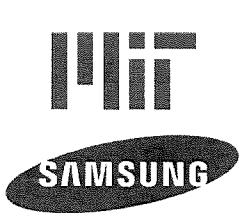
ECE 634: Digital Video Systems
Video coding standards: 3/2/17

Part 1

Professor Amy Reibman
MSEE 356
reibman@purdue.edu

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



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

Vivienne Sze (sze@mit.edu)
Madhukar Budagavi (m.budagavi@samsung.com)

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

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all other slides are mine, or individually indicated

Outline

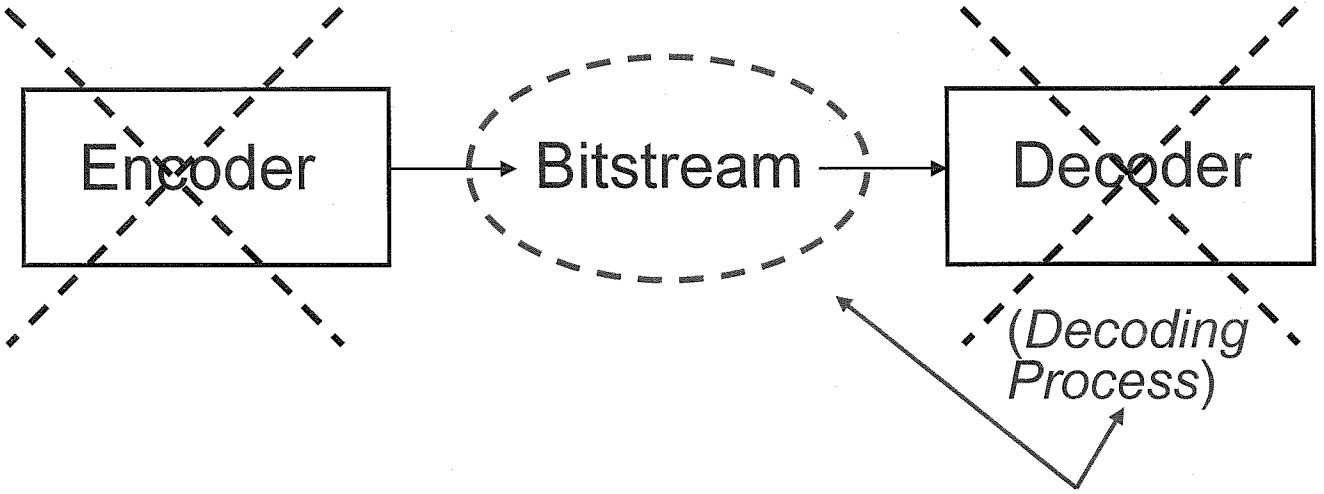
- Video Standardization
  - What is standardized: Interoperability
  - How does the standardization process work
  - Why does certain technology get included?
  - Profiles and levels

Motivation for Standards

- Goal of standards:
  - *Ensuring interoperability:* Enabling communication between devices made by different manufacturers
  - Promoting a technology or industry
  - Reducing costs

What do the Standards Specify?

What do the Standards Specify?



- Not the encoder
- Not the decoder
- Just the *bitstream syntax* and the *decoding process* (e.g., use IDCT, but not how to implement the IDCT)
  - → Enables improved encoding & decoding strategies to be employed in a standard-compatible manner

Timeline and "needs" of the standards

ITU : International Telecom. Union

ISO : International Standards organization

- H.261 (1990): Video conferencing
- MPEG-1 (1992): Non-interactive applications, VCD
- MPEG-2 and H.262 (1996): TV broadcast, DVD
- H.263 (Nov. 1995; Sept. 1997, Nov. 2000): Video conferencing
- MPEG-4 video (part 2) (1999): object-oriented coding
- H.264 and MPEG-4 part 10 (AVC) (2003): compression efficiency
- AVS (Audio and Visual Coding Standard) (2006): avoiding high licensing fees
- HEVC/H.265 (2013): compression efficiency and higher resolutions

"Current" Image and Video Compression Standards

Standard	Application	Bit Rate
JPEG	Continuous-tone still-image compression	Variable
H.261	Video telephony and teleconferencing over ISDN	p x 64 kb/s
MPEG-1	Video on digital storage media (CD-ROM)	1.5 Mb/s
MPEG-2	Digital Television	2-20 Mb/s
H.263	Video telephony over PSTN	33.6-? kb/s
MPEG-4	Object-based coding, synthetic content, interactivity	Variable
JPEG-2000	Improved still image compression	Variable
H.264 / MPEG-4 part AVC	Improved video compression	10's kb/s to Mb/s

MPEG and JPEG: International Standards Organization (ISO)

H.26x family: International Telecommunications Union (ITU)

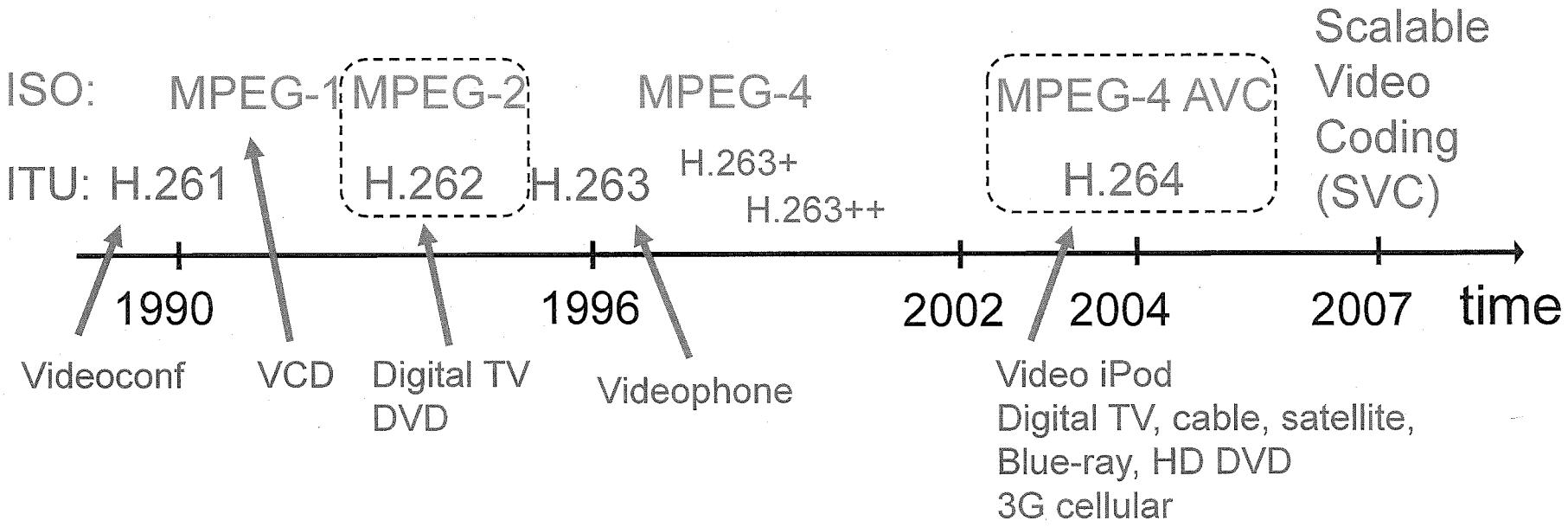
Multimedia Communications Standards and Applications

Standards	Application	Video Format	Raw Data Rate	Compressed Data Rate
H.320 (H.261)	Video conferencing over ISDN	CIF QCIF	37 Mbps 9.1 Mbps	>=384 Kbps >=64 Kbps
H.323 (H.263)	Video conferencing over Internet	4CIF/ CIF/ QCIF		>=64 Kbps
H.324 (H.263)	Video over phone lines/ wireless	QCIF	9.1 Mbps	>=18 Kbps
MPEG-1	Video distribution on CD/ WWW	CIF	30 Mbps	1.5 Mbps
MPEG-2	Video distribution on DVD / digital TV	CCIR601 4:2:0	128 Mbps	3-10 Mbps
MPEG-4	Multimedia distribution over Inter/Intra net	QCIF/CIF		28-1024 Kbps
GA-HDTV	HDTV broadcasting	SMPTE296/295	<=700 Mbps	18--45 Mbps
MPEG-7	Multimedia databases (content description and retrieval)			

ITU-T Multimedia Communications Standards

Network	System	Video	Audio	Mux	Control
PSTN	H.324	H.261/3	G.723.1	H.223	H.245
N-ISDN	H.320	H.261	G.7xx	H.221	H.242
B-ISDN/ATM	H.321	H.261	G.7xx	H.221	Q.2931
	H.310	H.261/2	G.7xx/MPEG	H.222.0/1	H.245
QoS LAN	H.322	H.261/3	G.7xx	H.221	H.242
Non-QoS LAN	H.323	H.261/3	G.7xx	H.225.0	H.245

History of Video Coding Standards



H.261 Video Coding Standard

- For video-conferencing/video phone
  - Video coding standard in H.320
  - Low delay (real-time, interactive)
  - Slow motion in general
- For transmission over ISDN
  - Fixed bandwidth: px64 Kbps, p=1,2,…,30
- Video Format:
  - CIF (352x288, above 128 Kbps)
  - QCIF (176x144, 64-128 Kbps)
  - 4:2:0 color format, progressive scan
- Work started in 1985; Standard published in 1990

MPEG-1 Overview

- Audio/video on CD-ROM (1.5 Mbps, SIF: 352x240).
  - Maximum: 1.856 mbps, 768x576 pels
- Start late 1988, test in 10/89, Committee Draft 9/90
- ISO/IEC 11172-1~5 (Systems, video, audio, compliance, software).
- Prompted explosion of digital video applications: MPEG1 video CD and downloadable video over Internet
- Software only decoding, made possible by the introduction of Pentium chips, key to the success in the commercial market
- MPEG-1 Audio
  - Offers 3 coding options (3 layers), higher layer have higher coding efficiency with more computations
  - MP3 = MPEG1 layer 3 audio

MPEG-2 Overview

- A/V broadcast (TV, HDTV, Terrestrial, Cable, Satellite, High Speed Inter/ Intranet) as well as DVD video
- 4~8 Mbps for TV quality, 10-15 for better quality at SDTV resolutions (BT. 601)
- 18-45 Mbps for HDTV applications
  - MPEG-2 video high profile at high level is the video coding standard used in HDTV
- Test in 11/91, Committee Draft 11/93
- ISO/IEC 13818-1~6 (Systems, video, audio, compliance, software, DSM-CC)
- Consist of various profiles and levels
- Backward compatible with MPEG1
- MPEG-2 Audio
  - Support 5.1 channel
  - MPEG2 AAC: requires 30% fewer bits than MPEG1 layer 3

H.263 Overview

- H.263 is the video coding standard in H.323/H.324, targeted for visual telephone over PSTN or Internet
- Can accommodate computationally more intensive options than H.261
  - Initial version (H.263 baseline): 1995
  - H.263+: 1997
  - H.263++: 2000
- Goal: Improved quality at lower rates
- Result: Significantly better quality at lower rates
  - Better video at 18-24 Kbps than H.261 at 64 Kbps
  - Enables video phone over regular phone lines (28.8 Kbps) or wireless modem

MPEG-4 Overview

- Video functionalities beyond MPEG-1/2
  - Interaction with individual objects
    - The displayed scene can be composed by the receiver from coded objects
  - Scalability of contents
  - Error resilience
  - Coding of both natural and synthetic audio and video
- Many other sections
  - Digital Rights Management
  - Advanced Audio Coding (AAC)

H.264/AVC Standards

- Finalized March 2003
- Developed by the joint video team (JVT) including video coding experts from the ITU-T and the ISO MPEG
- Also known as MPEG-4 part 10; Advanced Video Coding (AVC)
- Improved video coding efficiency, up to 50% over H.263++/ MPEG4
  - Half the bit rate for similar quality
  - Significantly better quality for the same bit rate
- Reference & figures for this section are from
  - *Ostermann et al., Video coding with H.264/AVC: Tools, performance, and complexity, IEEE Circuits and Systems Magazine, First Quarter, 2004*

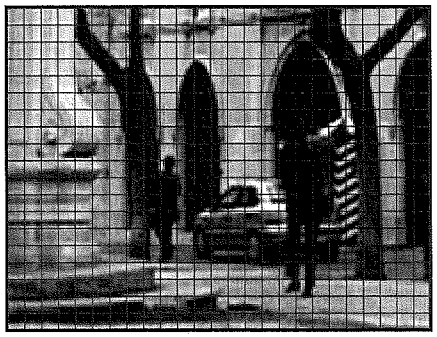
AVS (Audio Visual Coding Standard) Overview

- Chinese standard; 2002-2003 (Video)
- Licensing fees for all ISO and ITU standards after (not including) MPEG-1
- China produces more than 30 million Set Top Boxes
- Interlaced pictures, SDTV and HDTV
- Similar (slightly less) compression efficiency as H.264
- Interlaced pictures
- Intra prediction
- Variable block-size MC
- ¼ resolution motion, 4-tap interpolation filter
- 8x8 Integer Transform
- Deblocking

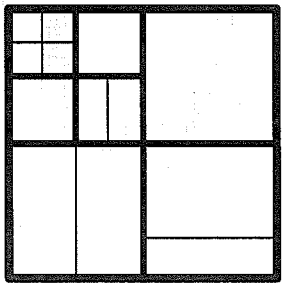
High Efficiency Video Coding (HEVC)

- October 2010: defined new Test Model for HEVC, HM1
- Targeting high efficiency and low complexity applications
- Block sizes from 8x8 to 64x64 in tree structure
- Quadtree structured block size from 4x4 to 32x32 samples
- Up to 34 directions for intra-prediction
- 6- or 12-tap interpolation filter, down to 1/4-sample
- Advanced motion vector prediction
- CABAC or Low Complexity Entropy Coding
- Deblocking filter or Adaptive Loop Filter
- Extended precision options
- Goal: 2x better video compression performance compared to H.264/ AVC.

H.265/HEVC vs. H.264/AVC Decoder



64x64



Larger and Flexible Coding Block Size

Larger Interpolation Filter

Picture Buffer

Decoded pixels

Fewer Edges

Sample Adaptive Offset

Motion Comp.

Deblocking Filter

Encoded bitstream

Entropy Decoder

Intra Prediction

Q^{-1} $+T^{-1}$

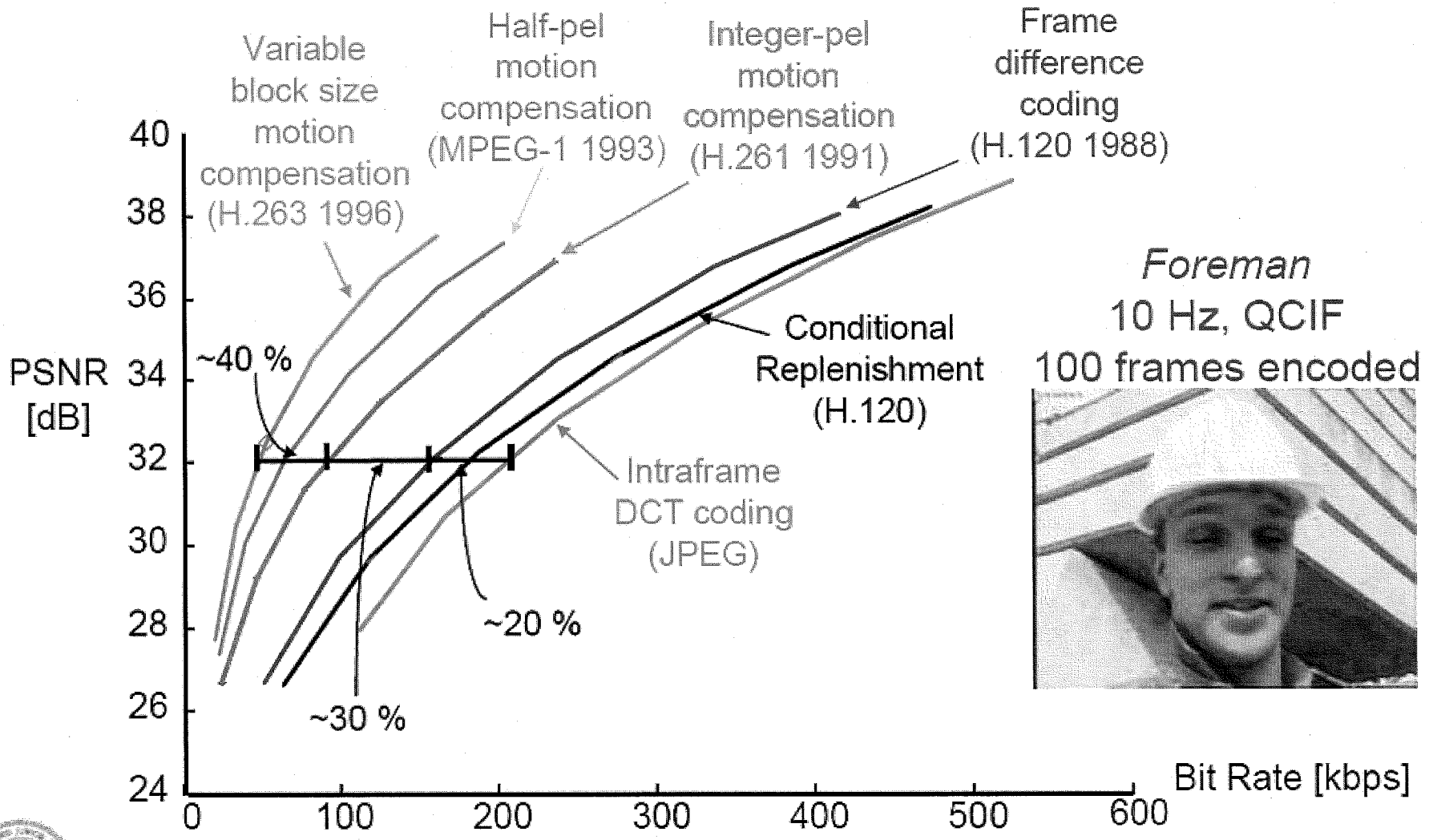
In-loop Filter

High Throughput CABAC & Advanced Motion Vector Prediction

Larger Transforms and More Sizes

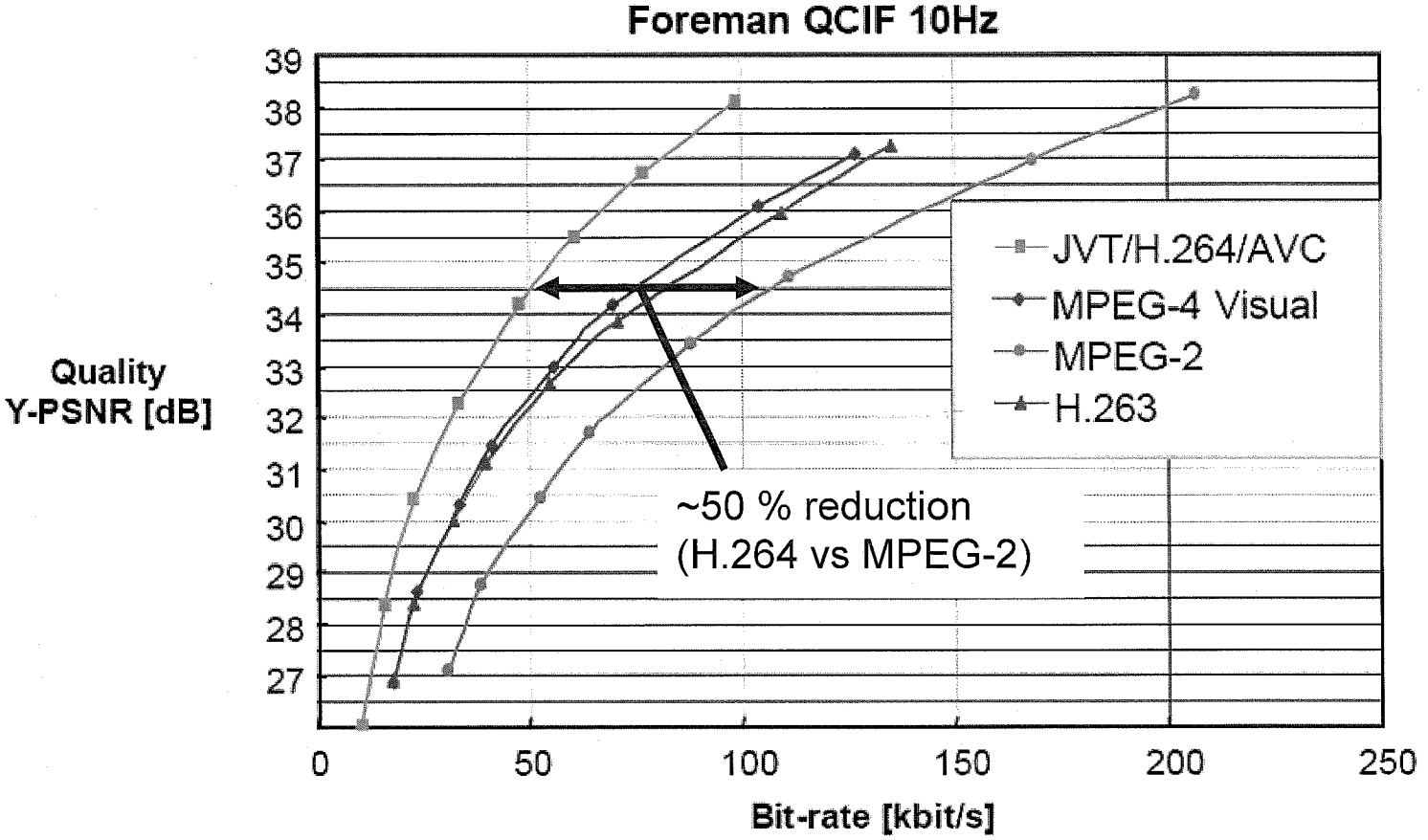
More Prediction Modes

Video compression progress

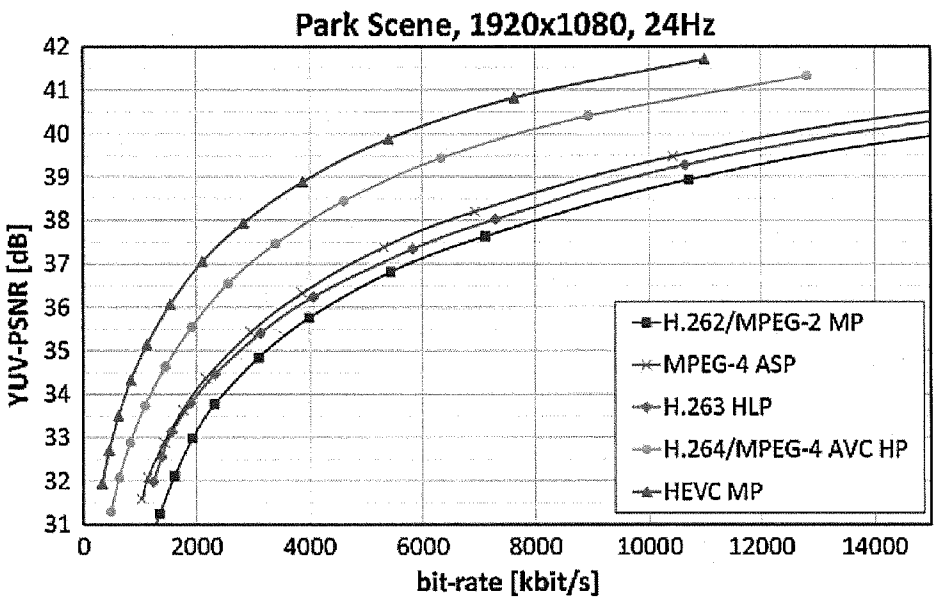


Example Comparison: Results depend strongly on specific sequence & coding tools employed!

Comparison to MPEG-2, H.263, MPEG-4p2



Coding Efficiency of HEVC (Objective)



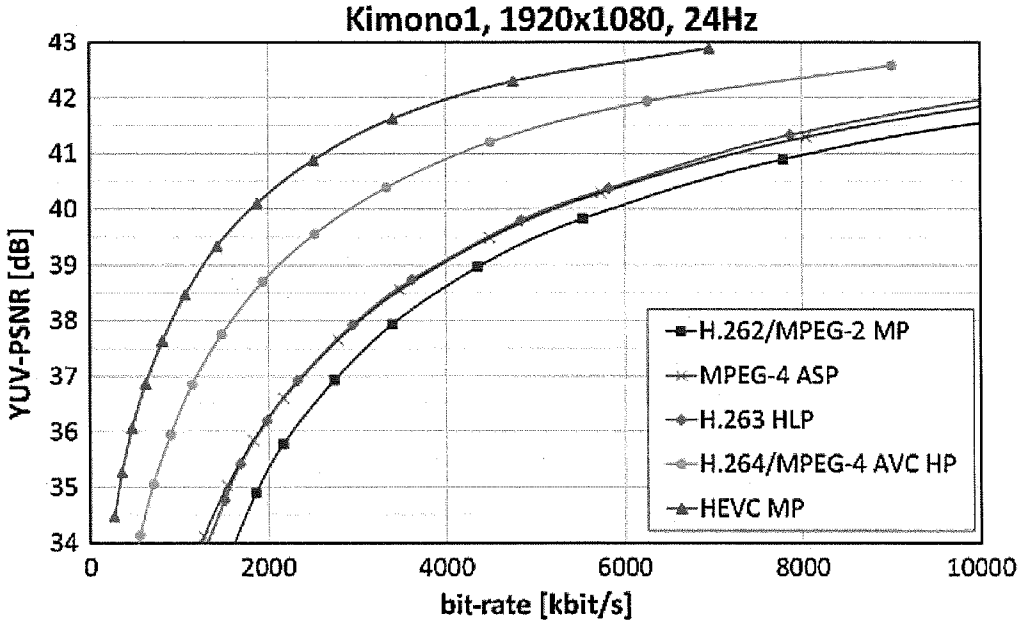


TABLE VI

AVERAGE BIT-RATE SAVINGS FOR EQUAL PSNR FOR ENTERTAINMENT APPLICATIONS

Encoding	Bit-Rate Savings Relative to			
	H.264/MPEG-4 AVC HP	MPEG-4 ASP	H.263 HLP	MPEG-2/ H.262 MP
HEVC MP	35.4%	63.7%	65.1%	70.8%
H.264/MPEG-4 AVC HP	–	44.5%	46.6%	55.4%
MPEG-4 ASP	–	–	3.9%	19.7%
H.263 HLP	–	–	–	16.2%

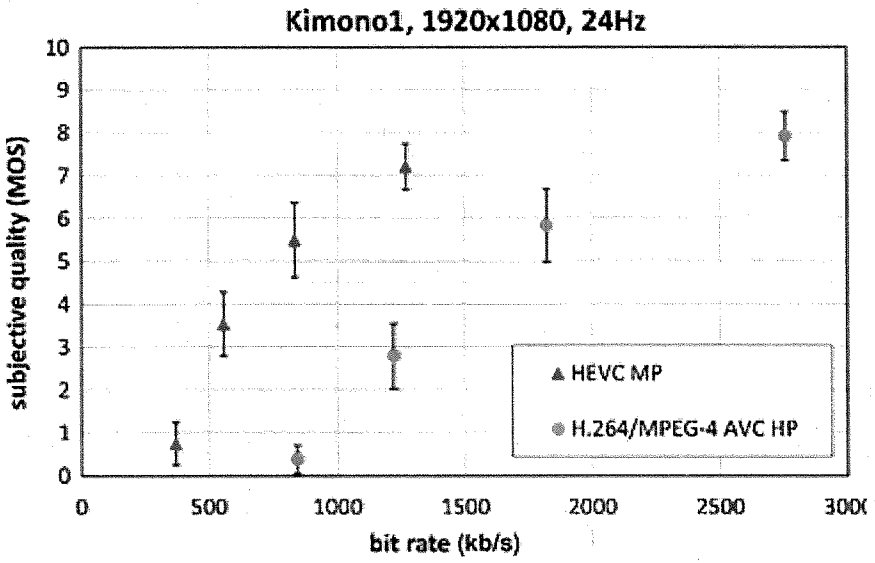
$$PSNR = 10\log_{10}\frac{(2^{bitdepth}-1)^2 * W * H}{\sum_i \{O_i - D_i\}^2}$$

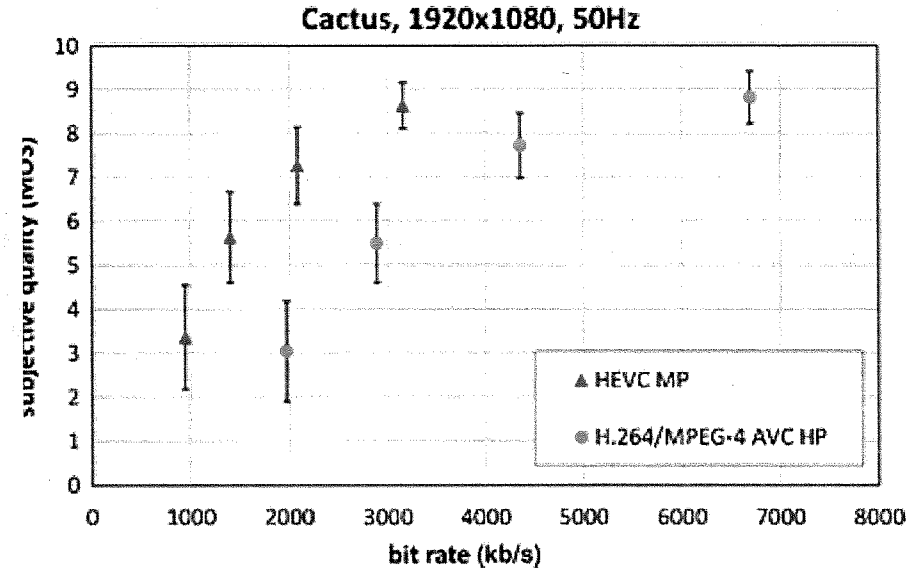
J. R. Ohm et al., "Comparison of the Coding Efficiency of Video Coding Standards—Including High Efficiency Video Coding (HEVC),"*IEEE Transactions on Circuits and Systems for Video Technology*, 2012

Coding Efficiency of HEVC (Subjective)

Subjective Tests for Entertainment Applications (Random Access)

Sequences	Bit-rate Savings
BQ Terrace	63.1%
Basketball Drive	66.6%
Kimono1	55.2%
Park Scene	49.7%
Cactus	50.2%
BQ Mall	41.6%
Basketball Drill	44.9%
Party Scene	29.8%
Race Horse	42.7%
Average	**49.3%**





J. Ohm et al., "Comparison of the Coding Efficiency of Video Coding Standards—Including High Efficiency Video Coding (HEVC),"*IEEE Transactions on Circuits and Systems for Video Technology*, 2012

Standardization Process

- Competition phase
- Collaboration phase
  - A Reference Model is defined
  - Companies make contributions
  - A contribution is incorporated into the (new) reference model ONLY if it:
    - Improves performance by a sufficient margin
    - Is replicated by at least one other company
    - Its performance improvement is not at the cost of "too much" complexity
- Verification phase

Video coding standards

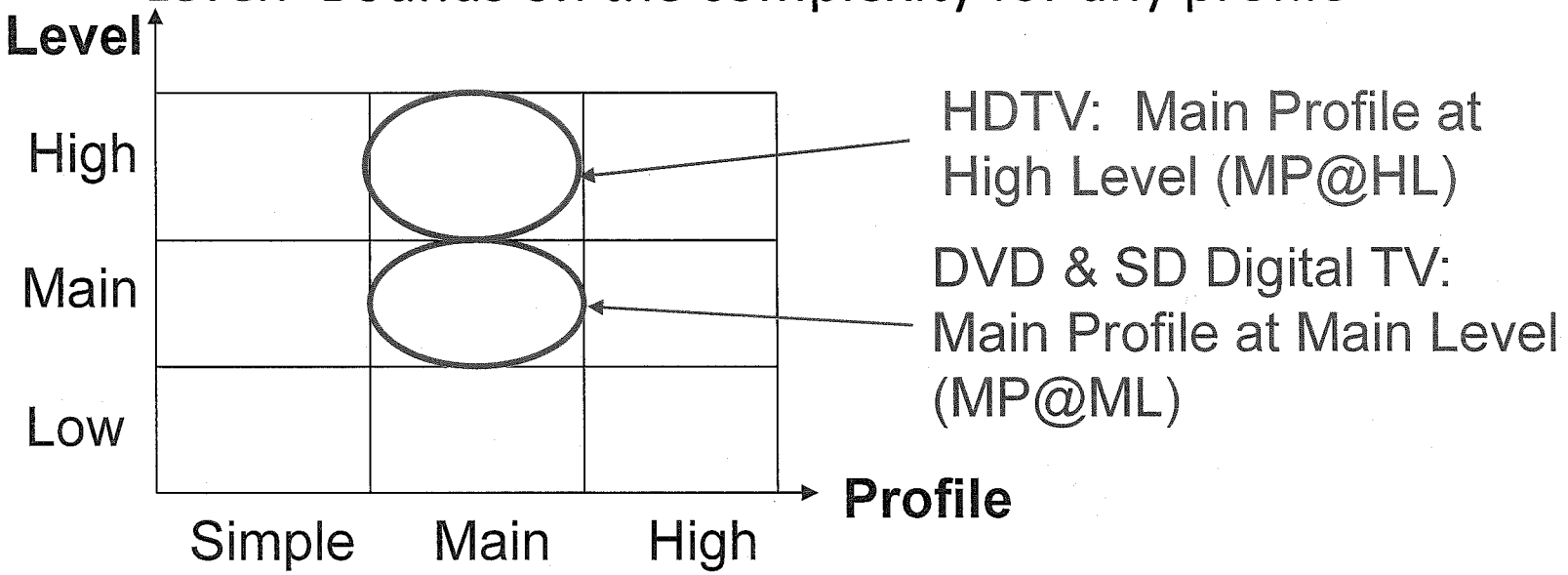
- Video coding standards define the operation of a decoder given a correct bitstream
- They do NOT describe an encoder

- Video coding standards typically define a toolkit
- Not all pieces of the toolkit need to be implemented to create a conforming bitstream

- Decoders must implement some subset of the toolkit to be declared "conforming"

MPEG-2 Profiles and Levels

- *Goal:* To enable more efficient implementations for different applications (interoperability points)
  - *Profile*: Subset of the tools applicable for a family of applications
  - *Level*: Bounds on the complexity for any profile



Profiles and Levels: Example H.264/AVC

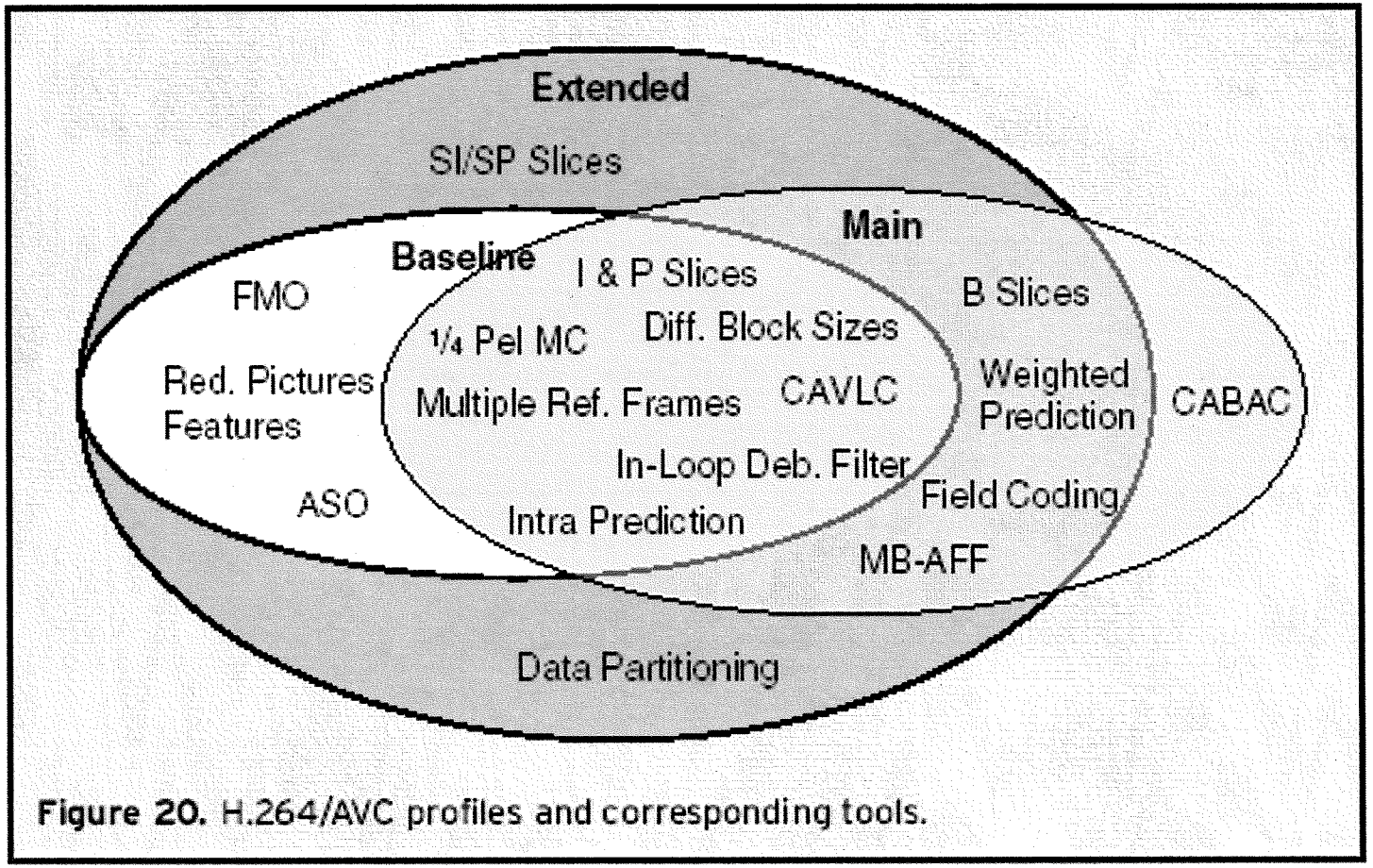


Figure 20. H.264/AVC profiles and corresponding tools.

From [Ostermann04]

Profiles and Levels in MPEG-2

			Profile						
			Simple (I, P) (4:2:0)	Main (I, P, B) (4:2:0)	SNR (I, P, B) (4:2:0)	Spatial (I, P, B) (4:2:0)	High (I, P, B) (4:2:0; 4:2:2)	Multiview (I, P, B) (4:2:0)	4:2:2 (I, P, B) (4:2:0; 4:2:2)
Level	Low	Pels/line			352	352		352	
		Lines/frame			288	288		288	
		fps			30	30		30	
		mbps			4	4		8	
	Main	Pels/line	720	720	720		720	720	720
		Lines/frame	576	576	576		576	576	512/608
		fps	30	30	30		30	30	30
		mbps	15	15	15		20	25	50
	High-1440	Pels/line	1440		1440	1440	1440		
		Lines/frame	1152		1152	1152	1152		
		fps	60		60	60	60		
		mbps	60		60	80	100		
	High	Pels/line	1920			1920	1920	1920	
		Lines/frame	1152			1152	1152	1152	
		fps	60			60	60	60	
		mbps	80			100	130	300	

I, P, B: allowable picture types. Maximum bit rates include all layers in case of scalable bit streams.

Profiles: tools

Levels: parameter range for a given profile

Main profile at main level (mp@ml) is the most popular, used for digital TV

Main profile at high level (mp@hl): HDTV

4:2:2 at main level (4:2:2@ml) is used for studio production