ECE 634: Digital Video Systems
Video coding standards: ~~3/2/17~~ 3/7/17

Part 3

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http://engineering.purdue.edu/~reibman/ece634/index.html

Slides with are taken from here

Design and Implementation of Next Generation Video Coding Systems (H.265/HEVC Tutorial)

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ISCAS Tutorial 2014

Overview of the High Efficiency Video Coding (HEVC) Standard

G.J. Sullivan, J.R. Ohm, W.J. Han, and T. Wiegand

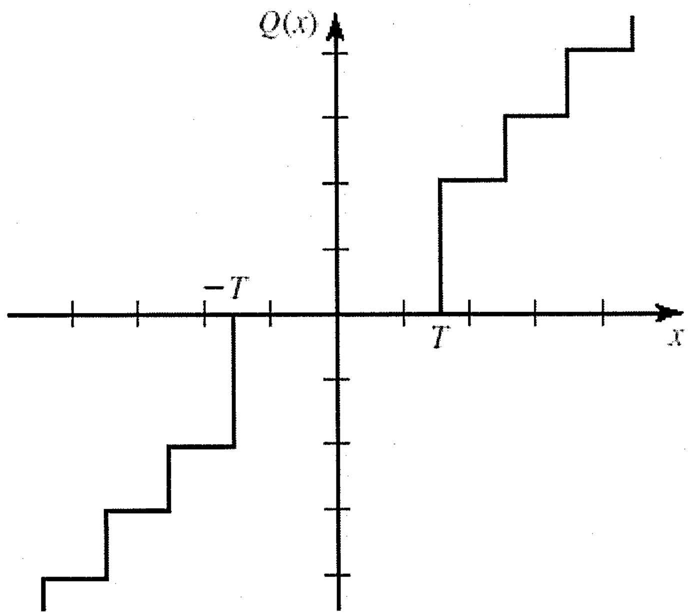
IEEE Trans. Circuits and Systems for Video Technology, vol. 22, no. 12, Dec., 2012

Gaewon Kim (Ph.D. course) and Prof. Changhoon Yim
Department of Internet and Multimedia Engineering, Konkuk University

Slides with ■ are taken from here

Quantization

H.261 DCT Coefficient Quantization



DC Coefficient in Intra-mode:
Uniform, stepsize=8

All other coefficients:
Uniform with deadzone, stepsize=2~64 (MQUANT)

Deadzone:
To avoid too many small coefficients being coded, which are typically due to noise

WIDTH OF DEADZONE IS AN ENCODER OPTION

More quantization

- MPEG-1
  - Using perceptual-based quantization matrix for I-blocks (same as JPEG)
  - Same quantization step sizes

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	39	46	56	69
27	29	35	38	46	56	69	83

H.264 quantization

- Need to adjust for Integer Transform by scaling the quantization step sizes

- Also, instead of having equally spaced Quantization step sizes, H.264 has logarithmically spaced quantization step sizes
  - Increasing the QP by 6 increases the quantization step size by a factor of 2
  - Increasing the QP by 1 increases the quantization step size by about 12%

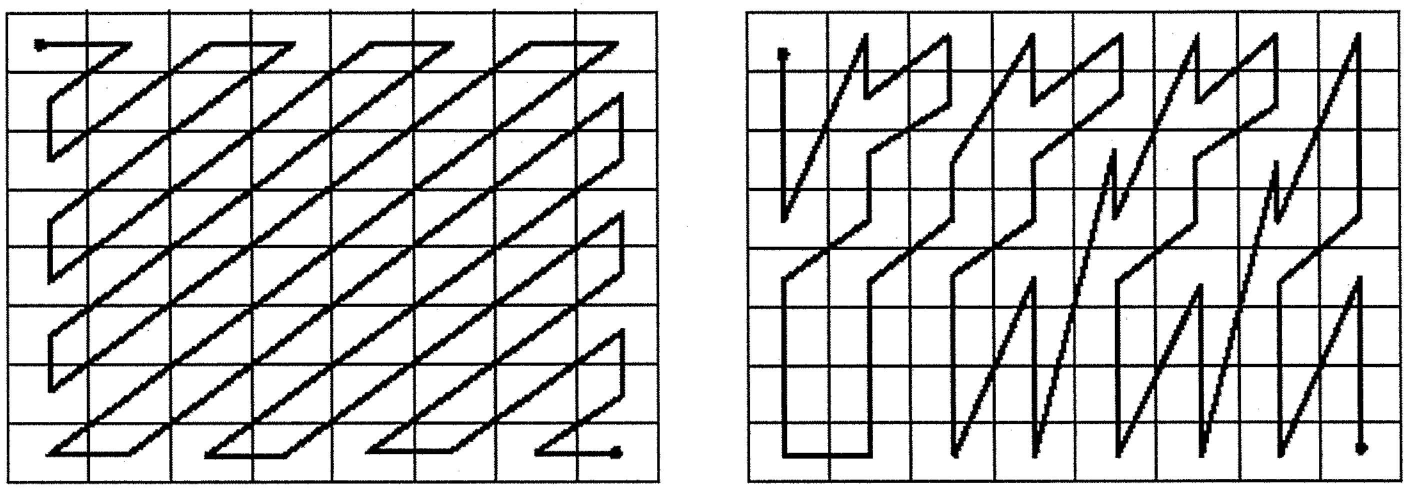
Variable Length Coding

- H.261
  - DCT coefficients are converted into runlength representations and then coded using VLC (Huffman coding for each pair of symbols)
    - Symbol: (Zero run-length, non-zero value range)
  - Other information are also coded using VLC (Huffman coding)
- H.263
  - 3-D VLC for DCT coefficients (runlength, value, EOB)
  - Syntax-based arithmetic coding (option)
    - 4% savings in bit rate for P-mode, 10% saving for I-mode, at 50% more computations
- MPEG-4
  - 3-D VLC similar to H.263

MPEG-2 DCT Modes

Two types of DCT and two types of scan pattern:

- **Frame DCT**: divides an MB into 4 blocks for Lum, as usual
- **Field DCT**: reorder pixels in an MB into top and bottom fields.



Zigzag scan   Alternate scan

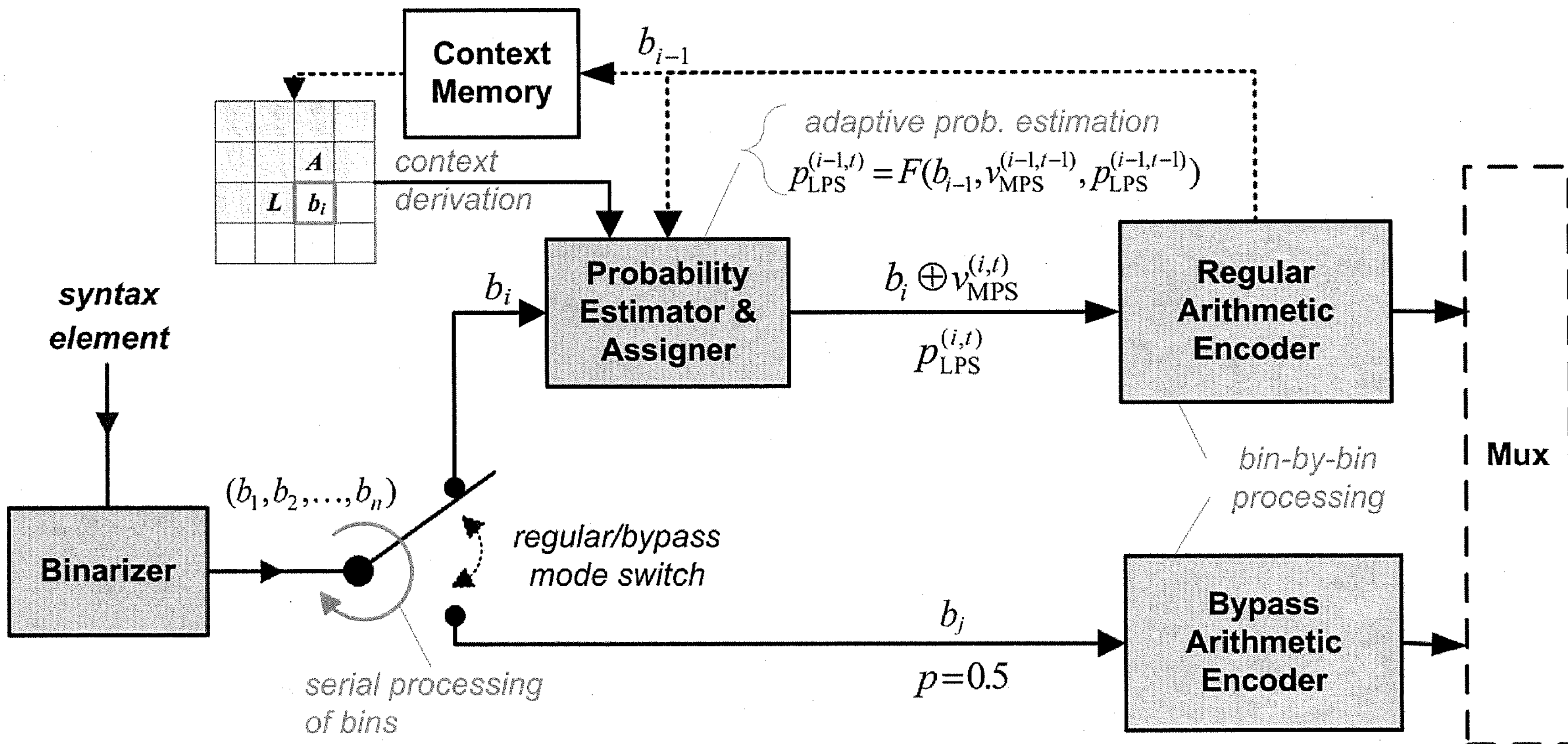
Figure 13.19 The zigzag scan as known from H.261, H.263, and MPEG-1 is augmented by the alternate scan in MPEG-2, in order to code interlaced blocks that have more correlation in the horizontal than in the vertical direction.

H.264 Entropy Coding

- Baseline technique: CAVLC (context adaptively switched sets of variable length codes)
- A more complex technique called CABAC: context-based adaptive binary arithmetic coding
- Both offer significant improvement over Huffman coding which uses pre-designed coding tables based on some assumed statistics

Entropy Coding

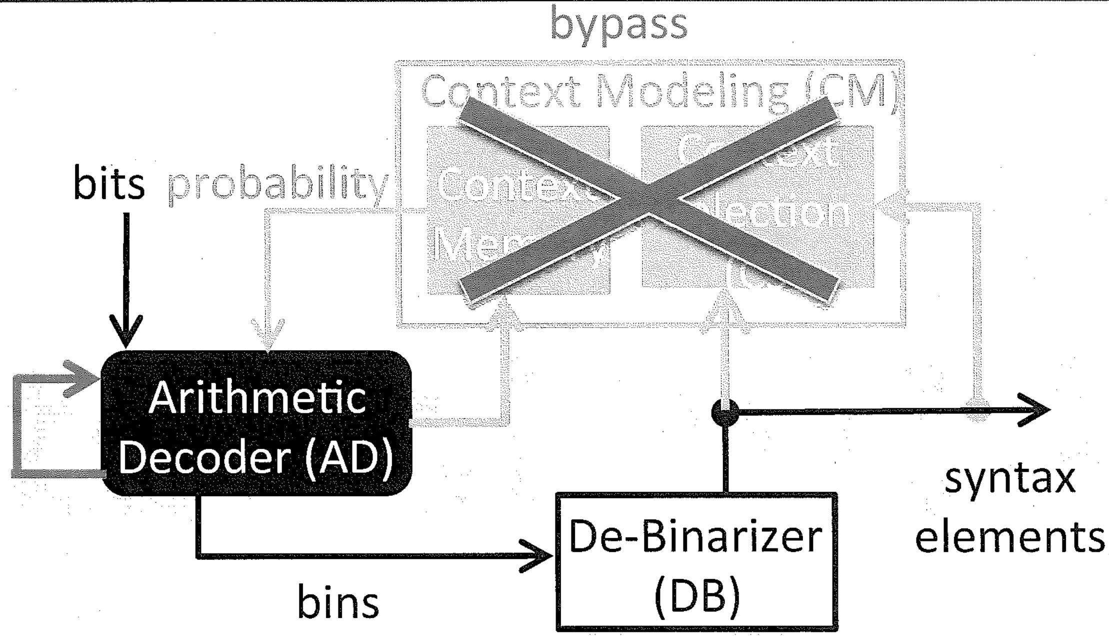
- Lossless compression of syntax elements
- HEVC uses Context Adaptive Binary Arithmetic Coding (CABAC)
  - 10 to 15% higher coding efficiency compared to CAVLC



V. Sze, D. Marpe, "Entropy Coding in HEVC," *High Efficiency Video Coding (HEVC): Algorithms and Architectures*, Springer, 2014.

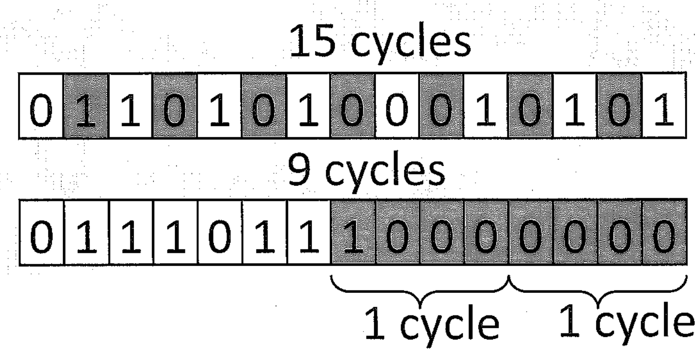
CABAC Throughput Improvements

- Reduce total number of bins
- Reduce context coded bins
- Reduce context dependencies
- **Grouping bypass bins**
- Reduce parsing dependencies
- Reduce memory requirements



Reduction in ***worst case*** bins for 16x16 pixels

	Total bins	Context bins	Bypass bins
H.264/AVC	20861	7805	13056
HEVC	14301	884	13417
Ratio	1.5x	9x	1x



- 3x reduction in context memory
- 20x reduction in line buffer for context selection

V. Sze, M. Budagavi, "High Throughput CABAC Entropy Coding in HEVC," *IEEE TCSVT*, 2012

Loop Filter

- In-Loop filtering can be applied to suppress propagation of coding noise temporally
- H.261
  - Separable filter [1/4,1/2,1/4]
  - Loop filter can be turned on or off
- MPEG-1
  - No loop filter (half-pel motion compensation provides some)
- H.263
  - Optional deblocking filter included in H.263+
  - Overlapped block motion effectively smoothes block boundaries
  - Decoder can choose to implement out-of-loop deblocking filter
- H.264
  - Deblocking filter adapts to the strength of the blocking artifact

H.264 Adaptive Deblocking

4 strengths available based on neighboring block types

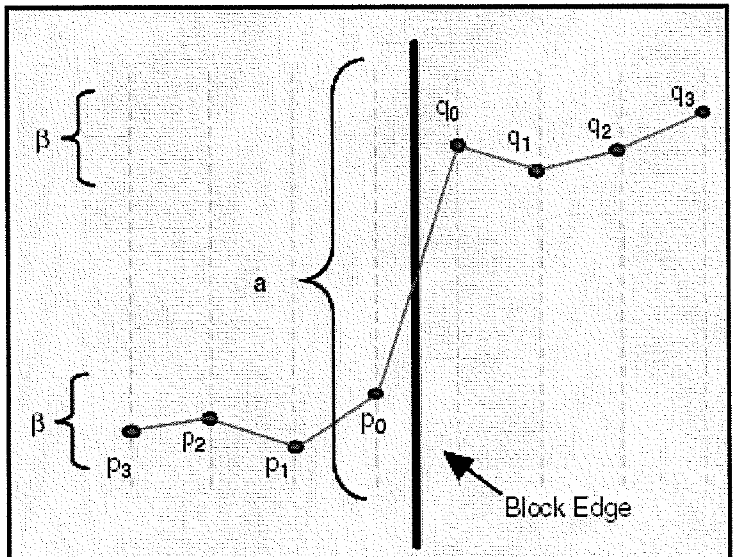


Figure 14. One-dimensional visualization of a block edge in a typical situation where the filter would be turned on.

From [Ostermann04]

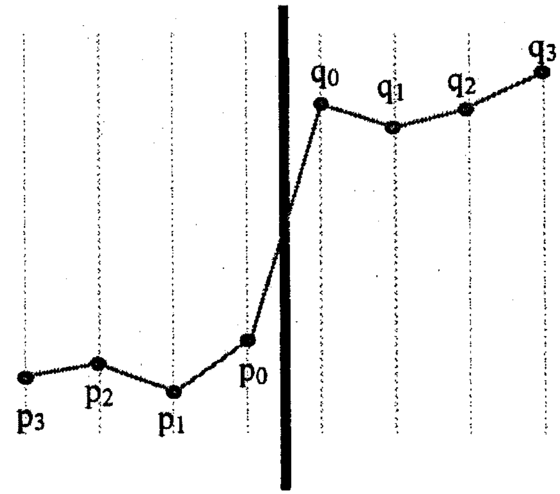
- Whether filtering will be turned on depends on the pixel differences involving pixels p0,…, q0,…, and the filter depends on block characteristics and coding mode
- Deblocking results in bit rate savings of 6-9% at medium qualities, and more remarkable subjective improvements

In-loop Filtering: Deblocking Filter

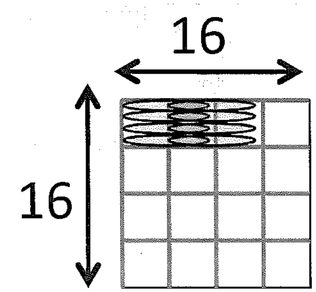
- Removes blocking artifacts due to block based processing
  - Computationally intensive in H.264/AVC

w/o deblocking

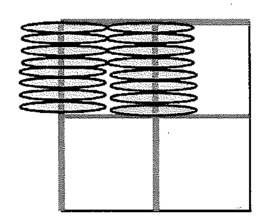
w/ deblocking



- In H.264/AVC, performed on every 4x4 block edge
  - Each macroblock has 128 pixel edges, 32 edge calculations
  - Each 4x4 depends on neighboring 4x4

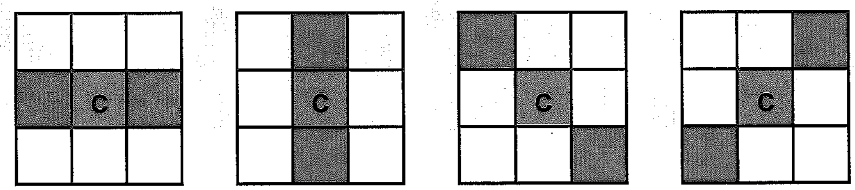


- In HEVC, performed on every 8x8 block edge
  - Each 16x16 CTU has 64 pixel edges, 8 edge calculations
  - All 8x8 are independent (can be processed in parallel)

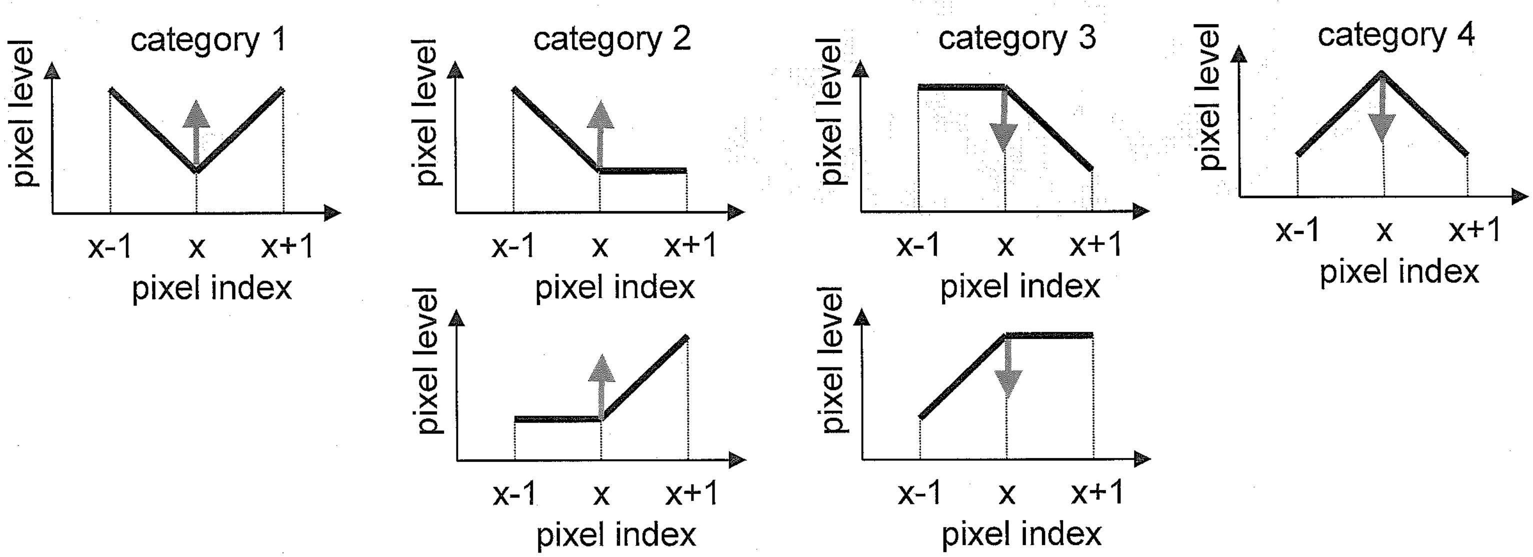


In-loop Filtering: Sample Adaptive Offset (SAO)

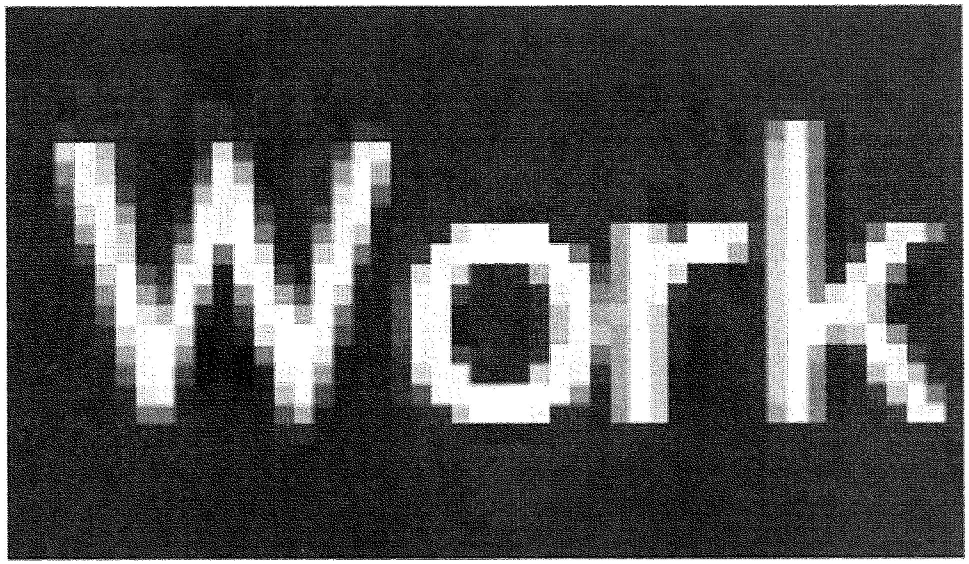
- Filter to address local discontinuities
  - Edge Offset and Band Offset
- Check neighbors in one of 4 directions (0, 90, 135, 45 degrees)



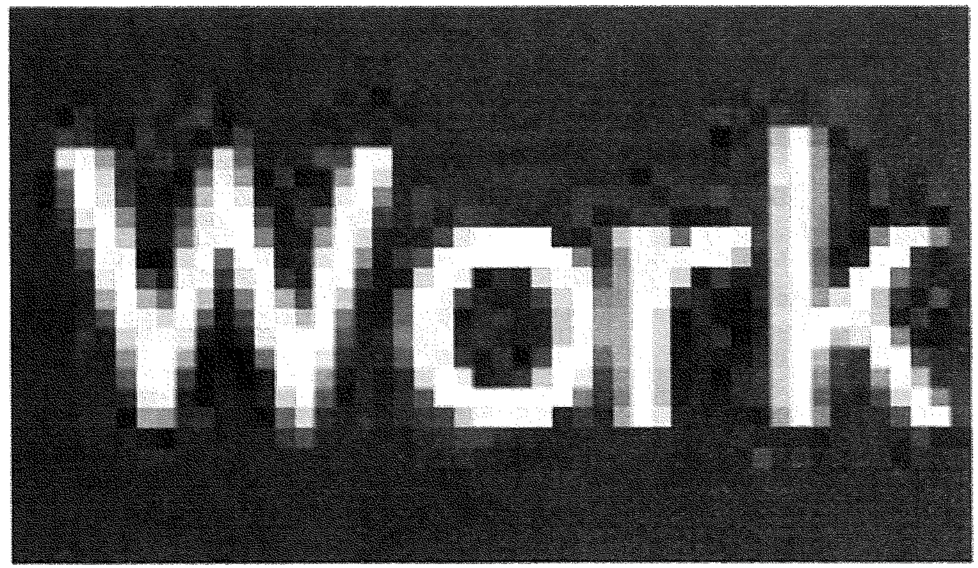
- Based on the values of the neighbors, apply one of 4 offsets



In-loop Filtering: Sample Adaptive Offset (SAO)



With SAO



Without SAO

C.-M. Fu et al., "Sample Adaptive Offset in the HEVC Standard," *IEEE Transactions on Circuits and Systems for Video Technology*, 2012

Removing Intra Artifacts (Pre-Processing)

- Reference Sample Smoothing
  - Smooth out neighboring pixels (i.e., reference samples) before using them for prediction
  - Reduce contouring artifacts caused by edges in the reference sample arrays
  - Two modes
    - Three-tap smoothing filter
    - Strong intra smoothing with corner reference pixels
  - Application of smoothing depends on PU size and prediction mode

w/o pre-filter w/ pre-filter

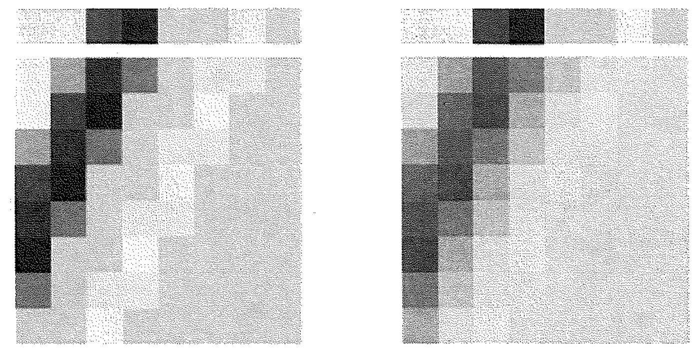
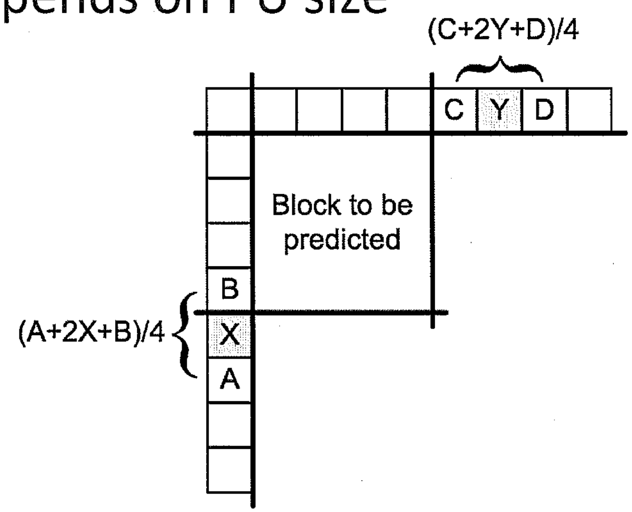
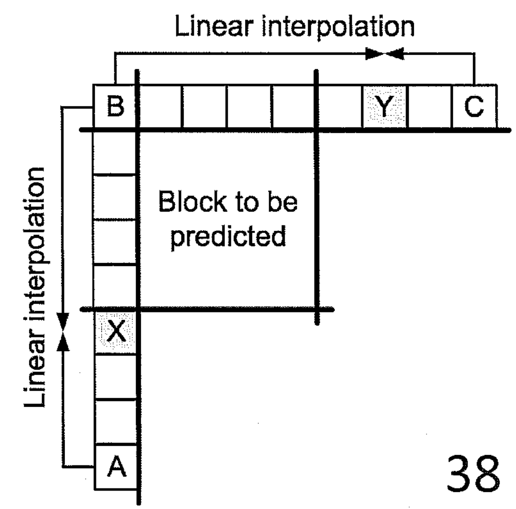


Image source: M. Wien, TCSVT, July 2003

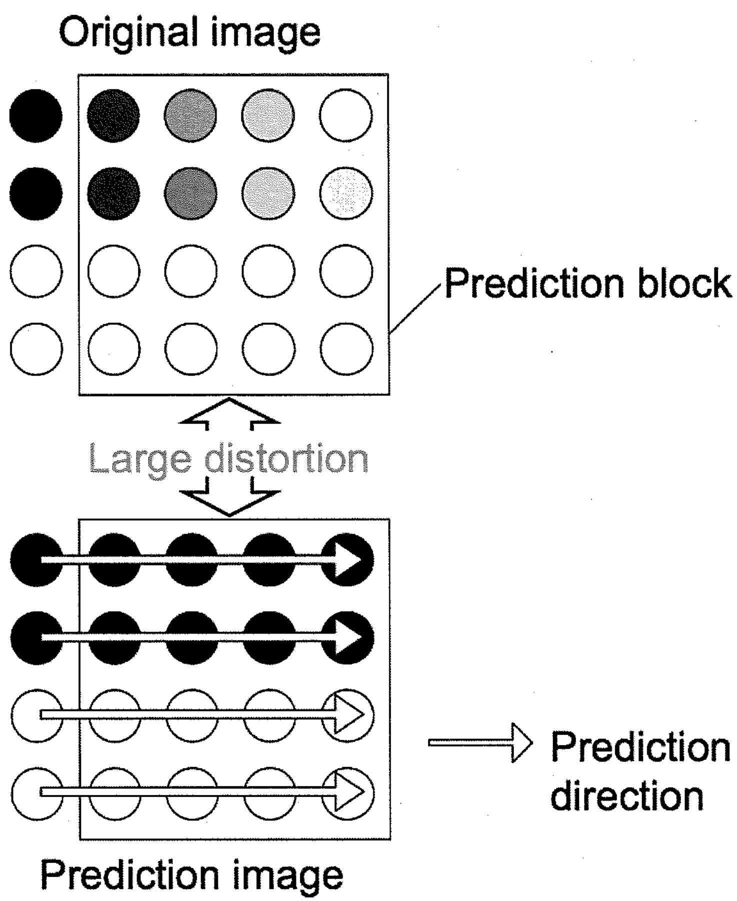
J. Lainema, W.-J. Han, "Intra Prediction in HEVC," *High Efficiency Video Coding (HEVC): Algorithms and Architectures*, Springer, 2014.





Removing Intra Artifacts (Post-Processing)

- Boundary Smoothing
  - Intra prediction may introduce discontinuities along block boundaries
  - Filter first prediction row and column with three-tap filter for DC prediction, and two-tap for horizontal and vertical prediction



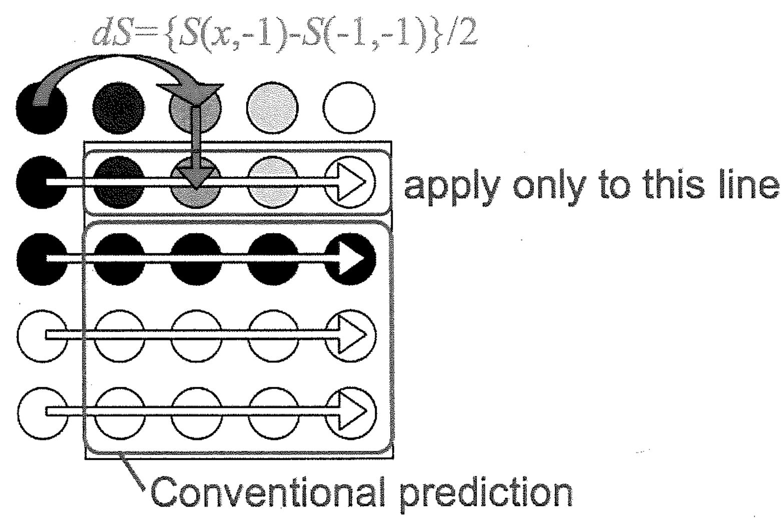
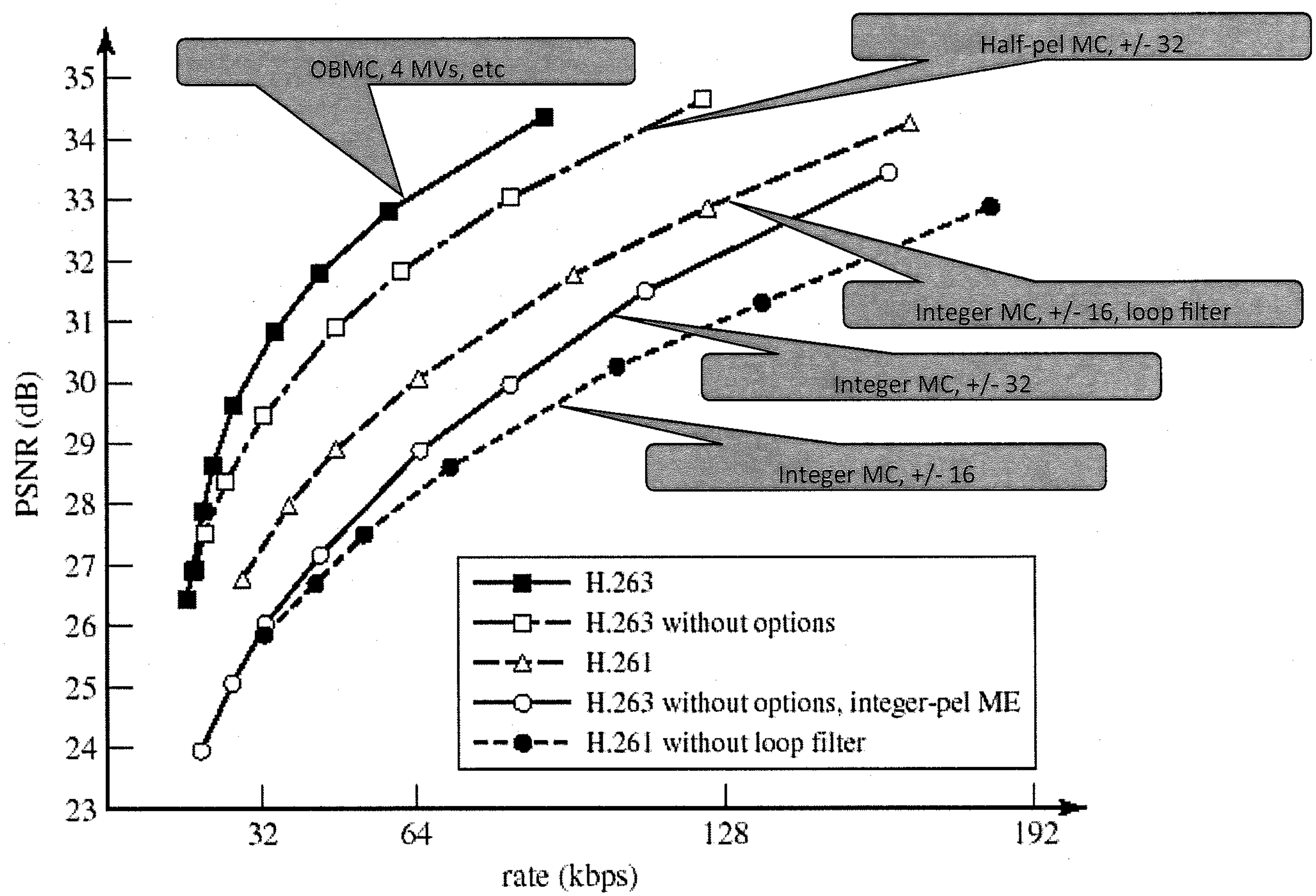


Image source: JCTVC-F172, July 2011

More comparisons between standards

Performance of H.261 and H.263



Forman, QCIF, 12.5 Hz

MPEG2 vs. MPEG1 Video

- MPEG1 only handles progressive sequences (SIF).
- MPEG2 is targeted primarily at interlaced sequences and at higher resolution (BT.601 = 4CIF).
- More sophisticated motion estimation methods (*frame/field prediction mode*) are developed to improve estimation accuracy for interlaced sequences.
- Different DCT modes and scanning methods are developed for interlaced sequences.
- MPEG2 has various scalability modes.
- MPEG2 has various profiles and levels, each combination targeted for different application

MPEG-4 vs. MPEG-1 Coding Efficiency

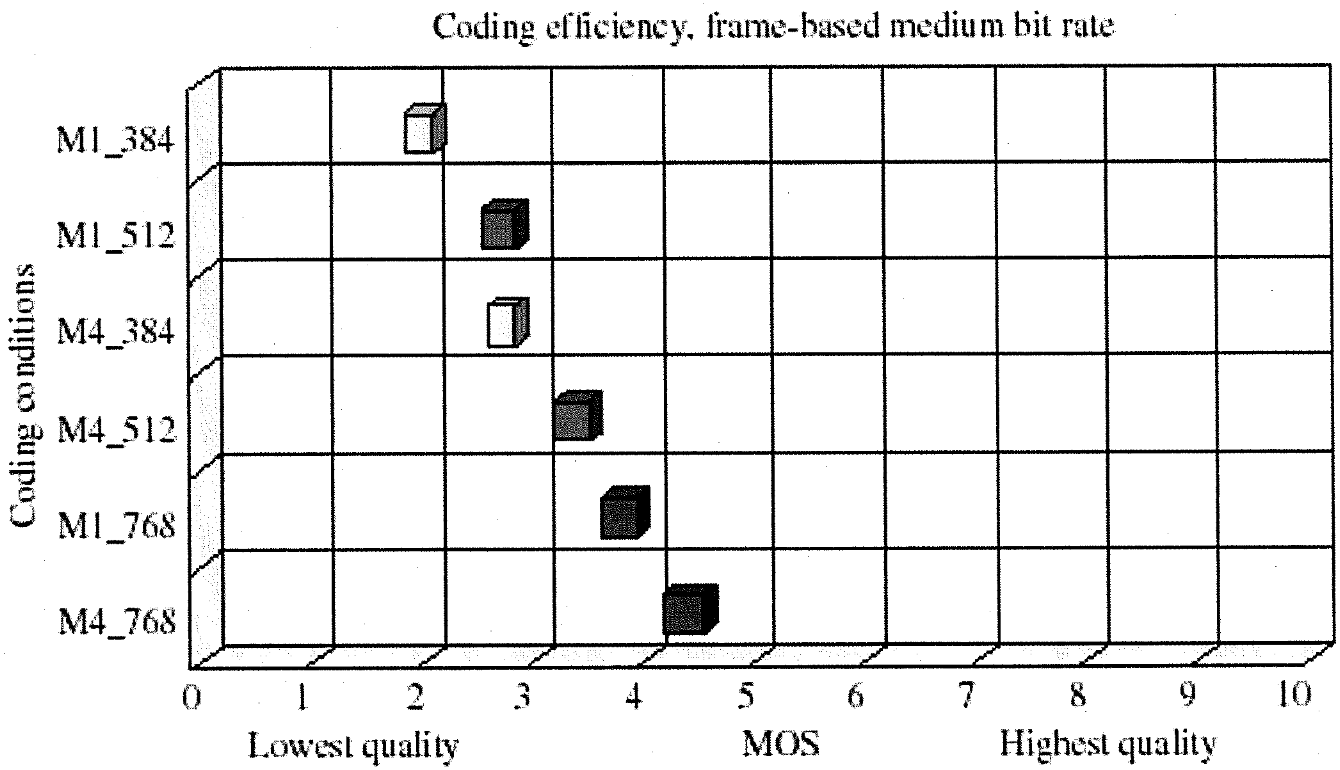


Figure 13.39 Subjective quality of MPEG-4 Main profile versus MPEG-1. M4_x is an MPEG-4 coder operating at the rate of x kbps; M1_x is an MPEG-1 encoder operating at the given rate [27].

Coding efficiency streaming

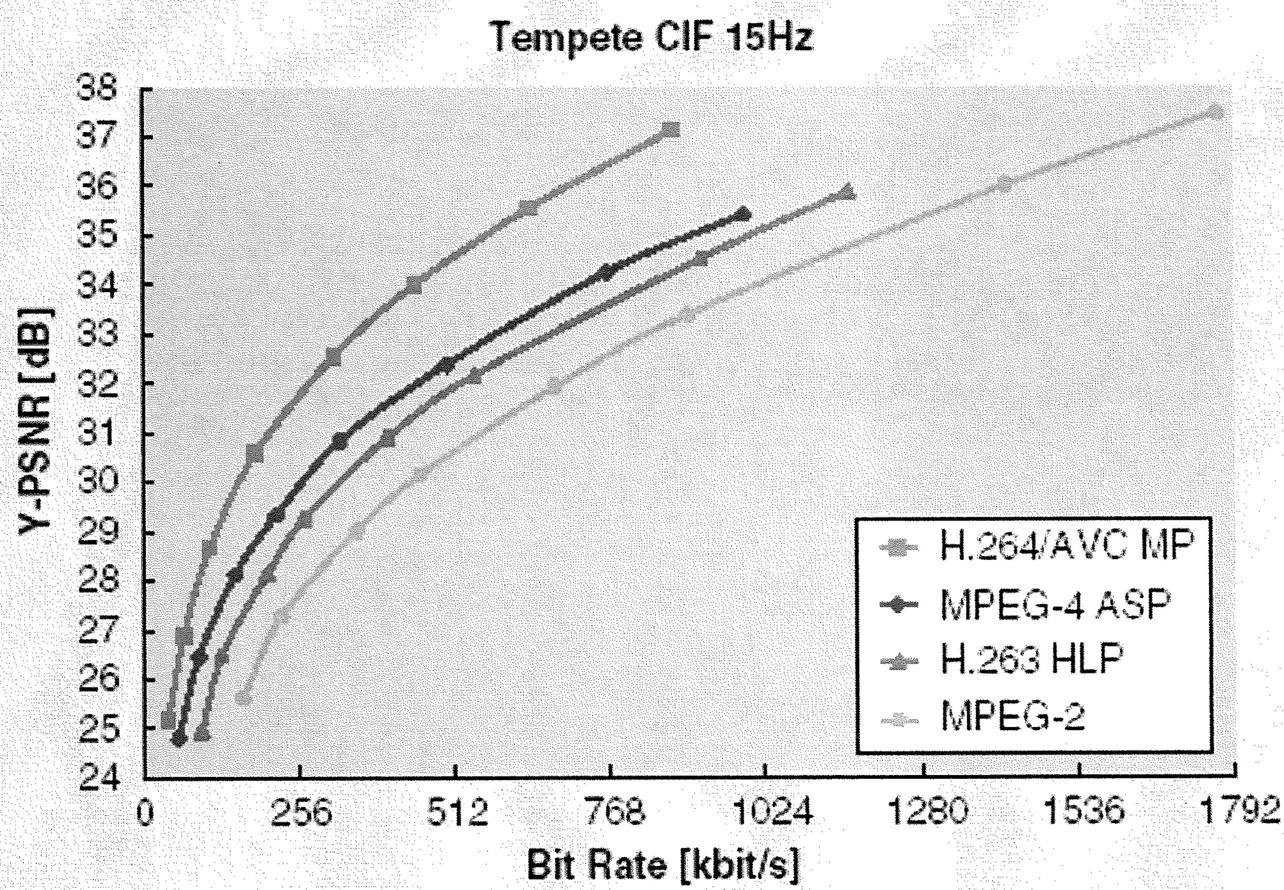


Figure 21. Luminance PSNR versus average bit rate for different coding standards, measured for the test sequence T
applications (from [36]).

From [Ostermann02]

Table 1.
Average bit rate savings for video streaming applications (from [10]).

	Average Bit Rate Savings Relative To:		
Coder	MPEG-4 ASP	H.263 HLP	MPEG-2
H.264/AVC MP	37.44%	47.58%	63.57%
MPEG-4 ASP	–	16.65%	42.95%
H.263 HLP	–	–	30.61%

Coding efficiency conferencing

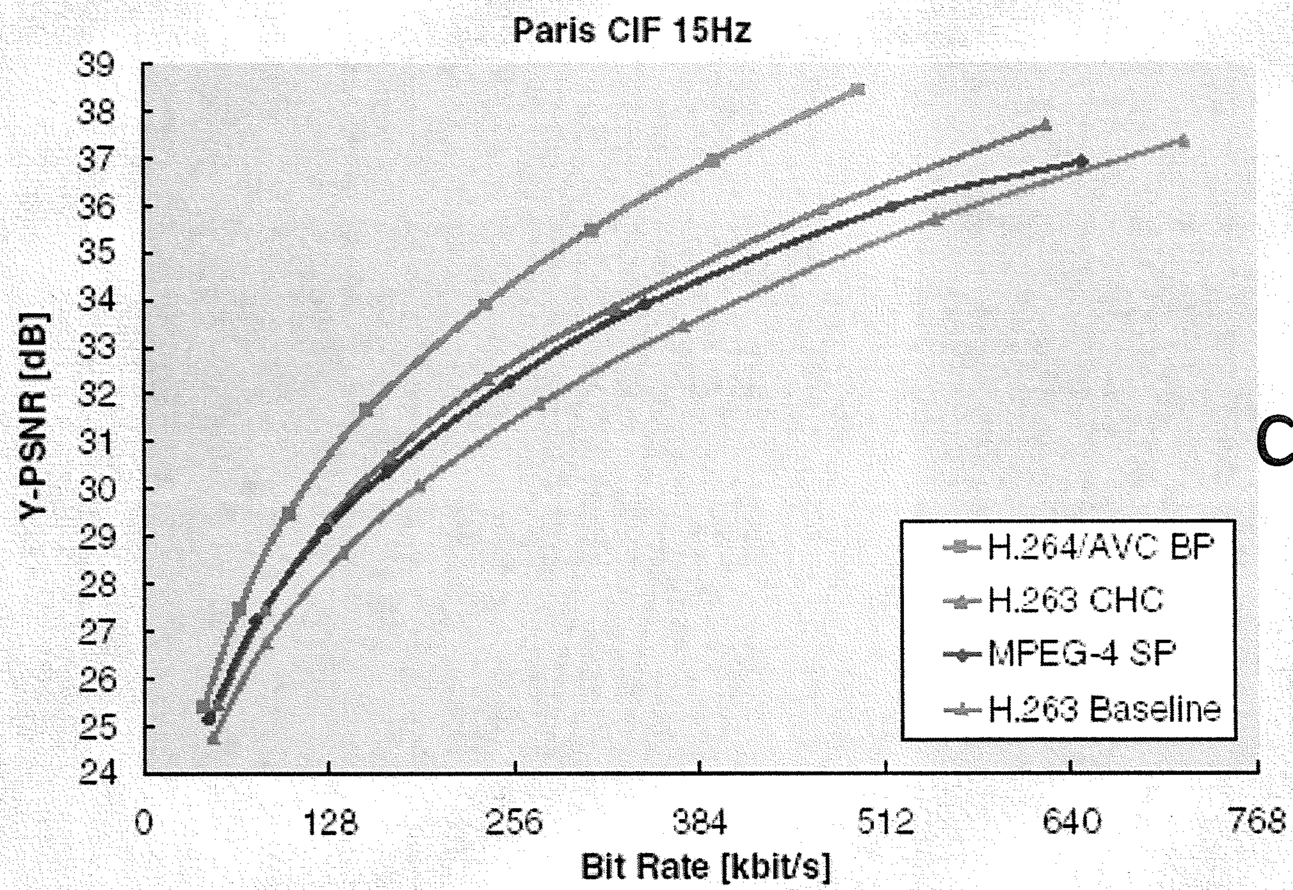


Figure 22. Luminance PSNR versus average bit rate for different coding standards, measured for the test sequence *Paris* for video c...

From [Ostermann02]

Table 2.
Average bit rate savings for video conferencing applications (from [10]).

Coder	Average Bit Rate Savings Relative To: H.263 CHC	MPEG-4 SP	H.263 Base
H.264/AVC BP	27.69%	29.37%	40.59%
H.263 CHC	–	2.04%	17.63%
MPEG-4 SP	–	–	15.69%

H.264 complexity

- H.264 decoder is about 2 times as complex as an MPEG-4 Visual decoder for the Simple profile
- H.264 encoder is about 10 times as complex as a corresponding MPEG-4 Visual encoder for the Simple profile
- The H.264/AVC main profile decoder suitable for entertainment applications is about 4 times more complex than MPEG-2

Summary

- H.261:
  - First video coding standard, targeted for video conferencing over ISDN
  - Uses block-based hybrid coding framework with integer-pel MC
- H.263:
  - Improved quality at lower bit rate, to enable video conferencing/ telephony below 54 bkps (modems or internet access, desktop conferencing)
  - Half-pel MC and other improvement
- MPEG-1 video
  - Video on CD and video on the Internet (good quality at 1.5 mbps)
  - Half-pel MC and bidirectional MC
- MPEG-2 video
  - TV/HDTV/DVD (4-15 mbps)
  - Extended from MPEG-1, considering interlaced video

Summary (Cnt'd)

- MPEG-4
  - To enable object manipulation and scene composition at the decoder → interactive TV/virtual reality
  - Object-based video coding: shape coding
  - Coding of synthetic video and audio: animation
- H.264:
  - Significant improvement in coding efficiency over H.263/MPEG4
  - Fundamentally similar ideas but with more adaptive/optimized implementation, feasible only with recent advance in computation power.
- Other MPEG standards
  - MPEG-7
    - To enable search and browsing of multimedia documents
  - MPEG-21
    - beyond MPEG-7, considering intellectual property protection, etc.

Some References

- Wang, Ostermann, Zhang, Chap. 13 (13.2, 13.4—13.6 except section on scalability, pp. 430-435), Section 9.3.2
- H.264:
  - J. Ostermann et al., Video coding with H.264/AVC: Tools, performance, and complexity, IEEE Circuits and Systems Magazine, First Quarter, 2004
  - IEEE Trans. Circuits and Systems for Video Technology, special issue on H.264, July 2003.
- AVS
  - http://vspc.ee.cuhk.edu.hk/~ele5431/AVS.pdf (King Ngan, Chinese University of Hong Kong)