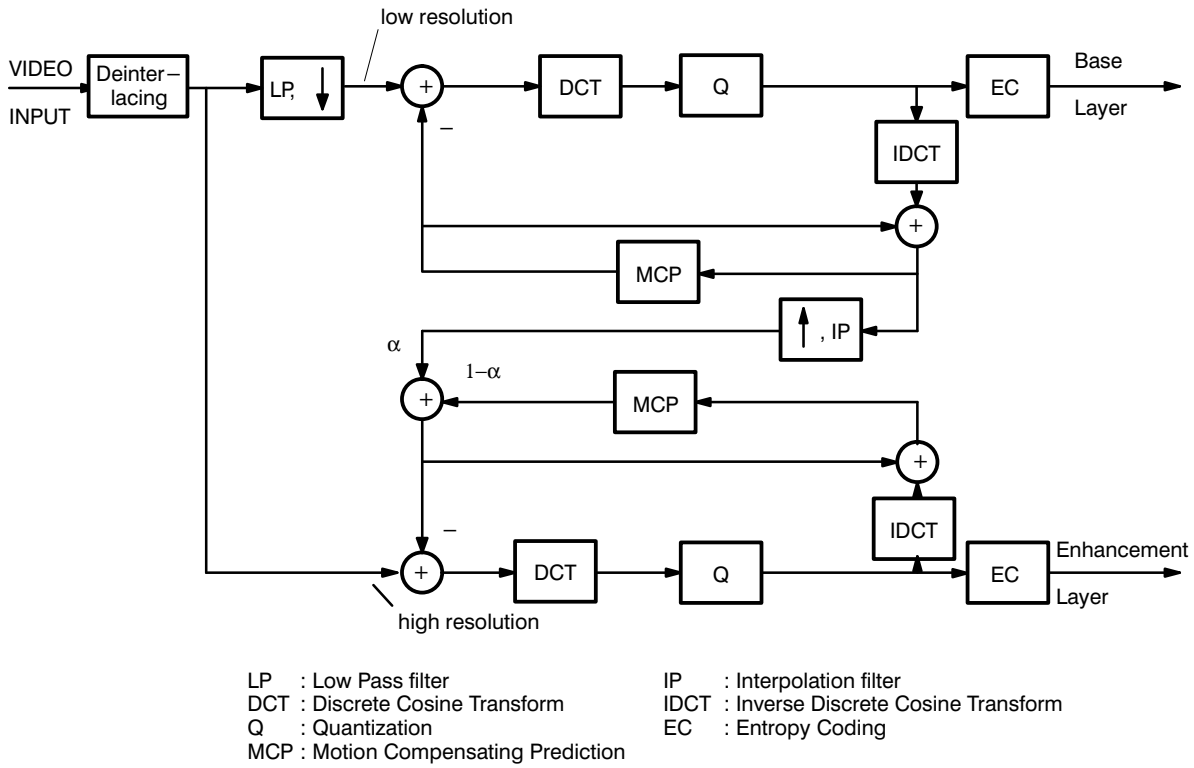


Fig.1. MPEG−2 spatial scalability coder with deinterlaced input

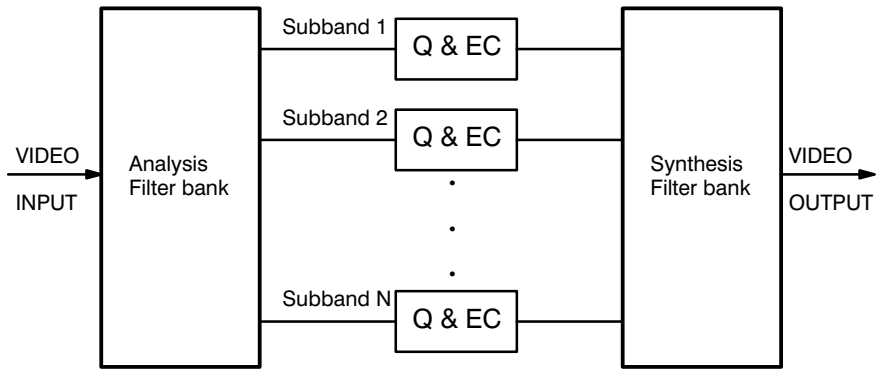
same bit rate as the original interlaced signal, with an equal subjective picture quality. By using deinterlaced signals the conversion between low and high resolution (IP in Fig. 1.) is simplified. The experiments were carried out using input signals deinterlaced according to [5].

This paper is organized as follows. In section 2 the complete proposed subband coding scheme consisting of motion compensating prediction (MCP) and prediction error coding is described. Section 3 gives experimental results for intra–frame coding compared with both scalable and non–scalable MPEG–2 coding.

2. Scalable Multiresolution Subband Coding

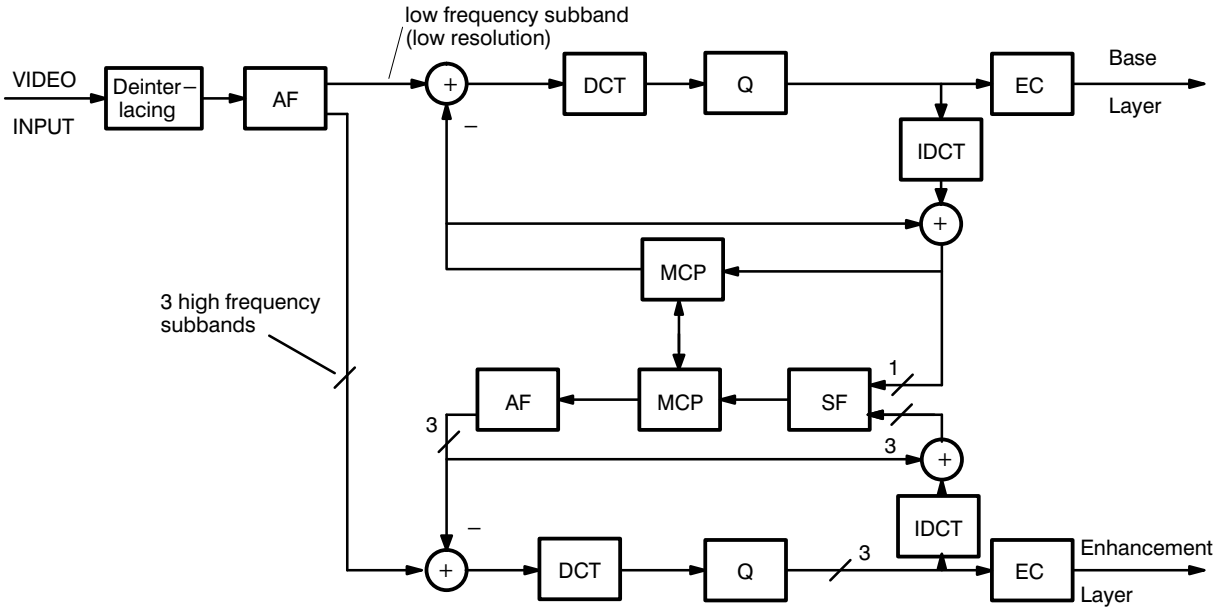
The subband coding system consists of an analysis filter bank at the encoder where the spectrum of the input signal is decomposed into several subbands, see Fig. 2. Each subband signal is separately quantized and entropy coded, taking into account human visual perception and signal statistics, respectively. On the decoder side the signal is reconstructed by a synthesis filter bank. The analysis and synthesis filter banks are specially designed to give perfect reconstruction in the case of lossless coding and transmission.

In the proposed scheme the input signal is decomposed by a 4–band analysis filter bank (AF) resulting in one low frequency and three high frequency subbands, see Fig. 3. In common with MPEG–2 SSP, the low frequency subband is encoded separately with a hybrid motion compensating DCT coder in the base layer to provide low resolution images. But unlike MPEG–2 SSP, the subband decomposition reduces the sampling rate in the enhancement layer.



Q & EC : Quantization and Entropy Coding

Fig. 2. Subband coding system



AF : Analysis Filter bank
DCT : Discrete Cosine Transform
Q : Quantization
MCP : Motion Compensating Prediction
SF : Synthesis Filter bank
IDCT : Inverse Discrete Cosine Transform
EC : Entropy Coding

Fig. 3. Proposed motion compensating hybrid subband/DCT based scheme

The motion vectors are estimated on the high resolution and are used in both low and high resolution MCP, so only one set of motion vectors has to be transmitted to the decoder.

High resolution images are reconstructed by synthesis filtering (SF) the reconstructed low and the three high frequency bands encoded in the base and the enhancement layer, respectively. The motion compensated prediction signal for the 3 high frequency bands of the current image is generated by applying motion compensating prediction (MCP) to a previously reconstructed high resolution image and subsequent analysis filtering. The resulting 3 high frequency subbands of the prediction error are separately DCT coded, see Fig. 3.

In order to provide a good picture quality for the low resolution images, the low pass filter proposed in MPEG–2 test model TM5 [3] is used within the analysis filter bank. For each subband signal a weighting matrix is introduced to allow a visually weighted quantization of the DCT–coefficients. The four weighting matrices are adjusted to give the same mean squared quantization error for each DCT coefficient as the non–scalable MPEG–2 reference encoder TM5 [3].

3. Experimental Results

In a first step of experiments the scalable multiresolution subband scheme is applied for encoding the I–frames only. In this case MCP is switched off for all frames. Simulations are carried out for constant–quality coding with fixed quantizer step sizes Q of 22, 16 and 10 (*qscale* in MPEG–2 syntax), corresponding to approximately 4, 6 and 9 Mbit/s for non–scalable MPEG–2 coding of Standard Definition TV (SDTV) signals.

To show that both MPEG–2 SSP and the proposed scheme are independent of the video input format, both Standard Definition TV (SDTV) and High Definition TV (HDTV) signals are used in the experiments. 50 frames of two SDTV signals (”Flower Garden” and ”Basketball–2”) and one HDTV signal (”Edinburgh Street”) have been evaluated.

Figs. 4. and 5. show the results for the SDTV signals ”Basketball–2” and ”Flower Garden” . Overall bit rate savings between 8.8% (Q=10) and 15.4% (Q=22) compared with MPEG–2 SSP are achieved. Compared with the non–scalable reference encoder TM5 [3], the increase is between 3.1% (Q=22) and 14.7% (Q=10).

The results for ”Edinburgh Street” are presented in Fig. 6. Compared with MPEG–2 SSP bit rate savings between 7.8% (Q=10) and 21.1% (Q=22) can be observed. Compared with the reference encoder TM5, the increase is between 7.2% (Q=16) and 19.4% (Q=10). For ”Edinburgh Street” and Q=22 the scalable subband scheme performs even better than the non–scalable reference encoder TM5.

Compared with the ”simulcast” case where both resolutions are coded independently the decrease in bit rate for the proposed scheme is between 31.3% and 44.1%, while for MPEG–2 SSP it is only between 25.2% and 29.2%.

4. Conclusion and future work

A scalable multiresolution subband coding scheme is presented. In contrast to MPEG–2 spatial scalability (SSP), the total number of coded samples is not increased due to a subband decomposition. In a first step,

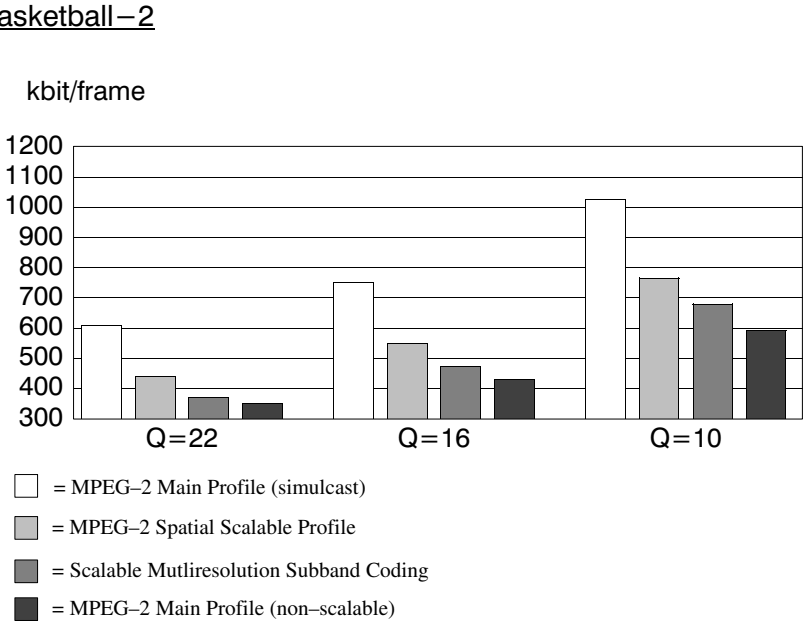


Fig. 4. Average number of encoding bits per I−frame for SDTV test sequence ”Basketball−2”

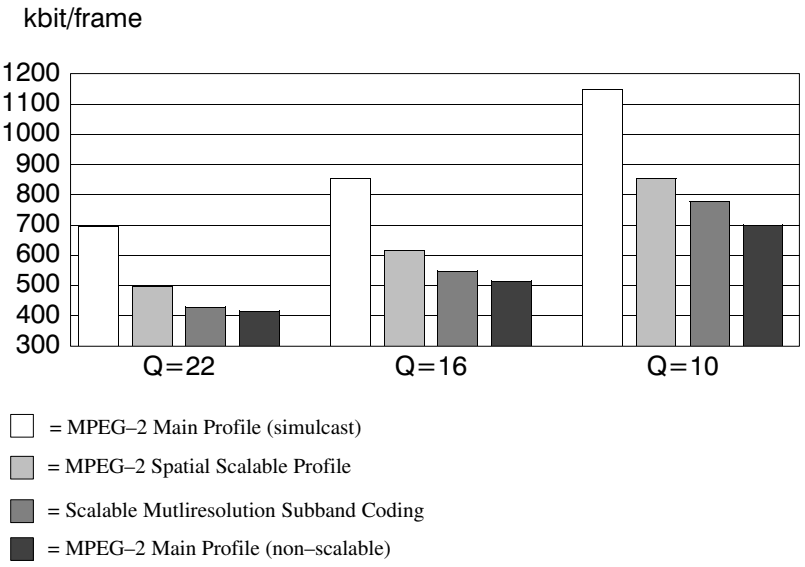


Fig. 5. Average number of encoding bits per I−frame for SDTV test sequence ”Flower Garden”

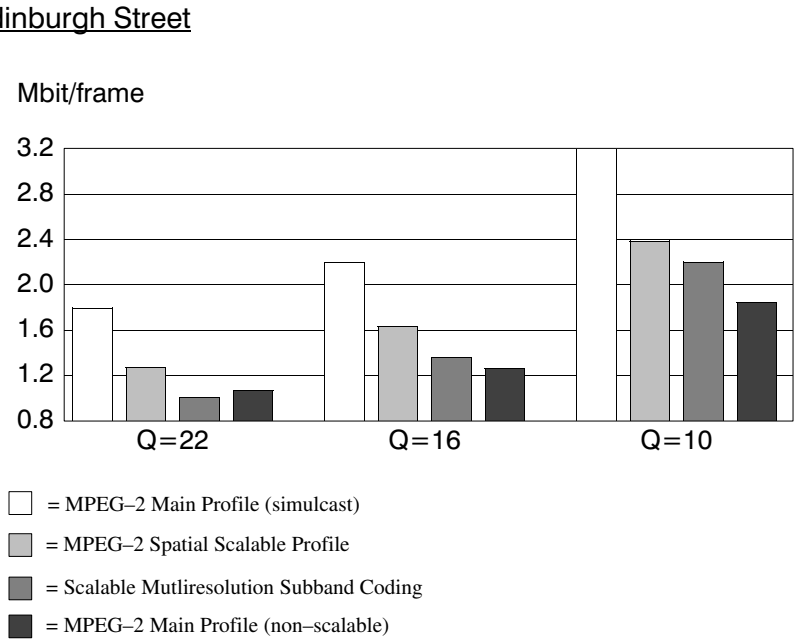


Fig. 6. Average number of encoding bits per I−frame for HDTV test sequence "Edinburgh Street"

experiments are carried out for for encoding the I–frames where bit rate savings between 7.8% and 21.1% compared with MPEG–2 SSP are achieved. The increase in bit rate compared with the non–scalable MPEG–2 reference encoder TM5 [3] is only between 3.1% and 19.4%.
In future experiments, inter–frame coding of P– and B–frames will be carried out.

References

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