VIDEO CODING WITH SPATIO-TEMPORAL SCALABILITY FOR APPLICATIONS IN HETEROGENEOUS COMMUNICATION NETWORKS

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Abstract: *The paper describes scalable hybrid video codecs for applications in heterogeneous communication networks characterized by various levels of Quality of Service. The proposed functionality of spatio-temporal scalability can be exploited for construction of highly scalable video codecs that produce several layers of bitstream thus allowing great flexibility of network management. The proposed hybrid solution exploits MPEG-like algorithm in P- and B-frames and wavelet decomposition in I-frames. The bitrate ratio of two consecutive layers can be about 1:2 up to 1:2.5. The paper comprises experimental results obtained for a two-layer system for progressive video sequence compression.*

Keywords: *Hierarchical video coding, video data compression, MPEG, spatio-temporal scalability*

1 INTRODUCTION

Recently, video and multimedia services are being rapidly developed. Their availability depends strongly on communication network infrastructure. High bitrates needed for video transmission impose severe requirements on communication networks. Existing communication networks are very inhomogeneous. There exist links of various available bitrate and various error rate (Fig.1).

Therefore there exist growing interests in video transmission through heterogeneous communication networks that are characterized by various available levels of Quality of Service. Different levels of Quality of Service (QoS) are often related to different available transmission bitrates. On the other hand, the service providers demand that the data are broadcasted once to a group of users accessed via heterogeneous links. For this purpose, the transmitted bitstream should be partitioned into some layers in such a way that lower layers can be decoded independently from the others thus producing images with reduced quality (progressive coding) or resolution (hierarchical coding). Various layers 1,...,N correspond to subsystems N1 to NN of a heterogeneous communication network (Fig. 2).

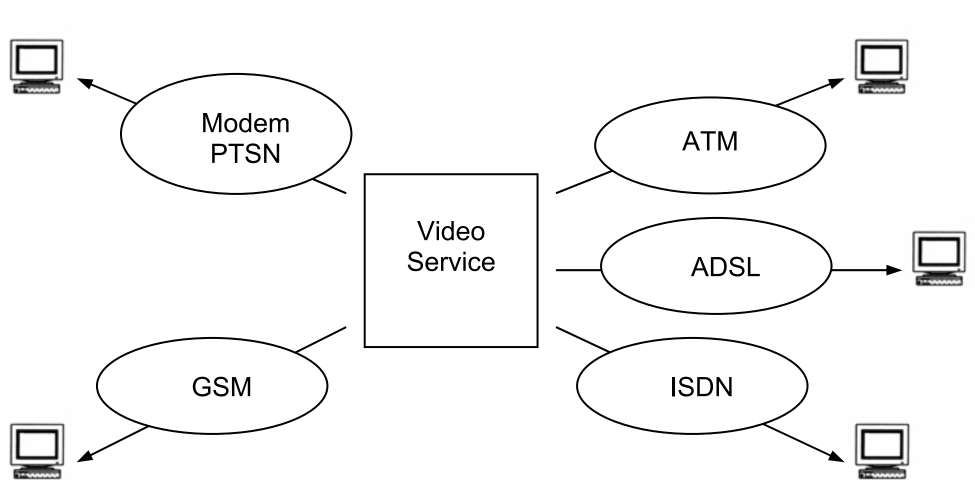


Figure 1. A heterogeneous communication network with video services.

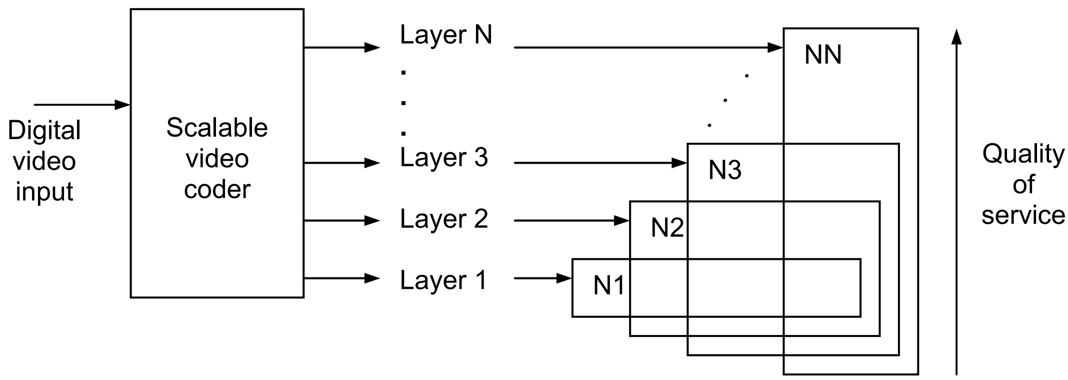


Figure 2. Multi-layer scalable video coding system in heterogeneous network that consists of sub-networks N1,...,NN.

In this paper, a structure of a hybrid highly scalable video coder is proposed. The goal is to achieve total bitrate of all layers of scalable coding possibly close to the bitrate of single-layer coding. The assumption is that high level of compatibility with the MPEG video coding standards would be ensured. In particular, it is assumed that the low-resolution base layer bitstream is fully compatible with the MPEG-2 standard which describes scalability with low numbers of available layers corresponding to various levels of QoS [1].

2 INTRAFRAME SCALABLE CODING

The intraframe spatially scalable (hierarchical) coding can be implemented using wavelet decomposition as it was already proposed in quit many references [2-6].

The layers correspond to various resolution images compressed. Figure 3 illustrates relations between individual layers and and spatial frequency bands of the images encoded on a given layer.

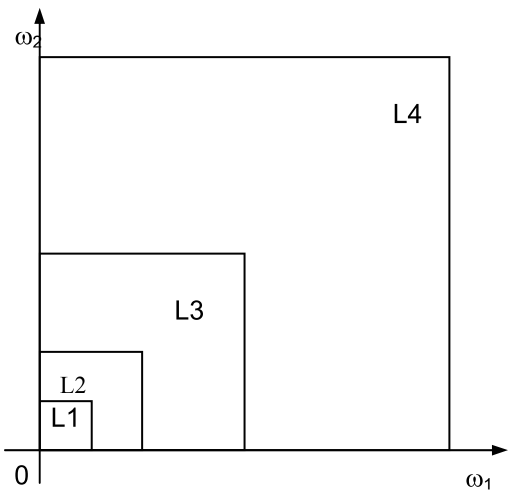


Figure 3. Layers in the spatial frequency domain.

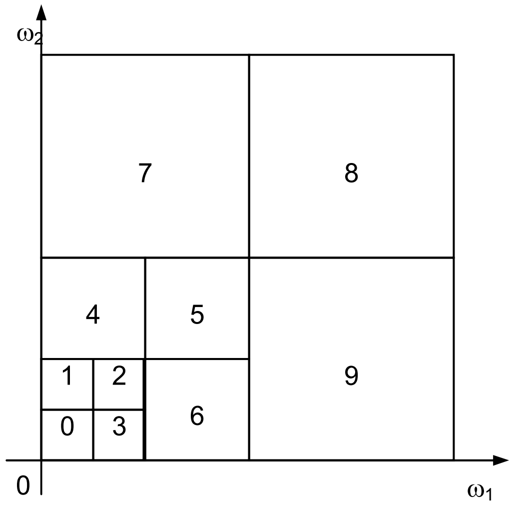


Figure 4. Subbands obtained using wavelet decomposition.

The layers correspond to subbands or groups of subbands obtained using wavelet decomposition (Fig.4). The correspondence between subbands and layers is shown in Table 1.

Table 1. Subbands and the corresponding layers by intraframe coding.

Layer	Subbands
L1	0
L2	1,2,3
L3	4,5,6
L4	7,8,9

3 INTERFRAME VIDEO CODING WITH THE FUNCTIONALITY OF SPATIO-TEMPORAL SCALABILITY

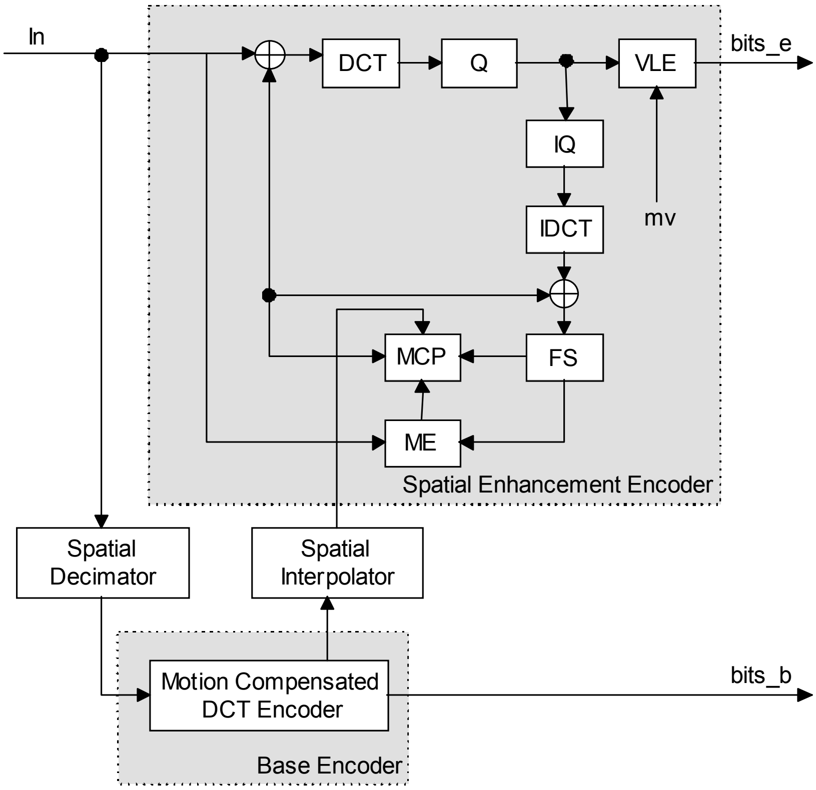
Unfortunately, spatially scalable systems proposed by MPEG-2 coding standard are inefficient because the bitrate overhead is very high as compared to bitrate of a single-layer MPEG encoder. Recently proposed MPEG-4 has proposed no substantial improvement. Therefore there were many attempts to improve the scheme of spatial scalability by application of subband decomposition [2-6]. Unfortunately, this approach suffers from problems with right bit allocation to the layers.

In order to avoid the above mentioned problem, spatio-temporal scalability is proposed [7,8]. Here, a low layer corresponds to pictures with reduced both spatial and temporal resolution. Higher layers are used to transmit the information needed for restoration of higher spatial and temporal resolution.

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.

The structure of the proposed coder in the interframe mode of operation is given in Fig. 5. In fact, it is slightly modified structure of a coder with the functionality of spatial scalability as proposed in the MPEG-2 standard [1].



DCT	Discrete cosine transform	FS	Frame memory
Q	Quantization	MCP	Motion-compensated predictor
IQ	Dequantization	ME	Motion estimator
IDCT	Inverse cosine transform		

Figure 5. Interframe coder: the two-layer case.

4 EXPERIMENTAL RESULTS

In order to verify the structure proposed a verification model have been prepared. The software is currently available for progressive sequences with the input resolution defined by the standard digital television resolution.

The experiments have been made with progressive 720 × 576, 50 Hz, 4:2:0 test sequences (cf. Table 2). Frames from the test sequences are shown in Figs. 6 and 7.

For a 16-frame GOP, the structure of the bitstream is shown in Fig. 8. It is assumed that a GOP consists of 12 B-frames, 3 P-frames and 1 I-frame.

The obtained results prove that the structure proposed can be used for multi-layer systems where the bitrate ratio of two consecutive layers is about 1:2 up to 1:2.5.

Table 2. The experimental results.

	Funfair	*Flower Garden*	*Stefan*	*Cheer*	*Bus*
Bitstream [Mb]	5.63	6.40	5.85	5.35	6.33
Average PSNR [dB] for luminance	32.17	30.92	35.11	31.99	34.51
Base layer bitstream [Mb]	2.16	2.17	2.14	2.15	2.15
Scalability overhead [%]	8.7	21.5	13.8	2.7	22.0

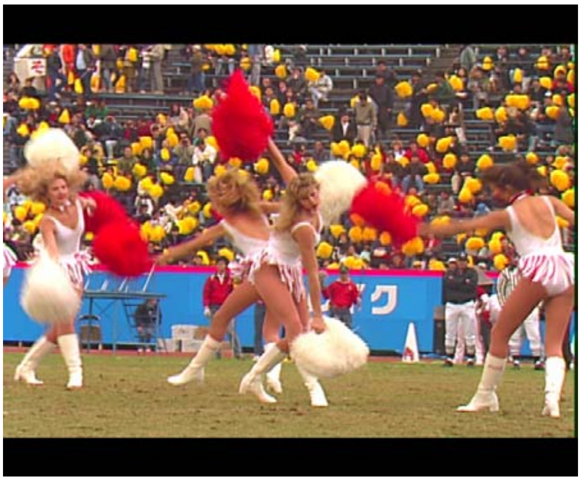


Figure 6. A frame from the test sequence *Cheer*.

Figure 6. A frame from the test sequence *Funfair*.

5 CONCLUSIONS

It is shown that application of a hybrid scheme that combines wavelet decomposition with MPEG-like structure of interframe coding leads to promising results which could be exploited by construction of multi-layer systems.

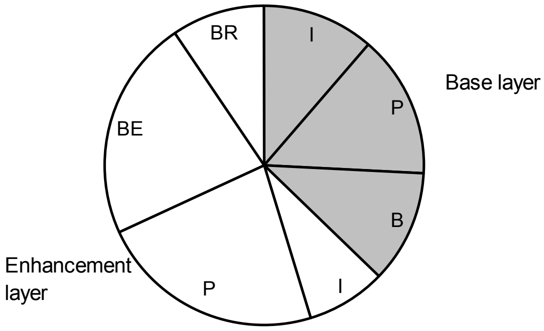


Figure 8. A typical bitstream structure.

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