Robust watermarking of H.264/SVC-encoded video: quality and resolution scalability

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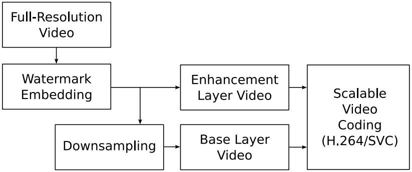
October 2010

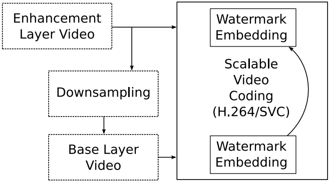
Outline

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

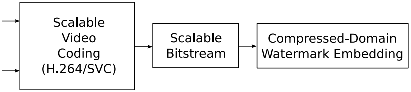
Embedding scenarios



Embedding before encoding



Integrated coding and watermarking

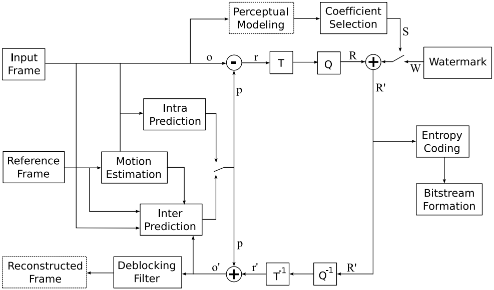


Watermarking the bitstream

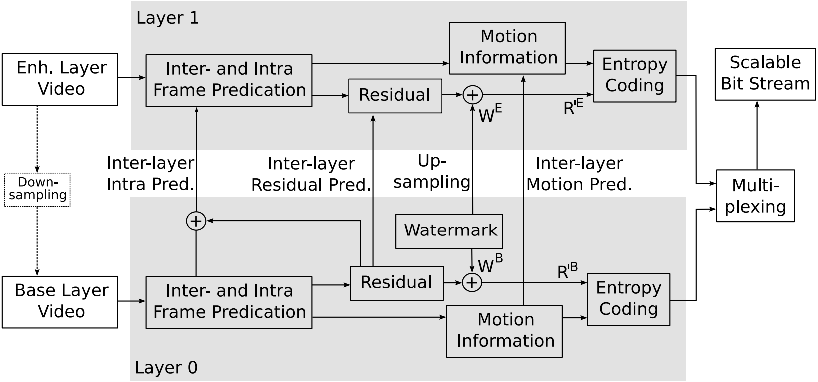
Watermarking of H.264 encoded video

Use framework of [Noorkami and Mersereau, 2007]:

- Embed additive spread-spectrum watermark in AC coefficients of (intra) 4×4 DCT resisual 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

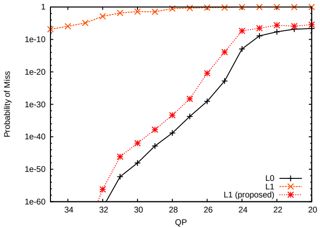


Watermarking multiple H.264/SVC (resolution) layers

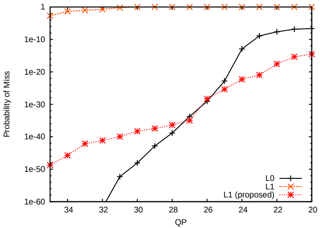
- H.264/SVC enables coding a single bitstream containing multiple resolution and/or quality layers [Schwarz and Wien, 2008]
- H.264/SVC adds new coding tools to exploit statistical dependency between layers via preditive coding
    - Inter layer intra prediction uses the upsampled reconstructed base 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 transfer between base and enhancement layer

- The base-layer (L0) watermark is hardly detectable in the decoded enhancement layer (L1)
- Independent watermarking of each layer increases bit rate (+10%)



Quality Layers



CGS Layers

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

Problems of prior work

- Base layer (L0) watermark does only partially (i.e. for high QP) transfer to the enhancement layer (L1)
- 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 (+3%)
- Detector uses sub-optimal linear correlation [Noorkami and Mersereau, 2007]

Proposal: Embed dependent watermark in higher layer

- Enhancement layer intra blocks are predominantely 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

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

$$R'_E = R_E + W_E$$

$W_B \ldots 4 \times 4$ base layer watermark signal
$S \ldots 4 \times 4$ AC coefficient selection matrix
$T, T^{-1} \ldots$ forward and inverse integer DCT transform
$H \ldots$ upsampling operation
$Q, Q^{-1} \ldots$ quantization and dequantization
$W_E \ldots$ enhancement layer watermark signal
$R_E, R'_E \ldots$ 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 verson 9.19.9, $QP = 25$
- Source code will become available at `http://www.wavelab.at/sources`

Detection performance on decoded resolution enhancement layer

Sequence	Probability of Miss ($P_f = 10^{-3}$)			
	L0	L1 (BL WM)	L1 (indep. WM)	L1 (proposed)
Foreman	$2.3 \cdot 10^{-25}$	0.81	0.0	$3.2 \cdot 10^{-17}$
Soccer	$2.6 \cdot 10^{-69}$	1.0	0.0	$1.1 \cdot 10^{-49}$
Bus	$1.0 \cdot 10^{-8}$	1.0	$2.5 \cdot 10^{-316}$	$6.2 \cdot 10^{-8}$
Container	$5.2 \cdot 10^{-119}$	0.44	0.0	$1.1 \cdot 10^{-91}$
Coastguard	$9.8 \cdot 10^{-133}$	0.68	0.0	$5.2 \cdot 10^{-97}$
Stefan	$8.5 \cdot 10^{-30}$	0.91	0.0	$3.2 \cdot 10^{-23}$

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

Bitrate of resolution enhacement layer

Sequence	Bit rate (Kbit/s)			
	L1 (no WM)	L1 (BL WM)	L1 (indep. WM)	L1 (proposed)
Foreman	883.1	939.5	1018.9	924.5
Soccer	1188.0	1239.1	1303.8	1227.0
Bus	1693.0	1732.0	1779.0	1721.0
Container	906.6	957.7	982.1	944.7
Coastguard	1506.6	1557.8	1572.6	1534.2
Stefan	1621.4	1657.0	1715.0	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 (-1%)
- Independent watermark in enhancement layer increases the bit rate ($+10\%$)
- Rao-Cauchy detector [Kwitt et al., 2008] improves detection performance over linear correlation
- LUD detection scenario, difficult to model
- Open issues: watermarking of P frames, multiple enhancement layers

References

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