

# Robust watermarking of H.264-encoded video: Extension to SVC

Peter Meerwald, Andreas Uhl

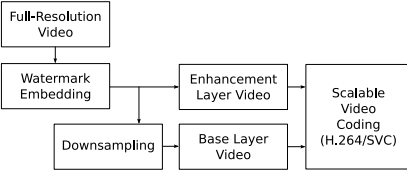
Dept. of Computer Sciences,  
University of Salzburg, Austria

August 2010

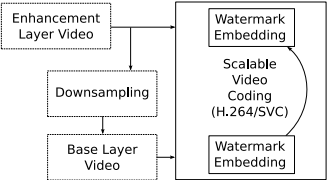
# Outline

- ▶ Embedding scenarios
- ▶ Watermarking of H.264 encoded video
- ▶ How to watermark multiple layers?
- ▶ Upsampling step
- ▶ Experimental results
- ▶ Conclusion

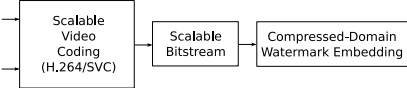
# Embedding scenarios



Embedding before encoding



Integrated coding and watermarking

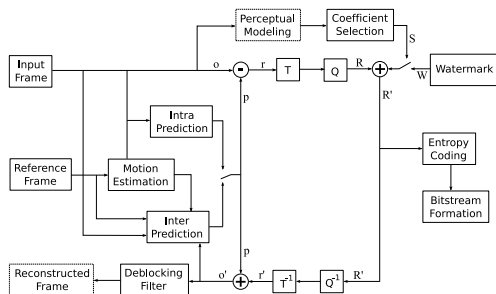


Watermarking the bitstream

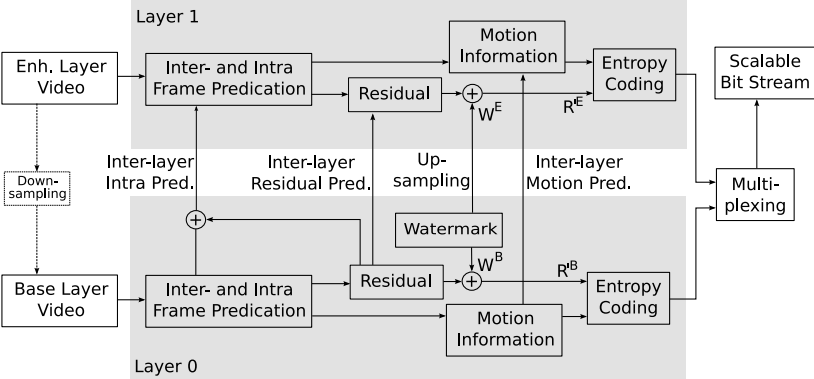
# Watermarking of H.264 encoded video

Use framework of [Noorkami and Mersereau, 2007]:

- ▶ Embed additive spread-spectrum watermark in AC coefficients of (intra)  $4 \times 4$  DCT residual blocks
- ▶ Select non-zero quantized coefficients (bitrate-aware watermarking) [Noorkami and Mersereau, 2008]
- ▶ Detector does not know embedding locations (location unaware detection, LUD)



# H264/SVC schemantic

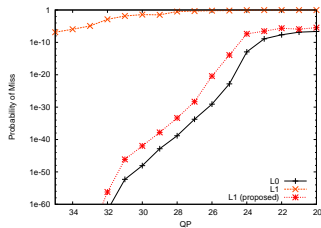


# Watermarking multiple H.264/SVC (resolution) layers

- ▶ H.264/SVC enables coding a single bitstream containing multiple resolution and/or quality layers [Schwarz and Wien, 2008]
- ▶ H.264/SVC adds new coding tools to exploit statistical dependency between layers via predictive coding
  - ▶ Inter layer intra prediction uses the upsampled reconstructed base layer signal of intra macroblocks
  - ▶ Inter layer motion prediction uses macroblock partitioning and motion information of the base layer
  - ▶ Inter layer residual prediction reduces the residual energy by the upsampled transform coefficients of the base layer

# Watermark signal transfer between base and resolution enhancement layer

- ▶ The base-layer watermark is hardly detectable in the decoded enhancement layer
- ▶ Independent watermarking of each layer increases bit rate



- ▶ Problem:
  - ▶ How to efficiently watermark resolution base- and enhancement layer?
  - ▶ Watermark should be detectable in bitstream and decoded video of both layer

## Problems of prior work

- ▶ Base layer watermark does only partially (i.e. for high QP) transfer to the enhancement layer
- ▶ Negative watermark is in the enhancement layer difference signal, but not in the decoded full resolution video
- ▶ Bit rate of enhancement layer increases due to added watermark signal energy in difference signal



## Proposal: Embed dependent watermark in higher layer

- ▶ Enhancement layer intra blocks are predominantly coded using inter-layer intra prediction; i.e. the difference between the upsampled base layer signal and the enhancement layer data is coded
- ▶ Propose to upsample base layer watermark signal and add to enhancement layer video data

$$W_E = Q(T(H(T^{-1}(S \cdot W_B))))$$

$$R'_E = R_E + W_E$$

$W_B$  ...  $4 \times 4$  base layer watermark signal

$S$  ...  $4 \times 4$  AC coefficient selection matrix

$T, T^{-1}$  ... forward and inverse integer DCT transform

$H$  ... upsampling operation

$Q$  ... quantization

$W_E$  ... enhancement layer watermark signal

$R_E, R'_E$  ... enhancement residual and watermarked residual block

# Experimental Results

- ▶ Use constant false-alarm rate (CFAR) detector [Kay, 1998] and assume Cauchy host signal model [Kwitt et al., 2008] for blind spread-spectrum watermark detection
- ▶ Encode well-known QCIF and CIF video sequences with JSVM reference software version 9.19.6,  $QP = 25$
- ▶ Source code will become available at <http://www.wavelab.at/sources>

## Detection performance on decoded enhancement layer

Sequence	Probability of Miss		
	L0	L1	L1 (proposed)
<i>Foreman</i>	$2.3 \cdot 10^{-25}$	0.81	$3.2 \cdot 10^{-17}$
<i>Soccer</i>	$2.6 \cdot 10^{-69}$	1.0	$1.1 \cdot 10^{-49}$
<i>Bus</i>	$1.0 \cdot 10^{-8}$	1.0	$6.2 \cdot 10^{-8}$
<i>Container</i>	$5.2 \cdot 10^{-119}$	0.44	$1.1 \cdot 10^{-91}$
<i>Coastguard</i>	$9.8 \cdot 10^{-133}$	0.68	$5.2 \cdot 10^{-97}$
<i>Stefan</i>	$8.5 \cdot 10^{-30}$	0.91	$3.2 \cdot 10^{-23}$

Base layer in QCIF format, CIF enhancement layer,  $QP = 25$   
Detection on first I frame

## Bitrate of resolution enhancement layer






Sequence	Bit rate (Kbit/s)		
	L1 (no watermark)	L1	L1 (proposed)
<i>Foreman</i>	883.1	939.5	924.5
<i>Soccer</i>	1188.0	1239.1	1227.0
<i>Bus</i>	1693.0	1732.0	1721.0
<i>Container</i>	906.6	957.7	944.7
<i>Coastguard</i>	1506.6	1557.8	1534.2
<i>Stefan</i>	1621.4	1657.0	1651.0

Base layer in QCIF format, CIF enhancement layer,  $QP = 25$   
Bitrate (in KBit/s) for the first 32 frames

# Conclusion

- ▶ Detection possible on decoded base- and resolution enhancement layer video and
- ▶ Lower bitrate for enhancement layer compared to only watermarking the base layer
- ▶ Independent watermark in enhancement layer increases the bit rate
- ▶ LUD detection scenario, difficult to model
- ▶ Open issues: watermarking of P frames, multiple enhancement layers

## References

-  Kay, S. (1998).  
*Fundamentals of Statistical Signal Processing: Detection Theory*, volume 2.  
Prentice-Hall.
-  Kwitt, R., Meerwald, P., and Uhl, A. (2008).  
A lightweight Rao-Cauchy detector for additive watermarking in the  
DWT-domain.  
In *Proceedings of the ACM Multimedia and Security Workshop (MMSEC '08)*,  
pages 33–41, Oxford, UK. ACM.
-  Noorkami, M. and Mersereau, R. M. (2007).  
A framework for robust watermarking of H.264 encoded video with controllable  
detection performance.  
*IEEE Transactions on Information Forensics and Security*, 2(1):14–23.
-  Noorkami, M. and Mersereau, R. M. (2008).  
Digital video watermarking in P-frames with controlled video bit-rate increase.  
*IEEE Transactions on Information Forensics and Security*, 3(3):441–455.
-  Schwarz, H. and Wien, M. (2008).  
The scalable video coding extension of the H.264/AVC standard.  
*IEEE Signal Processing Magazine*, 25(2):135–141.