Compact Lecture

Multimedia Coding: Methods & Applications

Part 4: Video Coding Basics

4.2: Video Coding Standards

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Principles for Image Sequence Coding

Extending still image coding by a ***temporal*** component:

1.) predictive approach (DPCM)

→ hybrid coding principle

2.) 3D transform based coding approach

→ w / o motion compensation

3.) region oriented coding approach

→ coding of regions based on features such as contour, texture, motion

4.) object based and model based coding

→ MPEG-4 Face and Body Animation

Relevant Current Coding Algorithms

Current video codecs (with market relevance):

• MPEG-1	VCD
• MPEG-2	Digital TV
• MPEG-4	Streaming, PVR (DivX)
• H.263 (H.261)	mobile Video, Video Telefonie
• H.264 (MPEG-4 Part10 / AVC)	Multimedia, Digital TV
• WM-9/10 bzw. VC-1 (Synonym)	Multimedia (PC, PDA)
• Quicktime 7	Streaming
• RealVideo 11	Streaming
• VP6 / 7	Adobe Flash (Online)

One has to differentiate between

- coding algorithm (MPEG-2, H.264, WM9, ….)
- implementation (MainConcept, Atheme, Envivio, …)
- file format (AVI, MPG, YUV, MXF, WMV, ….)
- player software (Quicktime, Envivio, Windows Media Player, ….)

Further Formats

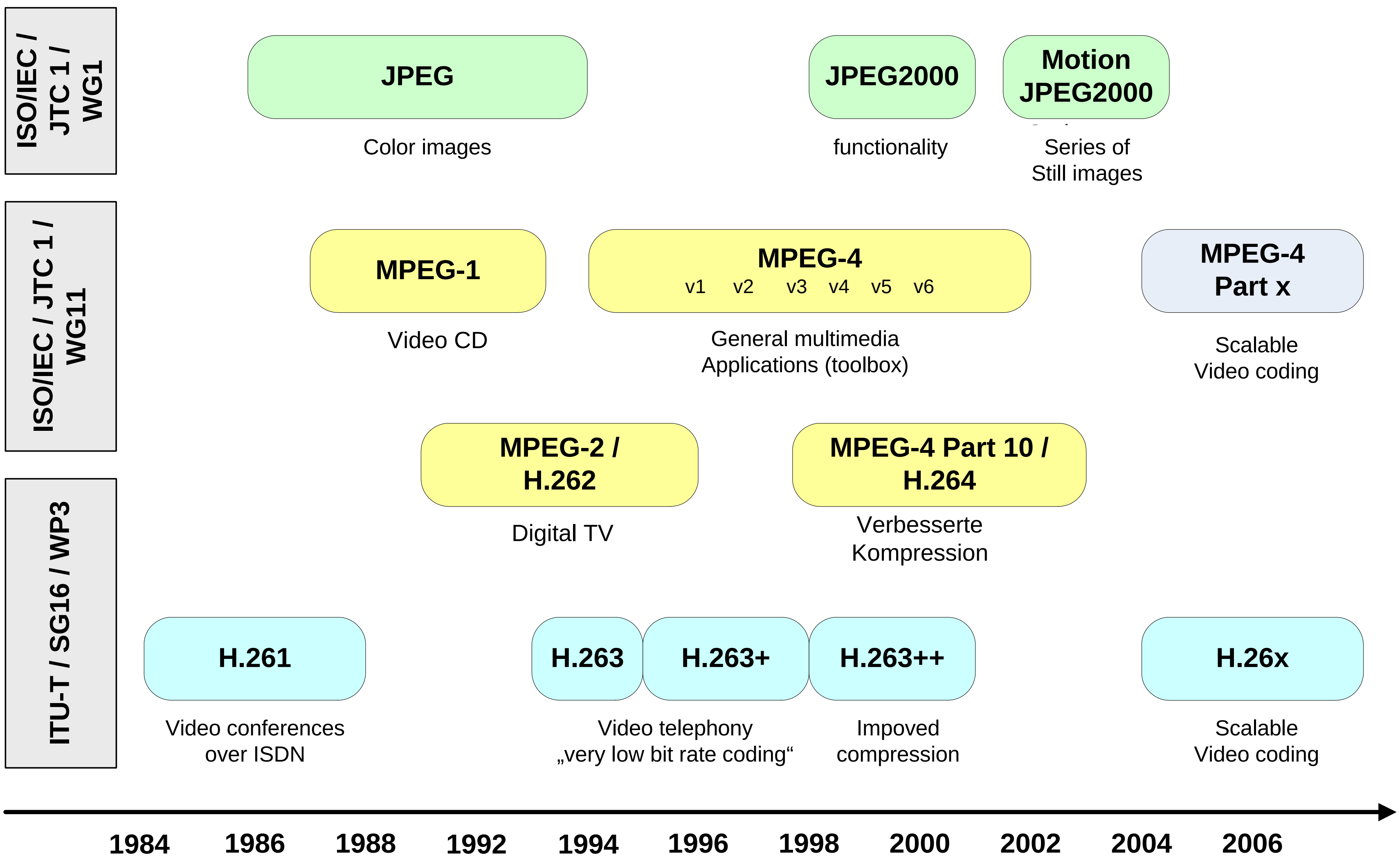
Professional / Semi-Professional

- DV / HDV-1 / HDV-2
- DVC
- DVCPRO
- DVCPRO 50
- DVCPRO HD
- HDCAM / HDCAM-SR

Significantly higher quality requirements for these formats

- Picture accurate editing (without recoding)
- lowest possible encoding distortions
  → maintaining quality in case of multiple encodings (generations)
- formats are more than just a coding format, storage media aspects included

History of Video Coding Standardization



Characteristics of the Standardization

- Video coding standards define the **<u>decoder</u>** (for speech and audio frequently specify the encoder)
- Motion compensation is specified, NOT the approach to estimate the parameters required for motion compensation (motion estimation is not specified)
- Definition of quantizer **<u>replacement values</u>**, NOT the quantization intervals
- there are negotiable options, for interoperability reasons it must be defined, which “options” the decoder supports → definition of profiles
- definition of a bitstream syntax
- Partially a completing file format is specified
- MPEG defines a reference coder for verification

Image Features

- image size
- frame rate
- aspect ratio
- Interlaced / progressive scanning
- color coding and color sampling

Image Formats

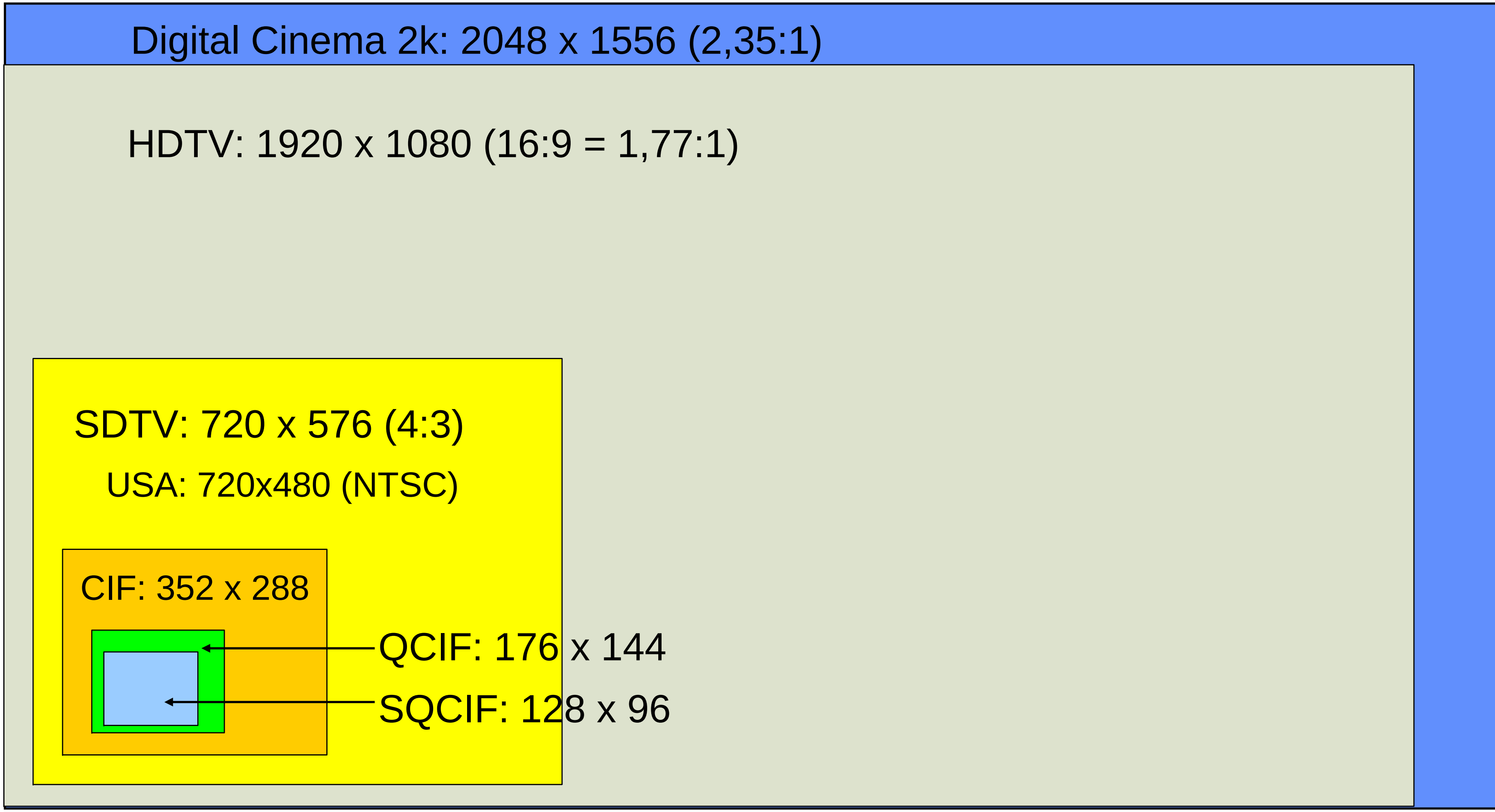


Image Sharpness depends on Resolution

Native 4k x 2k image

SDTV

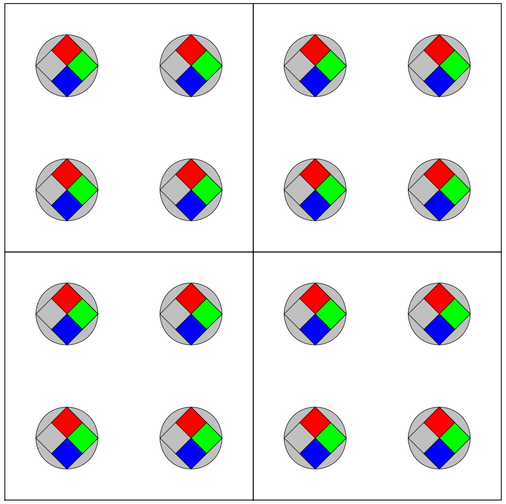
HDTV

4k x 2k

Color Formats

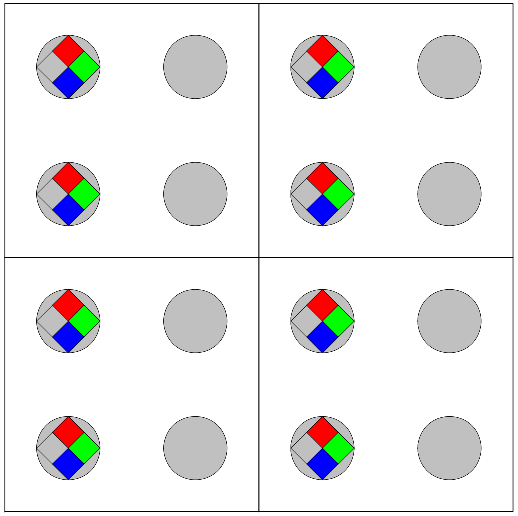
Color space for video coding is (Y Cb Cr)
Luminance (Y) has always full spatial resolution

4:4:4



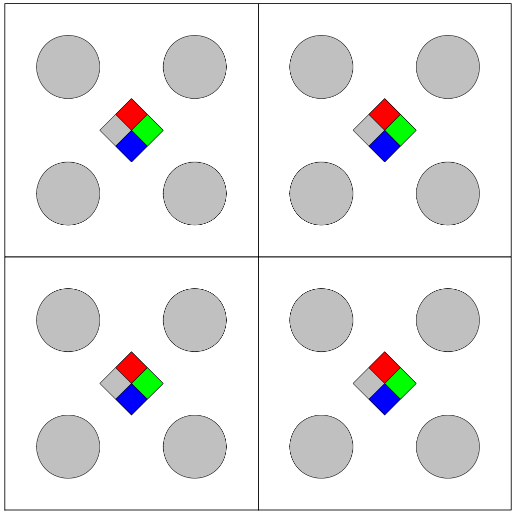
Full color resolution per pixel

4:2:2



2:1 horizontal
Sub-sampling
of chrominance

4:2:0



2:1 horizontal
and vertical
Sub-sampling
Of chrominance

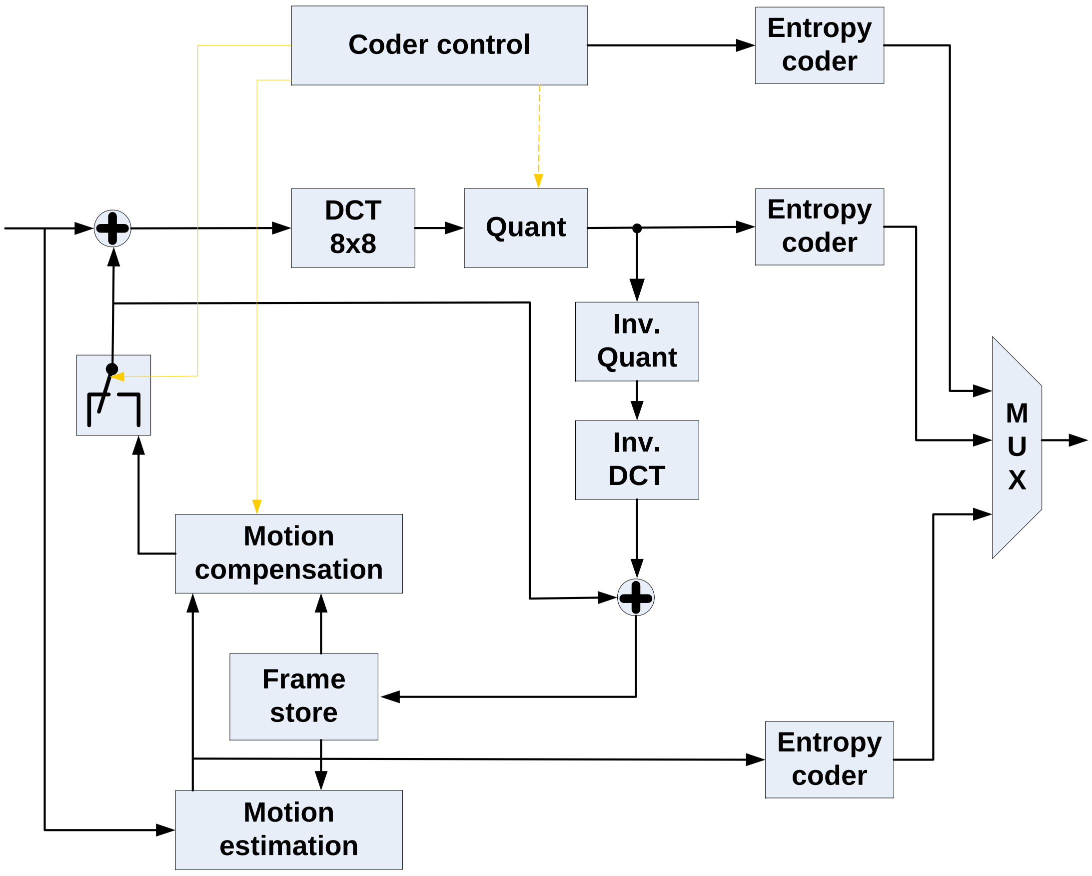
Interlaced Sampling

Summary of Parameters for Video Resolutions

Format	Spatial Resolution	Ratio	Pixel format	Frame rate	Scan	Colour Space	Netto bitrate
HDTV	1920 x 1080	16:9	rectangular	25Hz	Interlaced	YIQ 4:2:2	829 Mbps
	1280 x 720	16:9		50Hz	Progressive	YUV 4:2:2	737 Mbps
CCIR	704 x 576	4:3		25 Hz	Interlaced	YUV 4:2:2	162 Mbps
	704 x 480	4:3		30 Hz	Interlaced	YIQ 4:2:0	162 Mbps
16CIF	1408 x 1152	4:3		25 Hz	Progressive	YUV 4:2:0	487 Mbps
4CIF	704 x 576	4:3		25 Hz	Progressive	YUV 4:2:0	122 Mbps
CIF	352 x 288	4:3		25 Hz	Progressive	YUV 4:2:0	31 Mbps
SIF	352 x 240	4:3		30 Hz	Progressive	YIQ 4:2:0	31 Mbps
QCIF	176 x 144	4:3		25 Hz	Progressive	YUV 4:2:0	7,7, Mbps
SQCIF	128 x 96	4:3		25 Hz	Progressive	YUV 4:2:0	3,7 Mbps

The Hybrid Coding Scheme; Transform Coding with Motion Compensation

All current standards are based on the same coding principle



Application defined the Choice of coding parameters:

Communications:

- low latency / coding delay
- no random access to images

Digital TV

- random access to images
- high quality expectations

Digital media (DVD)

- random access to images
- high bandwidth available

Characteristics

Advantages

- Transmitter and receiver operate synchronously
  - No error accumulation
  - No drift of constant component
- Low coding delay
  - Minimal processing delay is processing time for 1 Macroblock
- Compensation independent of parameter estimation

Disadvantages

- Feedback of quantization error

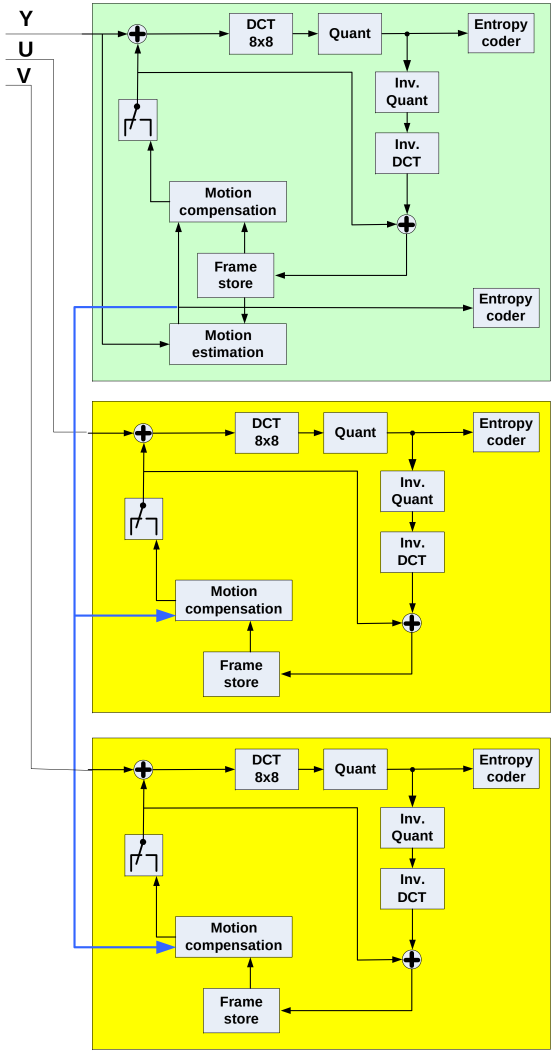
  increase of variance depends on prediction error

  → inefficient in case of large errors
- Impact on receiver in case of transmission errors

  → unlimited error propagation in time

Color Coding

- independent DPCM for each color component
- motion estimation only on Luminance
- scaled motion vectors for compensating the chrominance U V

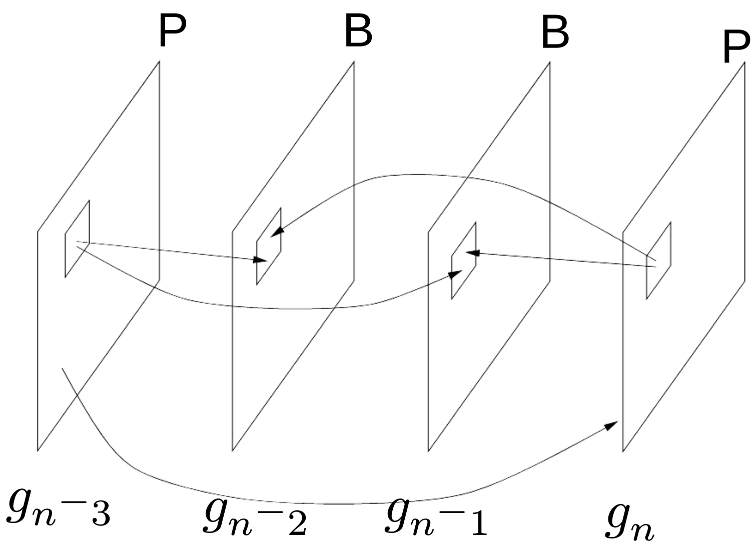


PB-Frames: Bi-directional Interpolation

P-Frames: predicted images of DPCM
B-Frames: calculated by bi-directional interpolation

$$\hat{g}_{n-k}(\mathbf{x}) = \frac{1}{2}\Big(g_n[\mathbf{x} + \alpha \cdot \mathbf{v}_n[\mathbf{x}]] + g_{n-M-1}[\mathbf{x} - (1-\alpha) \cdot \mathbf{v}_n[\mathbf{x}]]\Big)$$

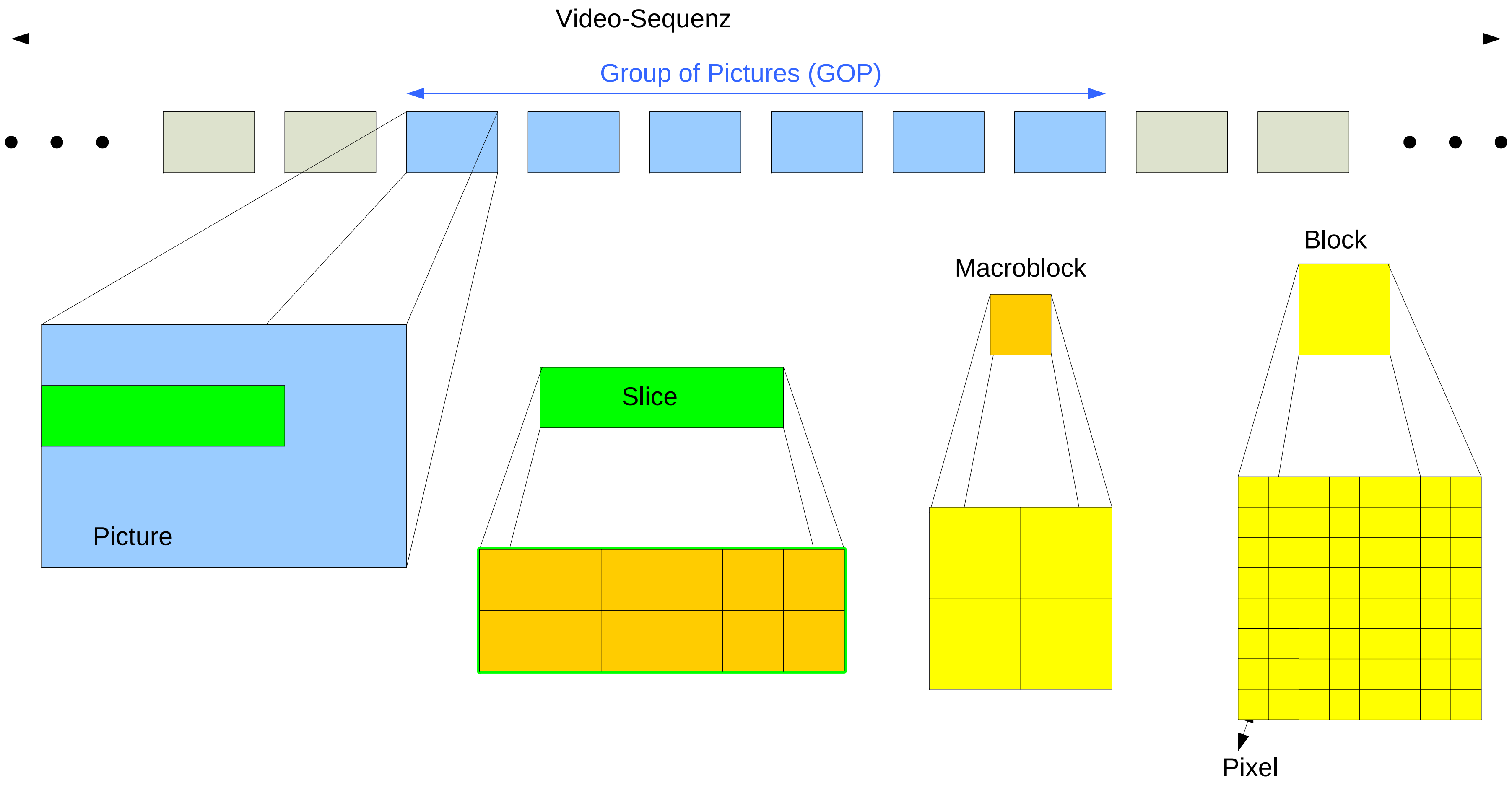
α: difference in time between B frame and P frame



Characteristics:

- prediction without additional coding of motion vectors
- only coding of prediction error image necessary
- distance in time between of M frames is identical to number of B frames M
- additional INTRA-coded frames (I-frames) with distance N
- typical sequence of coding types: I B B P B B P B B P B B I B B P B B P . . .

Hierarchical Syntax



ITU-T H.261 (1989)

Target application: (Video Codec for Audio-Visual Services at px64kbps)

- Video conferences over ISDN

Features:

- Sampling 4:2:0 → 16x16 Y and 8x8 Cb, Cr
- INTRA coding of individual pictures (frames)
- Forced INTRA coding of individual MB in certain distances
- 8x8 DCT
- Linear 8bit quantiser for INTRA-DC coefficients, fixed for all MB and GOB respectively
- Linear „dead-zone“ quantiser (31 steps) for all remaining coefficients
- 1 displacement vector / MB
- Integer-pel accuracy of displacement vectors
- Maximum displacement: 16x16
- Adaptive separable loop-filter: H = [1/4, ½, ¼]
- DPCM coding of displacement vectors
- Zig-zag scan order of coefficients (2D → 1D mapping)
- Run-length coding of coefficients
- Huffman tables for entropy coding
- Identical coding approach for Y, U, V

ITU-T H.263 (1996) / H.263+ (1997)

- **Target application (Video Coding for Low Bit Rate Communications)**
  - SW video-phone over analogue networks
  - Internet video streaming
- **Extensions compared to H.261**
  - Extended parameter space: supported image formats SQCIF, QCIF, CIF, 4CIF, 16CIF
  - Half-pel accurate motion compensation, NO loop-filter
  - 3D VLC tables (without EOB-Symbol)
  - More compact syntax → reduced overhead
  - Set of optional tools
    - efficiency / improved image quality (10 tools)
    - Robustness against transmission errors (3 tools)
    - scalability
    - „Reference Picture Resampling“
    - „Reduced Resolution Update“
- **Additional features (Annex U-Y) in H.263++**
  - Since 2001 named H.263

Toolbox

H.263+: Annex D-T

- **Image quality**
  - Unrestricted vectors, incl. RVLC (Annex D)
  - Syntax-based arithmetic coding (Annex E)
  - Advanced prediction mode (Annex F) → OBMC, 1 oder 4 vektoren / MB
  - PB pictures (Annex G)
  - Advanced INTRA Coding (H.263+)
  - Alternate INTER VLC
  - Modified Quantization
  - De-blocking Filter
  - Improved PB-Frames
- **Error robustness**
  - Sliced structure
  - Reference picture selection
  - Independent segment decoding
- **scalability**
  - temporal
  - SNR
  - spactial

ITU-T H.263 Level

- **Level 1:**
  - Advanced INTRA
  - De-blocking Filter
  - Full-frame freeze
  - Modified quantization
- **Level 2: Level 1 +**
  - Unrestricted motion vector
  - Slice structure
  - Reference picture re-sampling
- **Level 3: Level 2 +**
  - Advanced prediction
  - Improved PB
  - Independent segment decoding
  - Alternate VLC

ISO 11172: MPEG-1 (1992)

Target application

- Digital movies on CD-ROM (→ VCD)
- Picture quality comparable to VHS, audio in CD quality

Features

- Hybrid, block-based DCT transform coder
- Standard image format CIF, YUV 4:2:0, NO interlacing
- All images are coded (25 / 30~Hz frame frequency)
- Extensions compared to H.261
  - Extended parameter space (image size, frame rate)
  - Image sequence partitioned into „Group of Pictures" with I (INTRA), P (predictive), B (bidirectional), N=12
  - Slice structure, NO GOBs
  - Half-pel motion compensation
  - Tables for quantization
- Minimal implementation requirements

  Constrained Parameters Bitstream (CBR)
  - Coding of 396 Macro blocks / frame at 25Hz frame rate
  - max. bit rate 1.8 Mbps

ISO 13818: MPEG-2 (1994)

Target application

- Digital TV

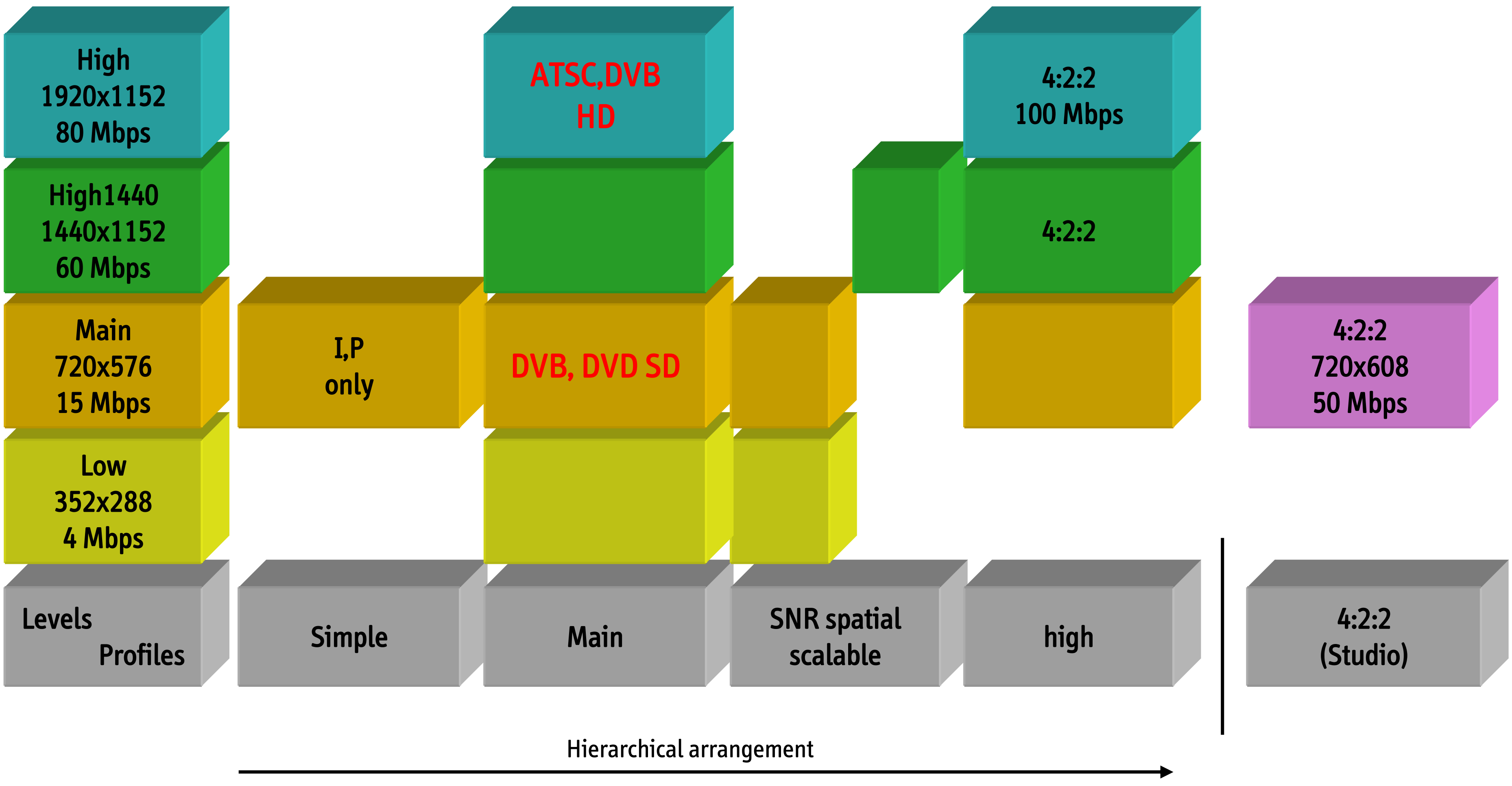
Significant Features

- Standard consists of 3 parts: systems, audio, video
- Support of interlaced material
- Significantly extending the supported image formats and bit rates
- Non-linear quantiser tables
- Manifold extensions and options
  → structuring in profiles and levels

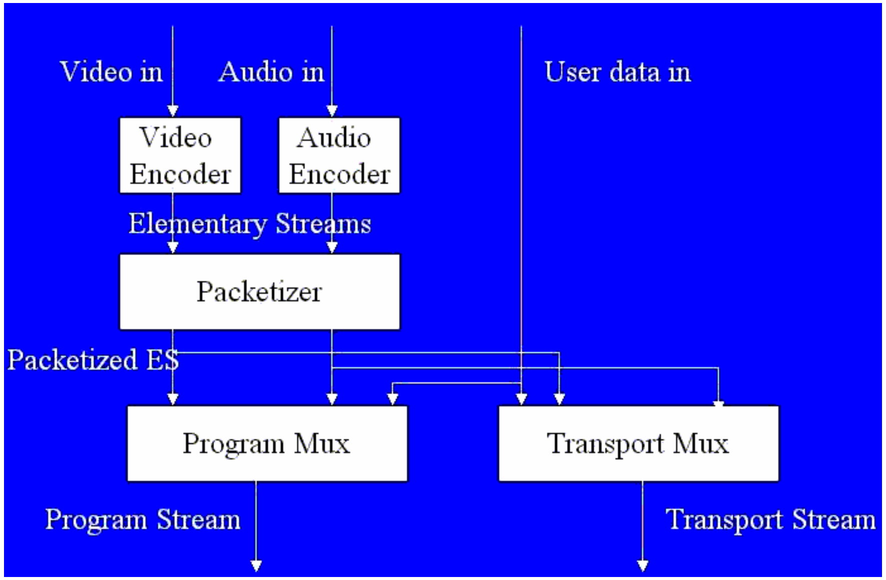
Market Relevance:

- Digital TV in DVB-S / C / T
- Studio production and contribution format
- MPEG-2 Systems (Transport stream) has very high importance as universal multiplex format (DAB / DMB, TV over DSL)

MPEG-2 Structure



MPEG-2 Systems

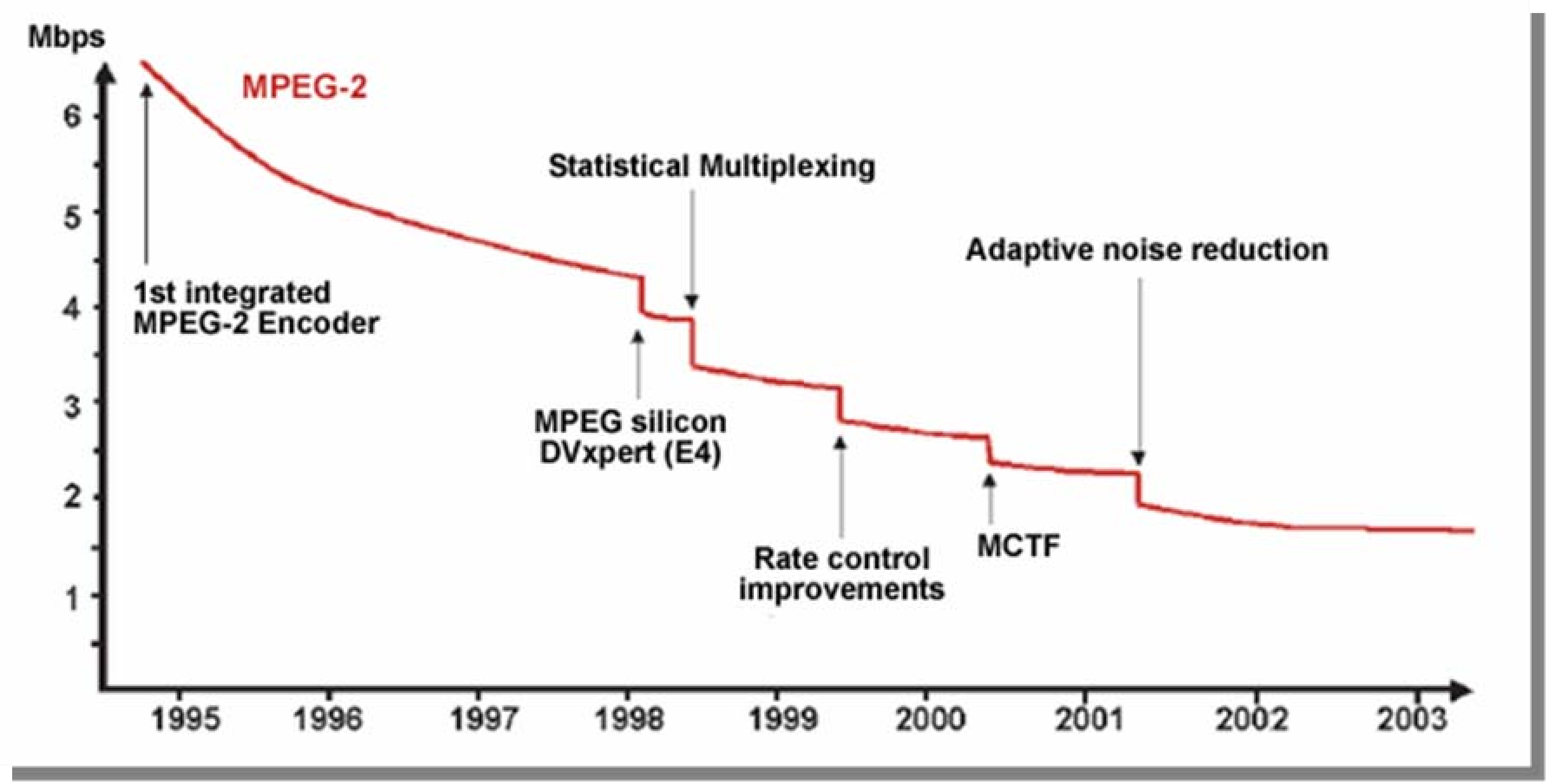


<u>Program Stream:</u>
- variable packet length < 64 kByte

<u>Transport Stream:</u>
- fixed length 188 byte
- time reference pro ES
- error protection (FEC)

Time Stamps:
- Presentation time stamp (PES)
- decode time stamp (PES)
- program clock reference

Improvements of MPEG-2 Performance



Quelle: Harmonic Inc

ISO 14496: MPEG-4 (1999)

Target Application:

universal coding of natural and synthetic audio-visual objects

Standard consists in the mean time of 23(!) parts

- (1) Systems (Scenes, elementary stream management, Sync Layer, FLEXMUX)
- (2) Visual (SHNC tools)
- (3) Audio (SNHC Tools)
- (4) Conformance testing
- (5) Reference Software (Verification Model → VM für Teil 1-3)
- (6) Delivery Multimedia Integration Framework (DMIF)
- (7) Optimized Visual reference Software
- (8) Carriage of MPEG-4 Content over IP-Networks
- (9) Reference Hardware Description
- (10) Advanced Video Coding (AVC)

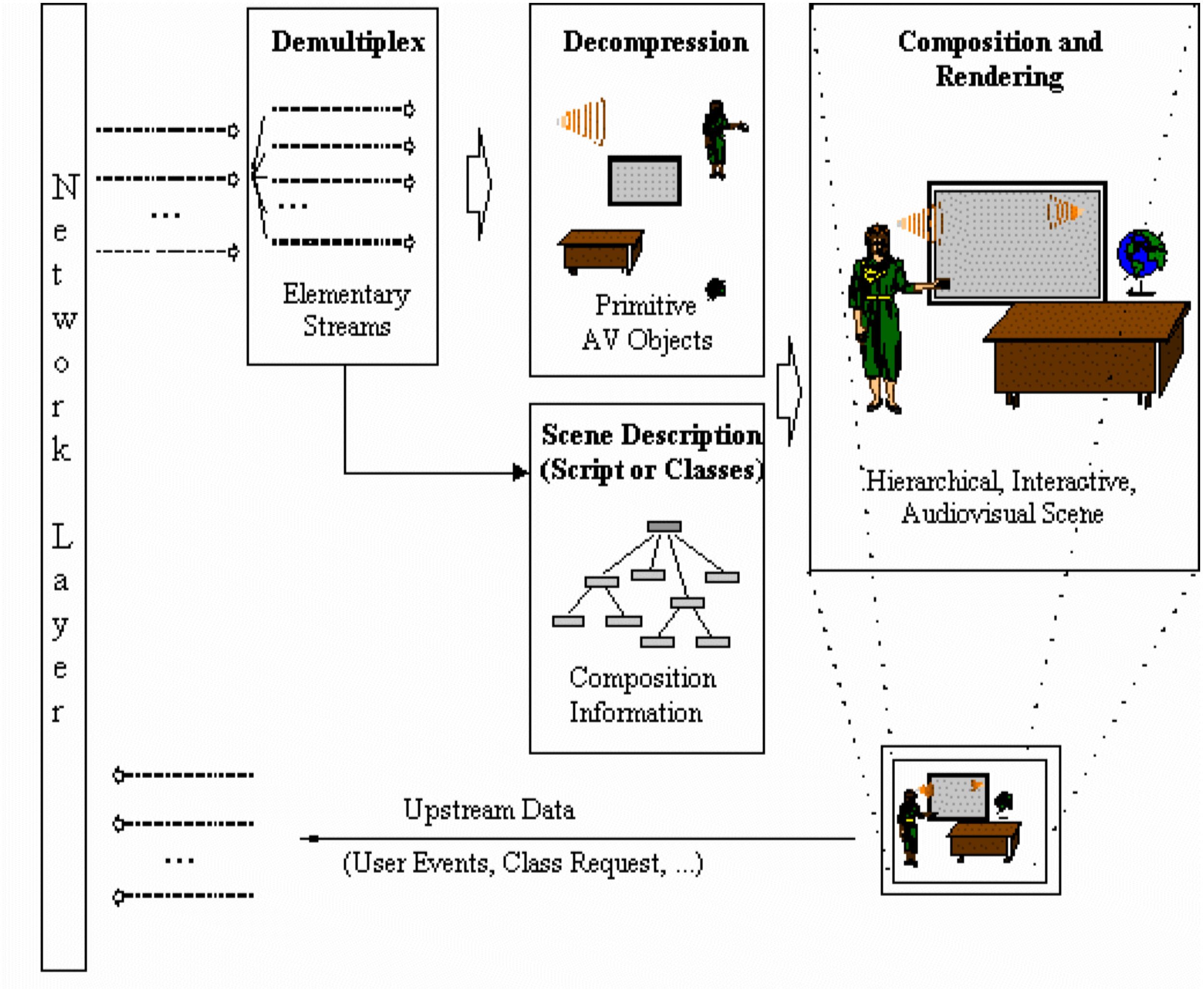
MPEG-4 Functionality

New concept compared to all earlier standards

- Describing the content based on <u>objects</u>
- Toolbox principle (receiver downloads the respective modules)

  collecting tools in <u>algorithms</u>
- Formal description language MSDL (MPEG Syntactic Description Language)
- <u>Interactivity</u> on object level
  - Object oriented manipulation and editing of bit streams
  - Random access to individual objects
- Improved coding efficiency
- Universal data transmission
  - Robust against transmission errors
  - Object oriented scalability
  - SNR scalability of objects

MPEG-4 Terminal



Profiles and Versions

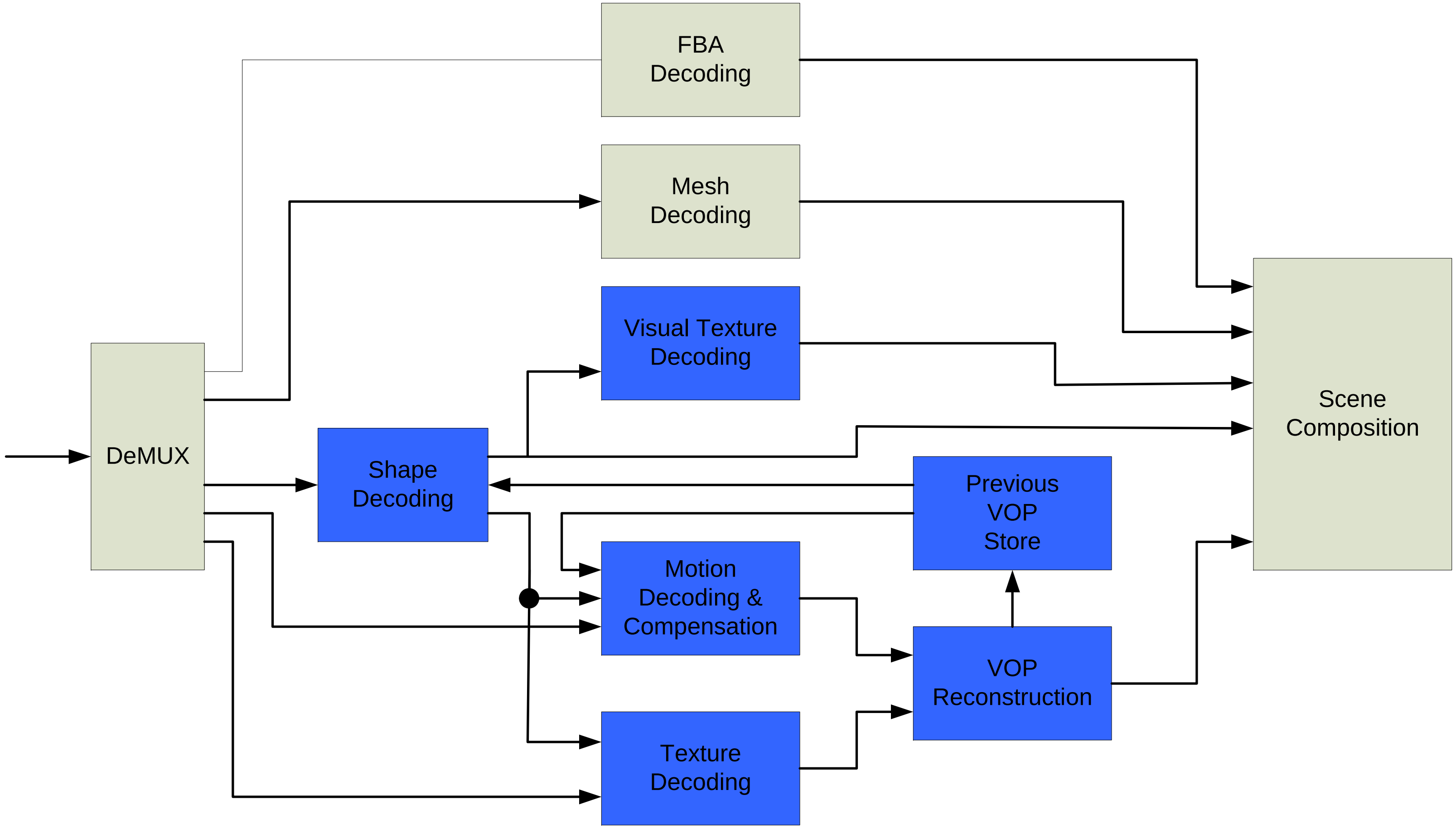
- **Visual Tools (33)**
  - Methods and components for coding
- **Visual Object types (18)**
  - Subdivided into 4 main categories
    - Rectangular video
    - Arbitrarily shaped video
    - Still visual
    - Synthetic video
- **Visual Profiles (19)**
  - Defines which objects could form together a scene

    → derive the necessary „visual tools“
- **MPEG-4 Versions**
  - tools and thus types and profiles have been developed in phases
    - version 1: May 1999
    - version 2: Feb 2000
    - version 3 with 7 Amendments: April 2001
    - Part 10 AVC: (2003)

Some Tools

Visual Tools	Visual Object Types						
	Simple	Core	Main	Advanced Real Time Simple	Advanced Coding Efficency	Advanced Simple	Fine Granularity Scalable
Basic	X	X	X	X	X	X	X
Error Resillience	X	X	X	X	X	X	X
Short Header	X	X	X	X	X	X	X
B-VOP		X	X		X	X	X
Method 1/2 Quantization		X	X		X	X	X
P-VOP based temporal scalability		X	X		X		
Binary Shape		X	X		X		
Grey Shape			X		X		
Interlace			X		X	X	X
Sprite			X				
Dynamic Resolution Conversion				X			
NewPred				X			
Global Motion Compensation					X	X	
¼ Pel Motion Compensation					X	X	
SA-DCT					X		
Fine Granularity Scalability							X
FGS Temporal Scalability							X

MPEG-4 „Natural Video“ Architecture



Coding of Arbitrarily Shaped Objects

Applying MPEG-4 – Audio and Video Coding

There are lots of software implementations

Xvid, DivX, openDivX, ffmpeg, 3ivx, Nero Digital, Quicktime, envivio, MainConcept, Sorenson

Applications for

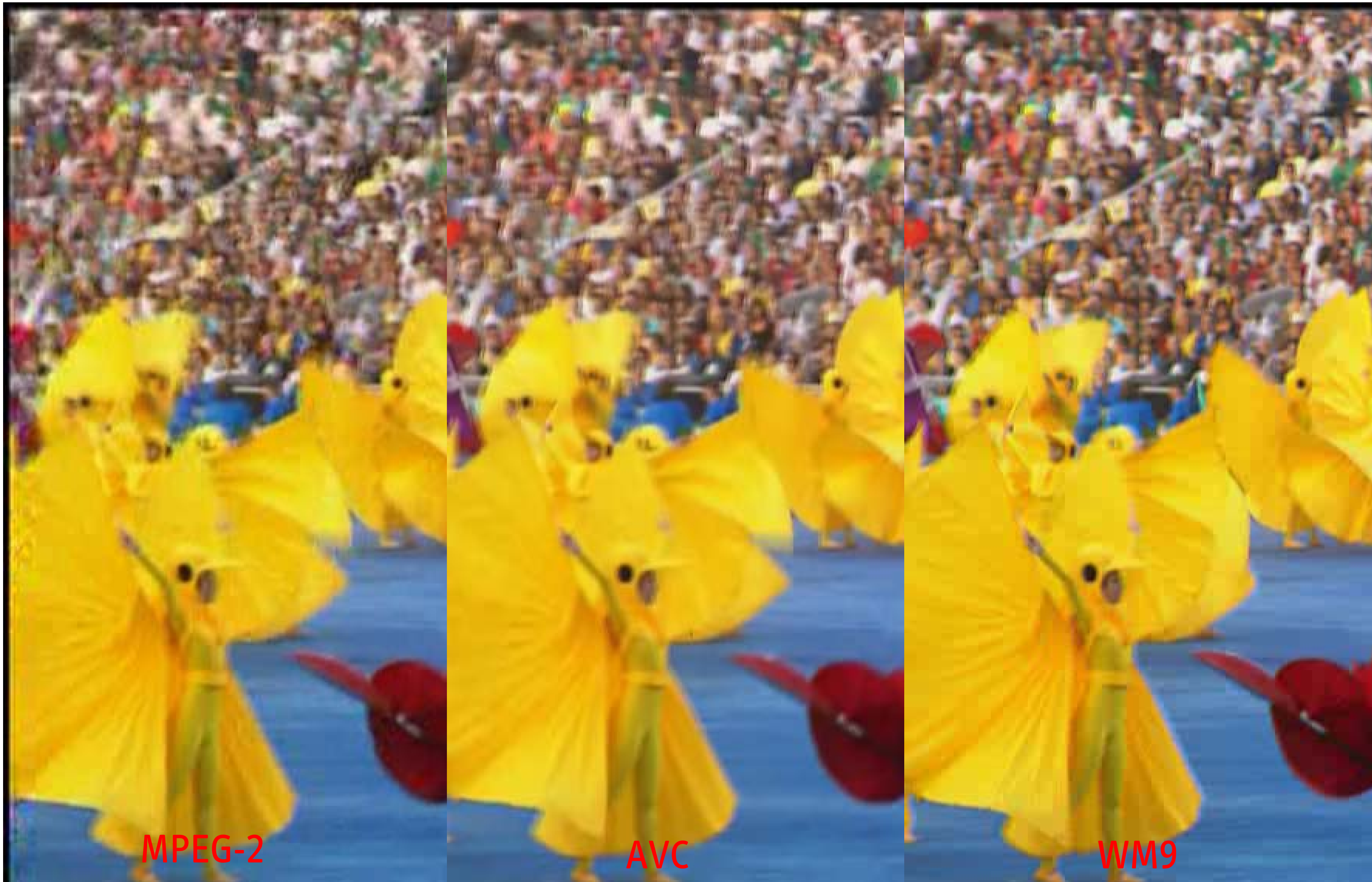
Internet Streaming

burning of videos on CD (DivX) / DVD

Video on mobile phones (H.263 / MPEG-4 ASP)

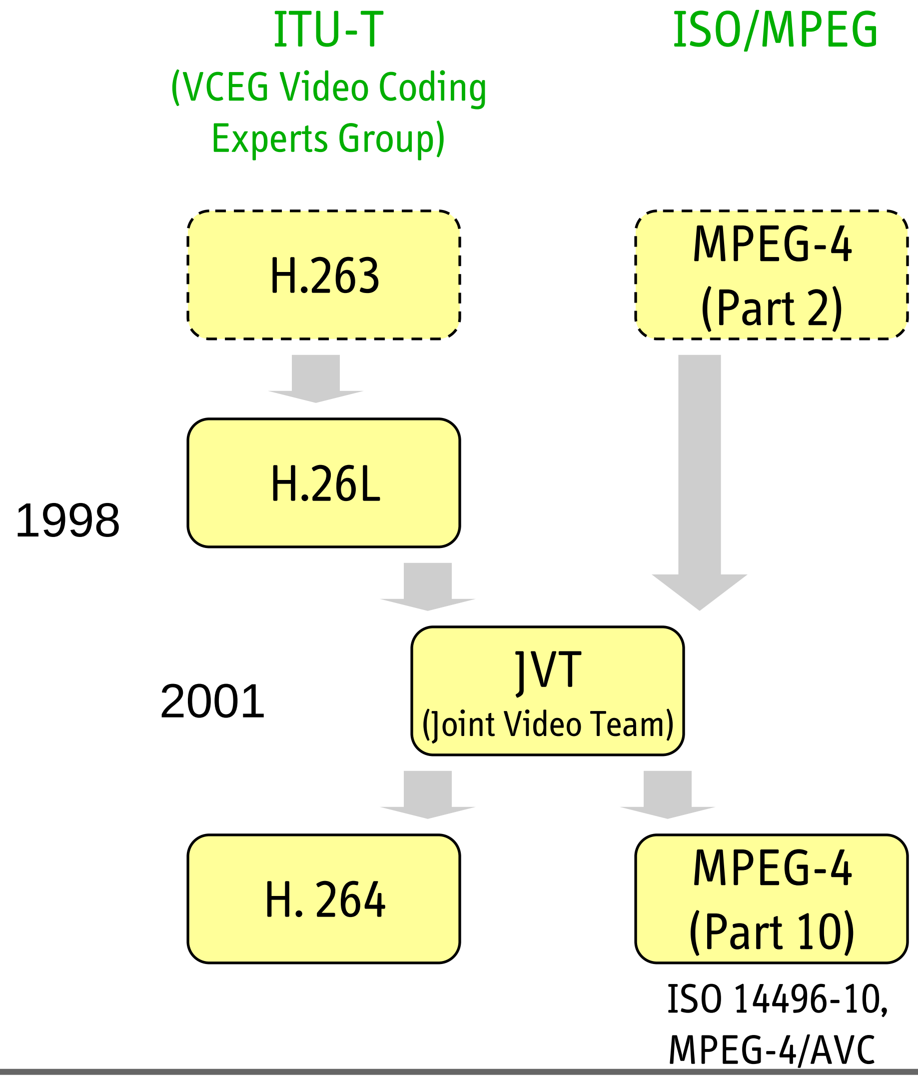
Other MPEG-4 components did not make it into the market - yet

Subjective Comparison: Barcelona 720x576 25Hz @ 3Mbps



H.264: One Standard – Lots of Names

H.26L,
MPEG-4 / AVC,
AVC,
JVT,
H.264,
14496-10,
MPEG-4 (Part 10)



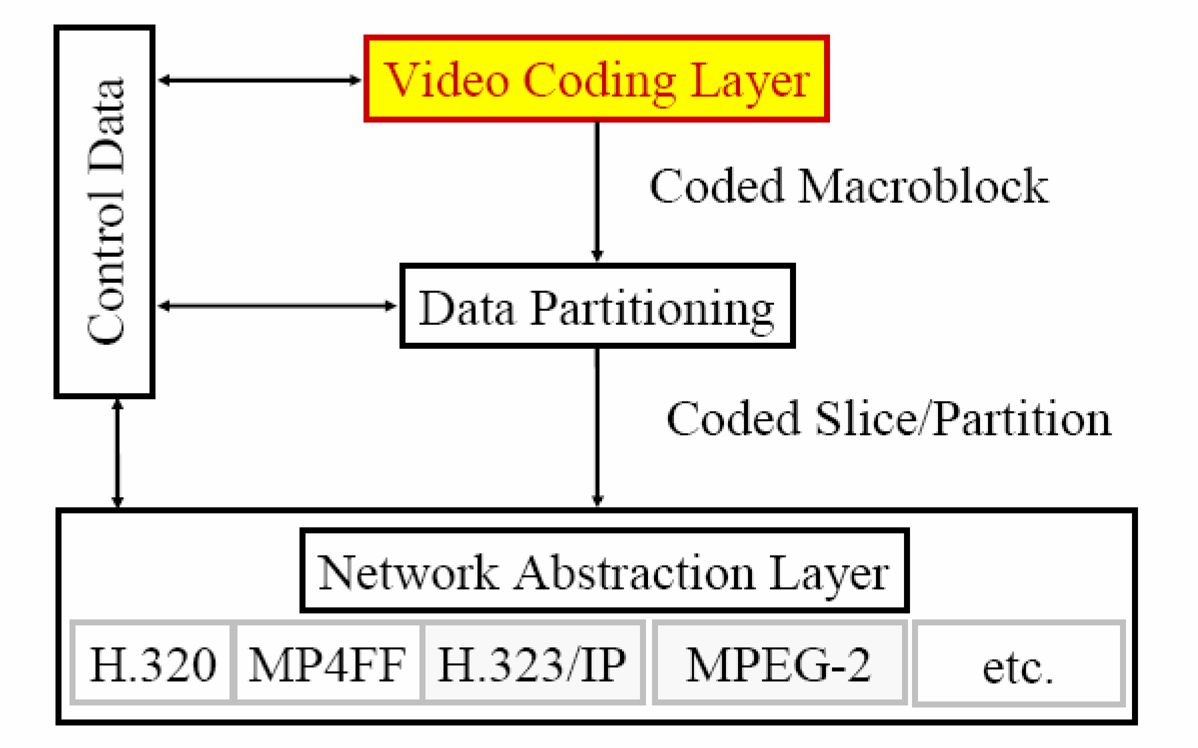
Target

- Improved coding efficiency
- Improved network adaptation
- Simple syntax

Applications

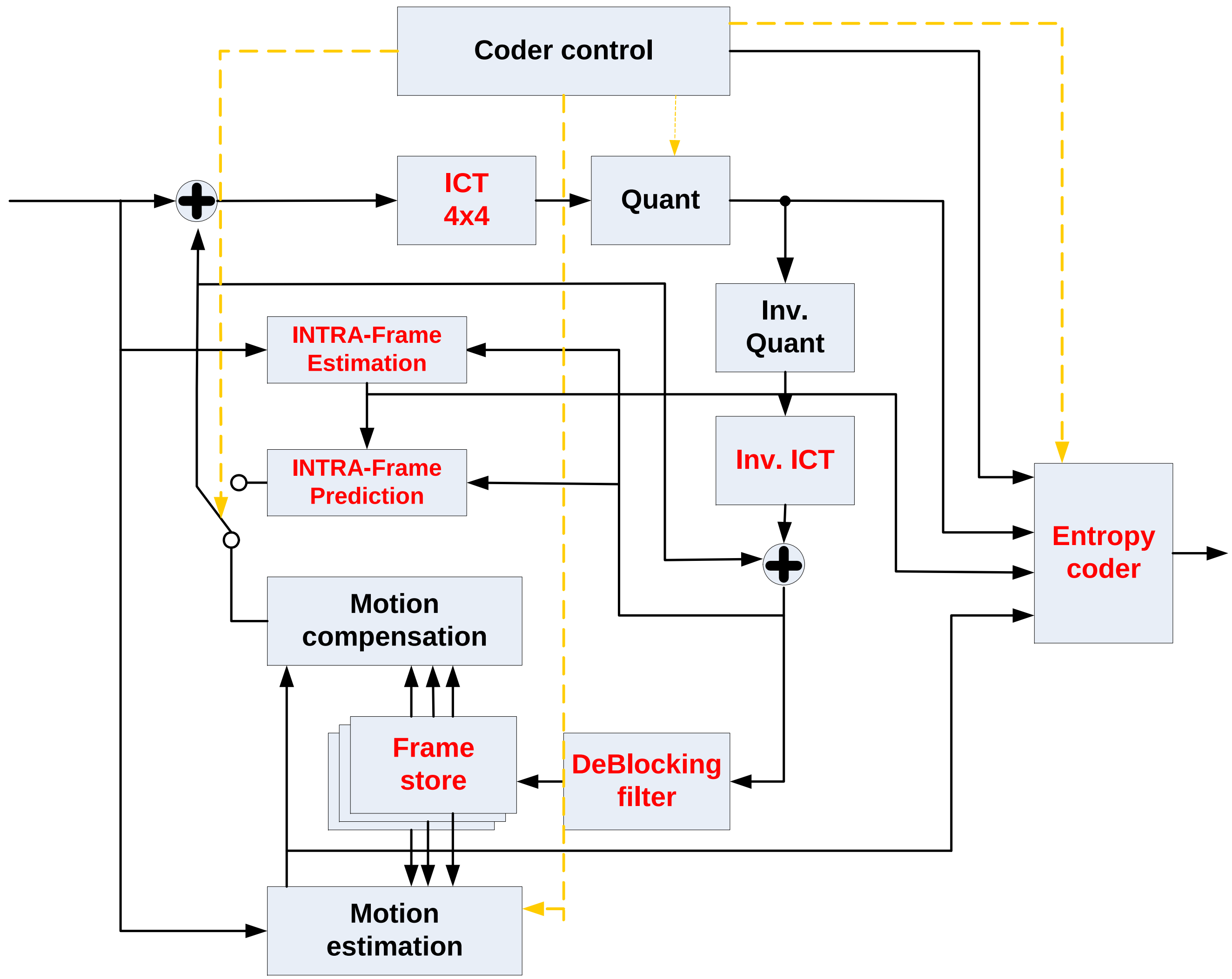
- „everything“

Basic Structure



Separating coding layer from the transmission aspects

Structure of H.264 / AVC



Where does the Coding Gain Comes from?

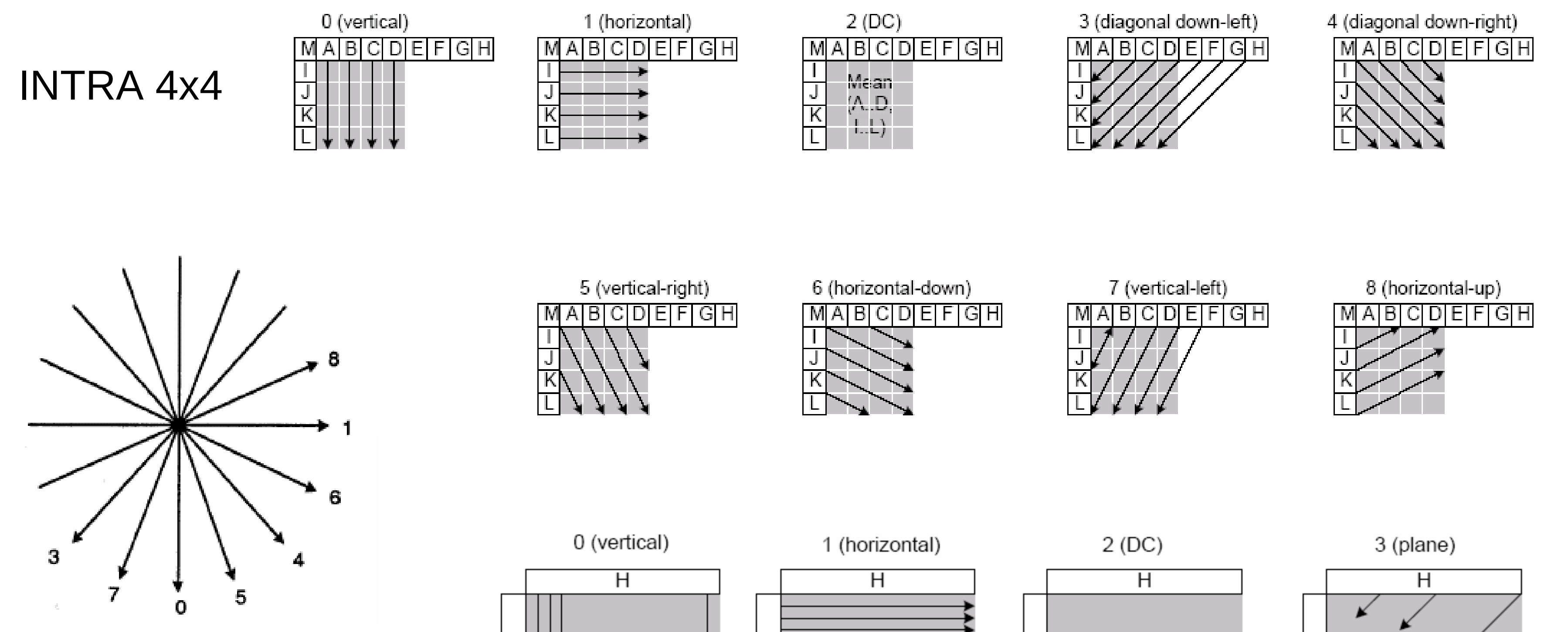
- **INTRA prediction modes (9 Modes, spatial domain)**
- **Integer Cosine Transform (ICT), 4x4**
- **more accurate quantiser steps (52)**
- **INTER processing**
  - Different block sizes for motion compensation
  - ¼-pel accurate motion vectors (and compensation)
  - Vectors can point outside the image boundaries (extrapolation filters / mirroring)
  - Taking multiple reference frames into account for motion compensation and prediction
  - Weighted prediction
  - De-blocking filter inside of the prediction loop (spatial domain)
- **Entropy Coding**
  - UVLC
  - CAVLC (context adaptive VLC)
  - CABAC (context adaptive arithmetic coding)

Codec contains additionally different error protection tools

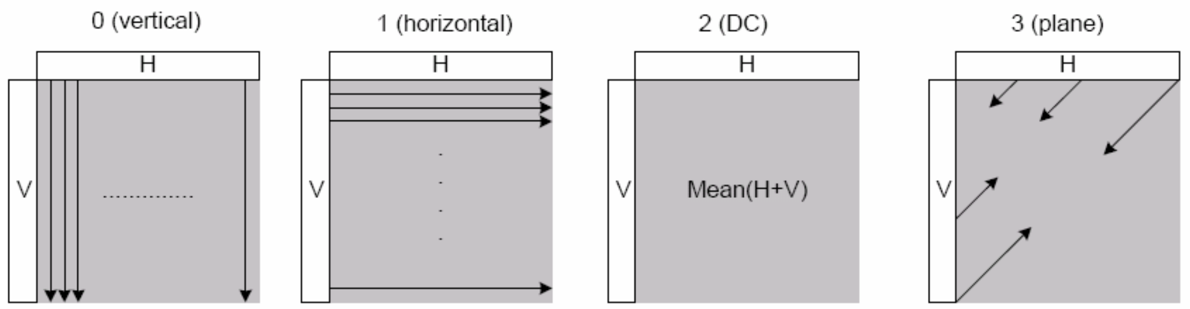
Intra Prediction -- Luminance

Prediction in the spatial domain

INTRA 4x4

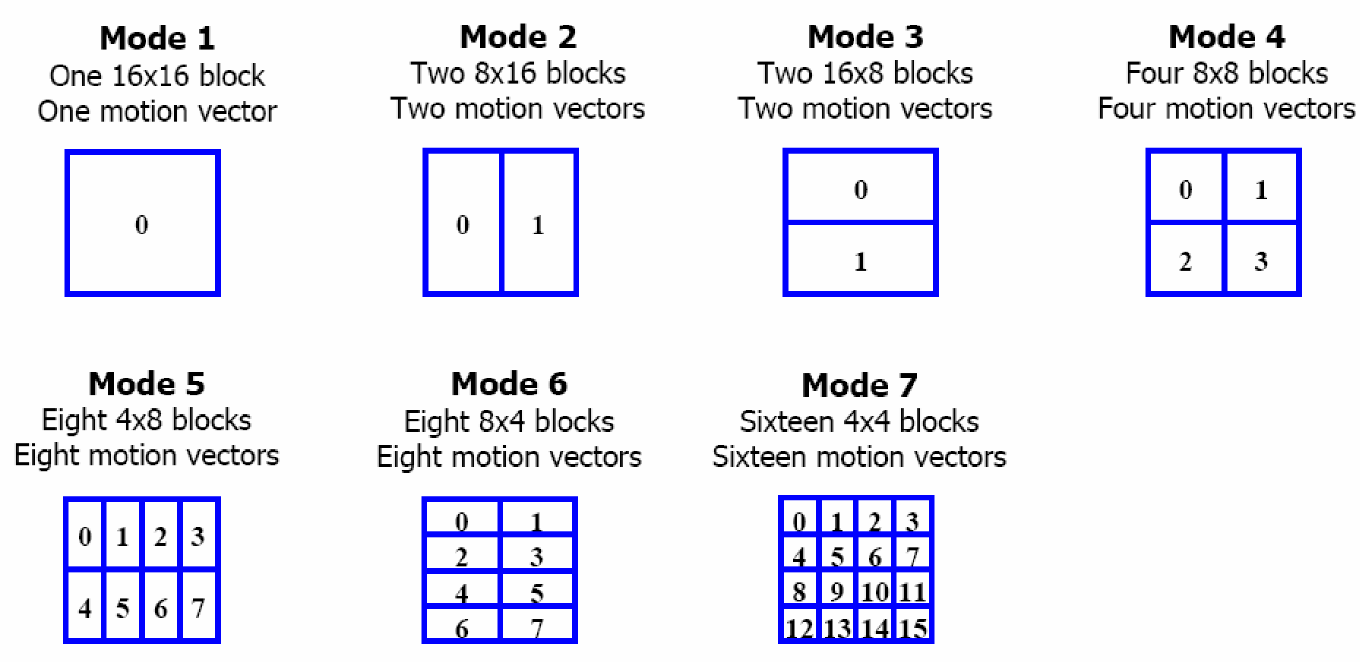


INTRA16x16



Inter Prediction

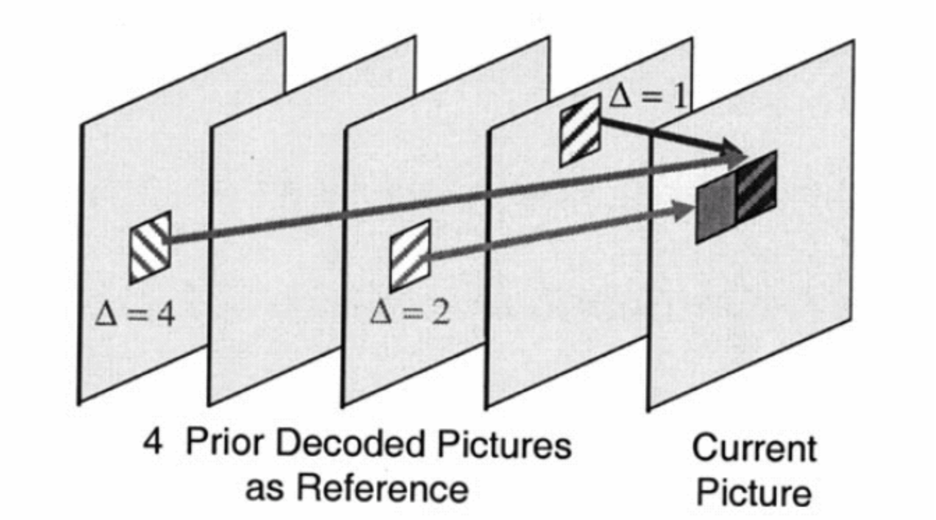
- **different block sizes are supported**
- **maximum of 16 motion vectors can be transmitted per MB**



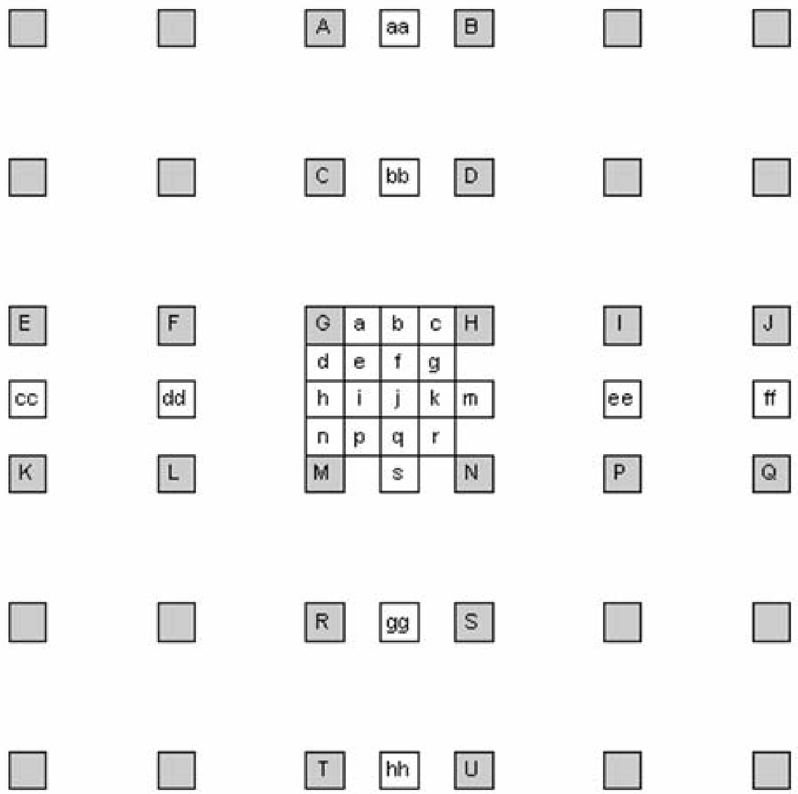
Motion Estimation and Compensation

Motion vectors

- ¼-pel accurate resolution (vector amplitude)
- Requires interpolation (2 step filtering)
- Predicting motion vectors spatially and temporarily
- Large vector amplitudes supported
- all vectors may point outside the image boundaries
- B-frames
- Multiple reference frames (temporal



Sub-pel Accurate Motion Compensation



The half-sample positions are obtained by applying a one-dimensional 6-tap filter

$$* \begin{cases} b_1 = (E - 5F + 20G + 20H - 5I + J) \\ h_1 = (A - 5C + 20G + 20M - 5R + T) \end{cases}$$

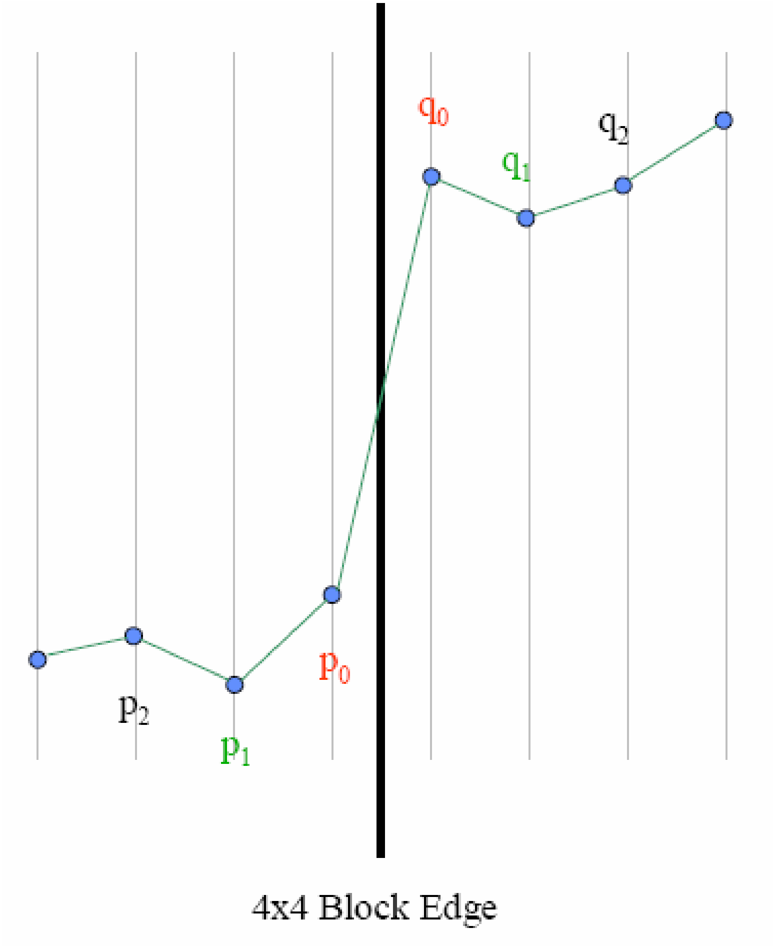
$$* \begin{cases} b = Clip1((b_1 + 16) \gg 5) \\ h = Clip1((h_1 + 16) \gg 5) \end{cases}$$

$$* \begin{cases} j_1 = cc - 5dd + 20h_1 + 20m_1 - 5ee + ff \\ j = Clip1((j_1 + 512) \gg 10) \end{cases}$$

The quarter-sample positions are generated by averaging samples at integer- and half-sample positions

$$* \begin{cases} a = (G + b + 1) \gg 1 \\ e = (b + h + 1) \gg 1 \end{cases}$$

De-Blocking Filter



1D visualization of block edge

filtering of p_0 <u>and</u> q_0 in case of:

1. $|p_0 - q_0| < \alpha(QP)$
2. $|p_1 - p_0| < \beta(QP)$
3. $|q_1 - q_0| < \beta(QP)$

mit $\beta(QP) << \alpha(QP)$

filtering of p_1 <u>or</u> q_1 in case of:

$$|p_2 - p_0| < \beta(QP)$$

oder

$$|q_2 - q_0| < \beta(QP)$$

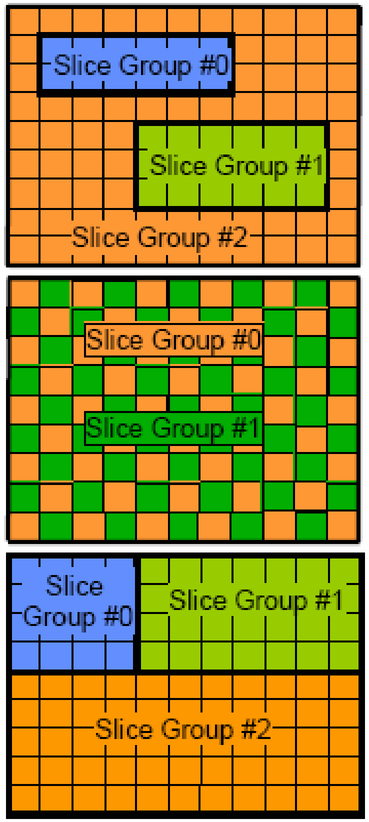
Flexible Macroblock Ordering

Slice Group

- is defined as a set of specific arrangement of blocks
- slice group may contain a single or multiple slice

Macroblock Allocation Map

- interleaved slices
- distributed macro-blocks
- explicit assignment of a slice group to each macro-block position in raster-scan order
- a single or multiple “foreground” slice groups and a single “remainder” slice group



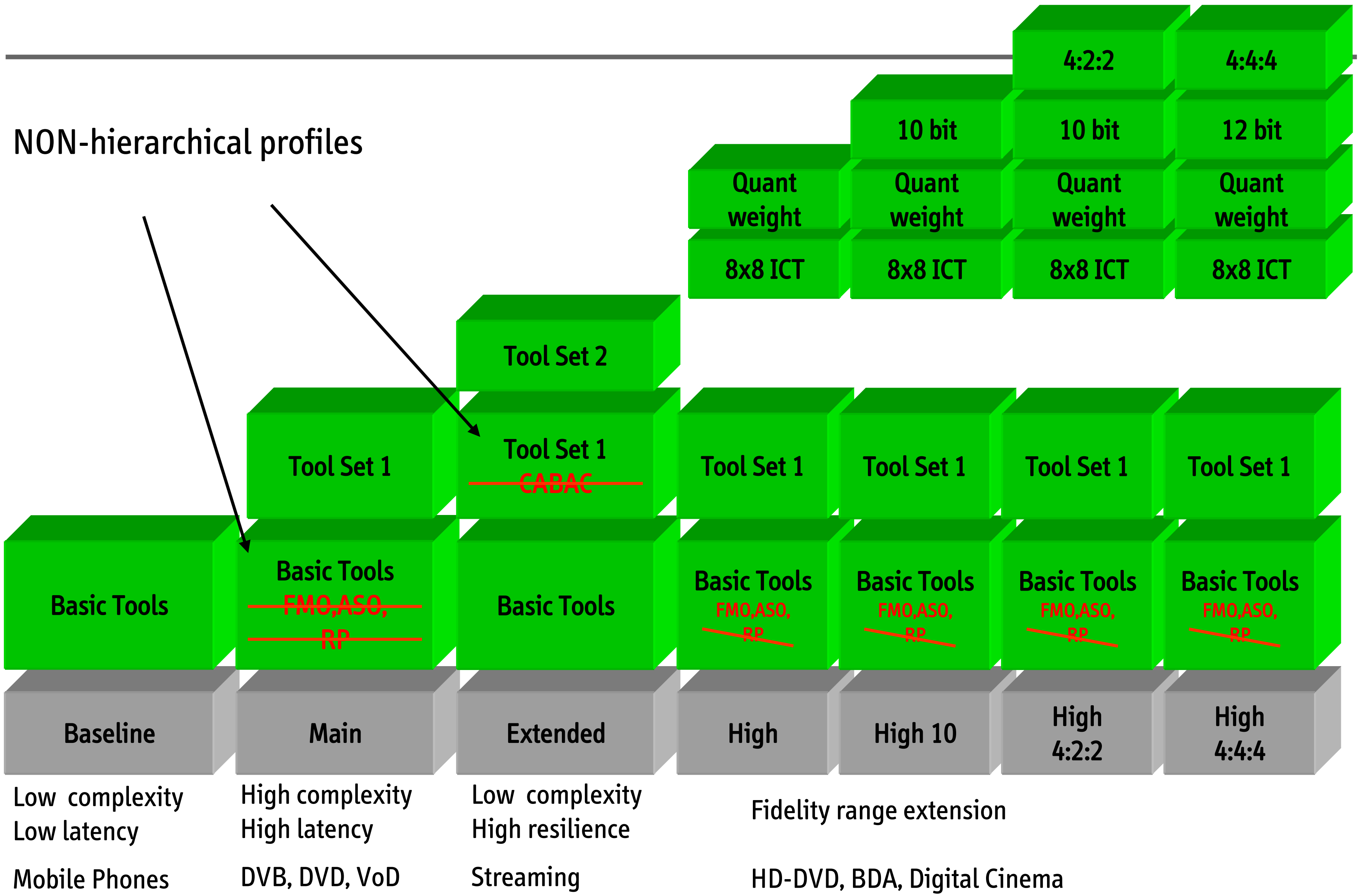
Structuring of the AVC Tools

	Basic	Main	Extended	High, …
4x4 ICT, I&P frames, Filter, …	x	x	x	x
8x8 ICT				x
Perceptual Quant. weighting matrix				X
B slices		X	X	X
Interlaced encoding, fields		X	X	X
Weighted Preditction		X	X	X
CAVLC	X	X	X	X
CABAC		X		X
Flexible MB Ordering (FMO)	x		X	
Redundant Slices	x		X	
Arbitrary Slice Ordering	X		x	
Data patitioning			X	
SI / SP Frames (Switched)			X	
4:2:2, 4:4:4 / 10,12bit				X

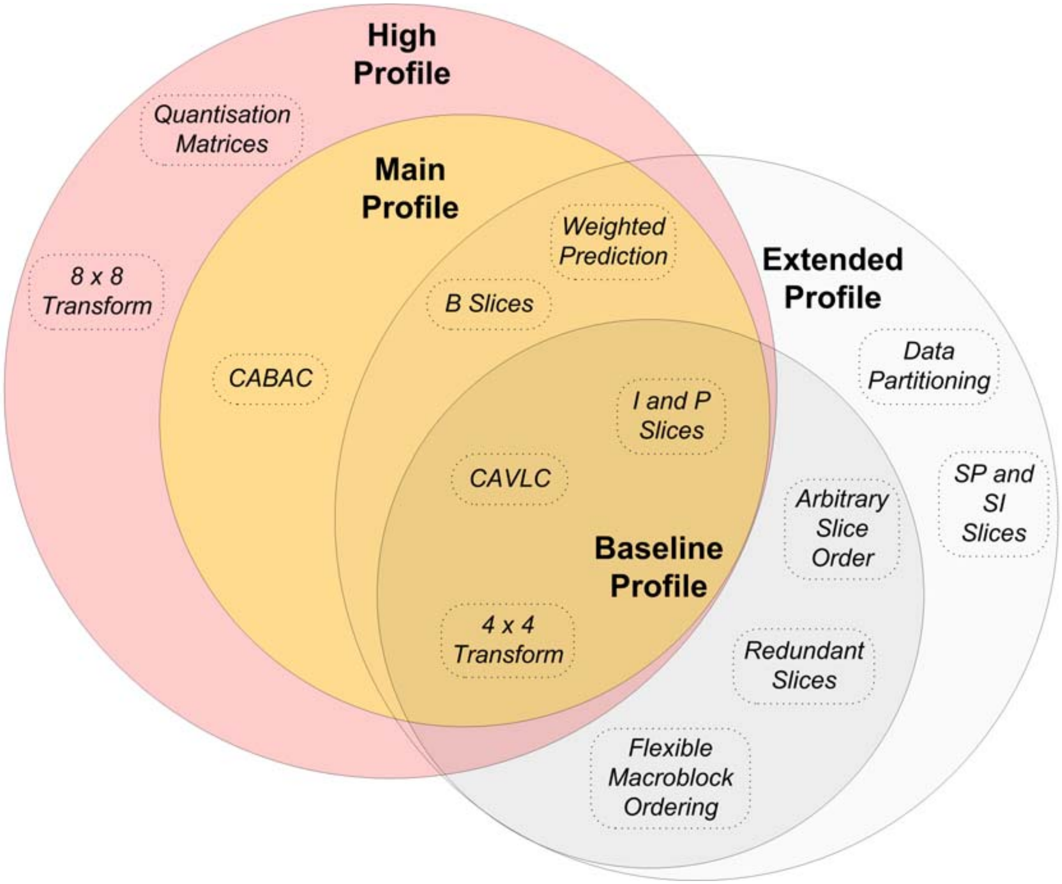
Extensive number of coding tools

→ Challenge to identify and parameterize the appropriate tools for a certain application

Profil – Level Structure



Dependency of Profiles



Levels

Level	1	2	3	4	5
Max. image size [MB]	**99**	**396**	**1620**	**8192**	**22080**
Decoder rate [MB/s]	**1485**	**11880**	**40500**	**245760**	**589824**
Decoder memory [kB]	**148,5**	**891**	**3037,5**	**12288**	**41310**
Max. video bit rate [kbps]	**64**	**2000**	**10000**	**20000**	**135000**
Typical image size and frame rates	**QCIF 15 Hz**	**CIF 20 Hz**	**625 SD 25 Hz**	**1080 HD 30,1 Hz**	**3680x1536 26,7 Hz**
Max number of reference frames for typical image sizes	**4**	**6**	**5**	**4**	**5**

Observation:

- Levels are internally subdivided → there are "intermediate levels"
- AVC encompasses a very large range of formats and applications
  from QCIF to Digital Cinema (4kx2k)

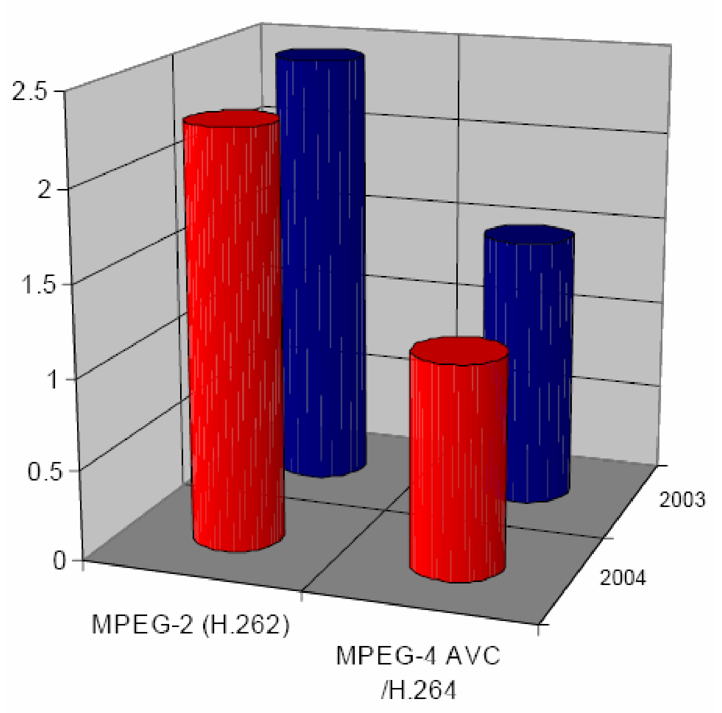
Qualitative Comparison

Core characteristics of H.264

- higher coding efficiency (compression ratio)
- At the expense of a higher complexity

Quantitative comparison quite difficult, as it depends on:

- **encoder implementation**
  - Approach for motion estimation
  - Rate control / rate distortion optimization
  - Pre-processing (noise reduction, …)
  - Online / Offline (1-pass, 2-pass)
  - …..
- **criterion for comparison (PSNR, MOS, …)**
- **Codec parameters and configuration**
- **video material, bit rates, …**



Quelle: MP4 Industry Forum

Coder Control

Extensive options to parameterized:
→ "artful selection" of parameters determines the coded image quality
→ control of buffer level in order to avoid overflow and underflow (buffer has limited size)
→ Codecs frequently contain a rate control with rate-distortion optimization

Coder control is Not normative:
Aim: optimal selection of parameters (parameter vector p)
for minimizing the distortion D given a target bit rate R

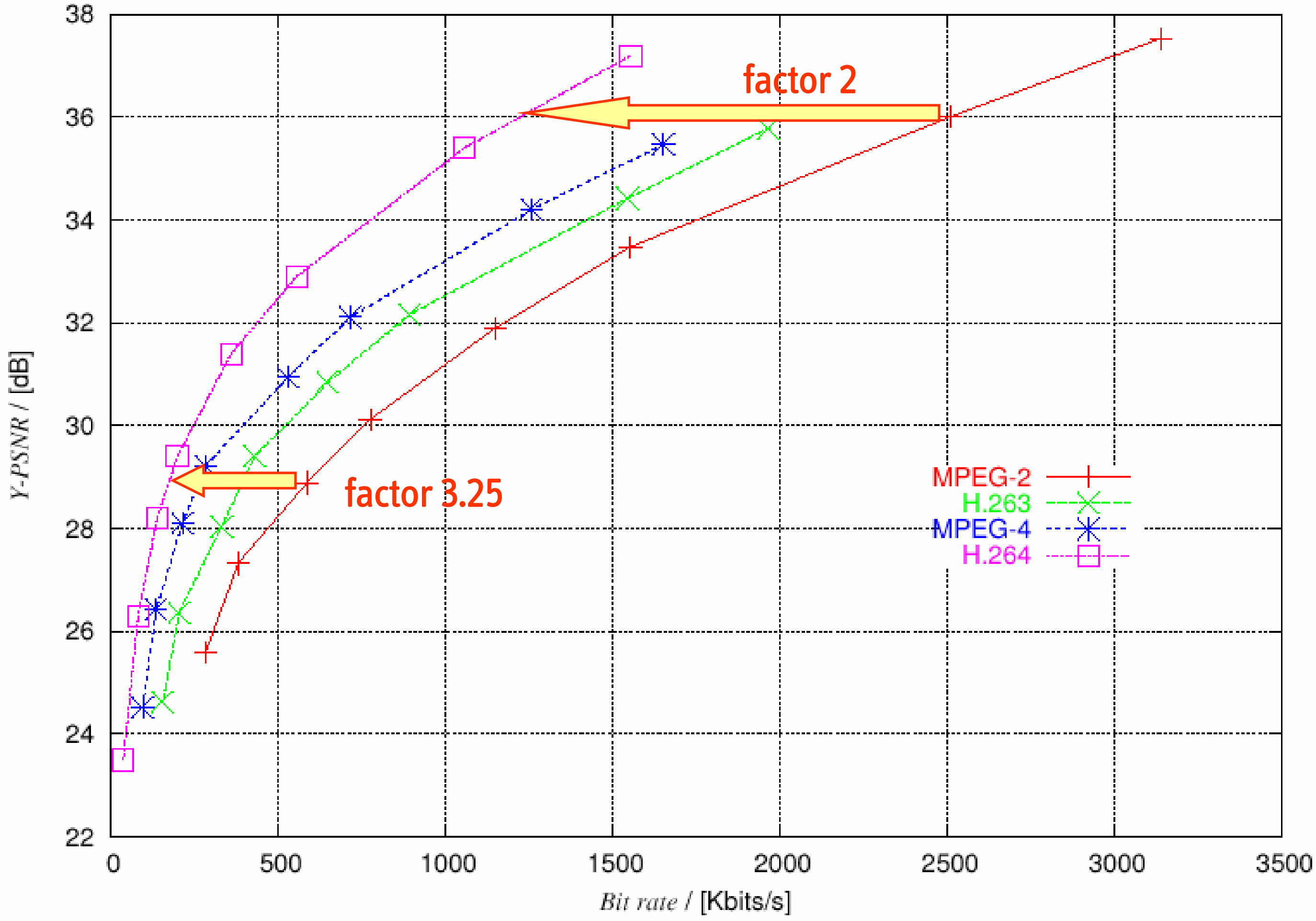
Problem: locally selecting parameters does not guarantee global optimization

$$\min_p D(p) \Leftrightarrow R(p) \leq R_T$$

$$p_{opt} = \mathrm{argmin}_p \{D(p) + \lambda R(p)\}$$

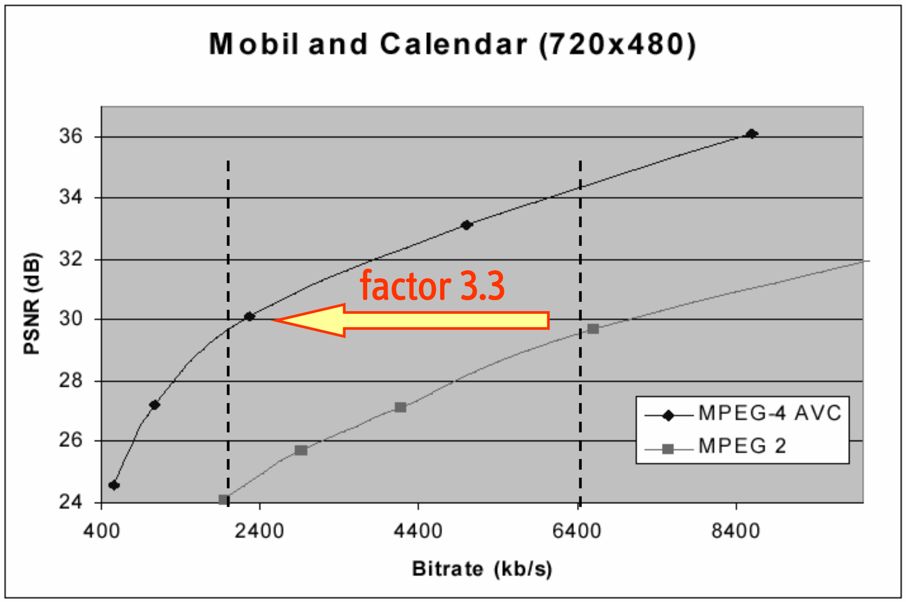
λ: control parameter

Coding Gain (main profile)



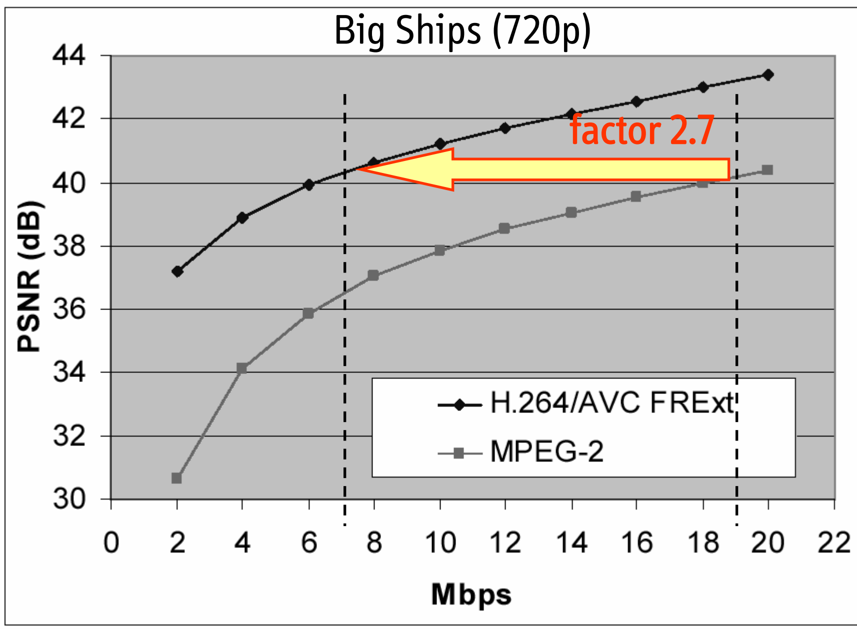
Source: T. Halbach, NTNU, 2003

Coding Gain (higher quality)



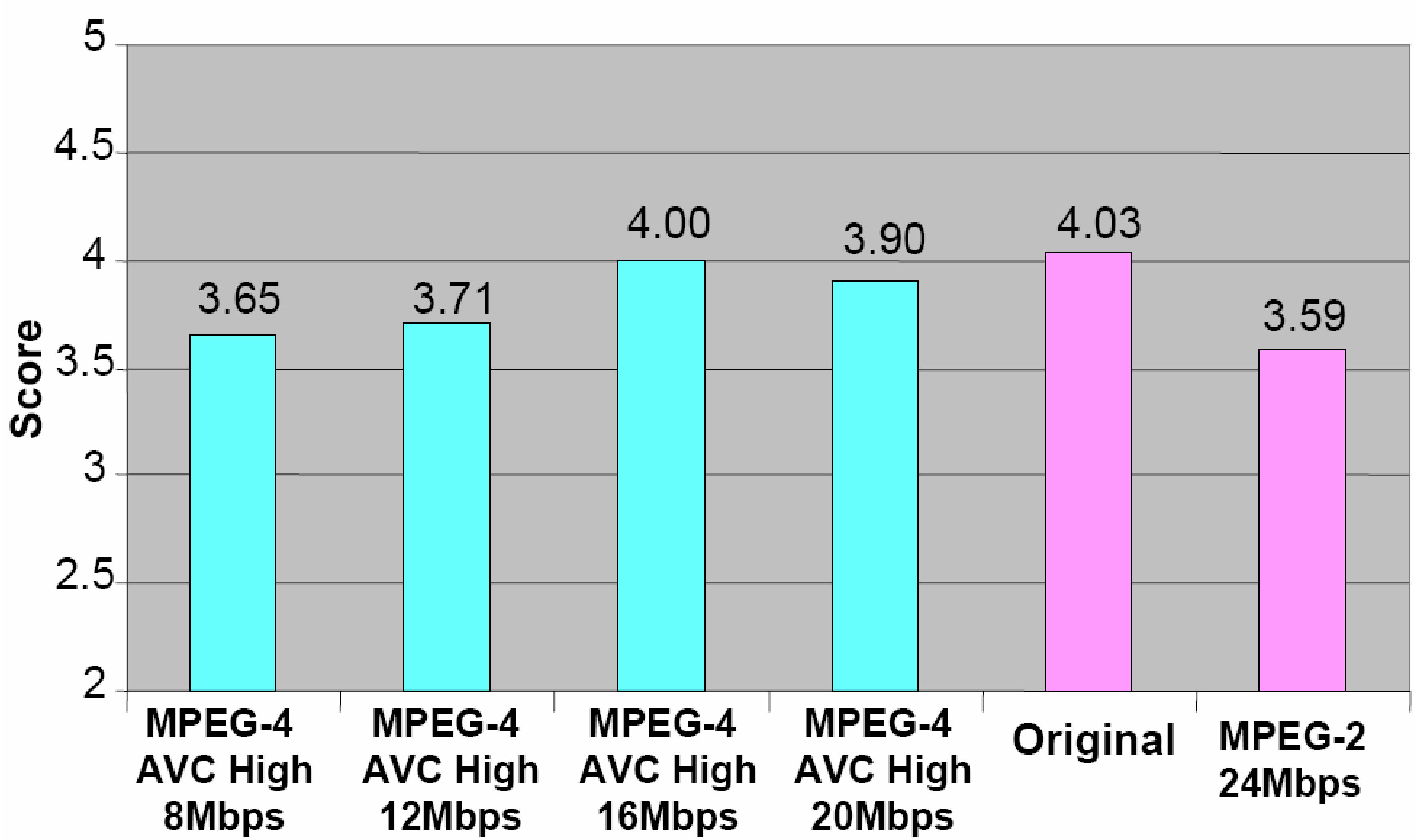
SD,
Main profile

HD,
FRExt profiles



Source: Sullivan, Topiwala, Luthra
SPIE Conf 2004

MPEG-2 vs MPEG-4 AVC High Profile
BDA Subjective Evaluation of Image Quality 2004



Source: Panasonic

BDA: Blue ray Disc Association

Application Areas Currently aimed for

SDTV over DSL

AVC Level 3, Main Profile (+HD 720p) 1.5 – 4 Mbps

HDTV over DVB-S2

AVC Level 4, High Profile (1080i) 8 – 12 Mbps

Blue Ray Disc (besides MPEG-2, VC-1)

TV over IP / Video streaming

Mobile broadcast

Components available in the market

- Chips available (TI, ASPEX, Samsung, MediaTek, ...)
- SW-Encoder (MainConcept, Moonlight, ...)
- SW-Decoder (many implementation available)
- HW-Encoder (Tandberg, Thomson, SciAtlanta, Ateme, ….)
- STBs (commercially available for DVB-T, HD, IPTV)

Microsoft VC-1

- **Employs similar algorithms than MPEG-4/AVC**
  - Optimized for speed and PC implementation
- **Provides interface to Microsoft's Digital Rights Management (DRM)**
  - „Trojanian horse?
  - Preferred solution by content owners, in particular Hollywood
- **Has been standardized by SMPTE (during discussions about H.254 licensing conditions)**
  - Possible utilization of IPRs get obvious
  - Got International Standard (FCD) in 2005
  - Got relevance for other standardization activities, e.g. in DVB for IP implementation guidelines
- **3 Profile**
  - SIMPLE PC, mobile
  - MAIN SDTV, Broadcast
  - ADVANCED HDTV up to 1080, 50p

Analysis of Image Quality

- **Mathematical criteria:**
  - PSNR
  - Moving Picture Quality Metric
  - General Video Quality Model
  - Structural Distrotion Based Model

- **Subjective rating methods**
  - Double Stimulus Impairment Scale
  - Double Stimulus Continuous Quality.-Scale
  - Single Stimulus Continuous Quality Evaluation
  - Simultaneous Double Stimulus for Continuous Evaluation
  - Subjective Assessment Methodology for Video Quality (SMAVIQ by EBU)

PSNR

Arithmetic approach

Identify differences between a reference and the test material

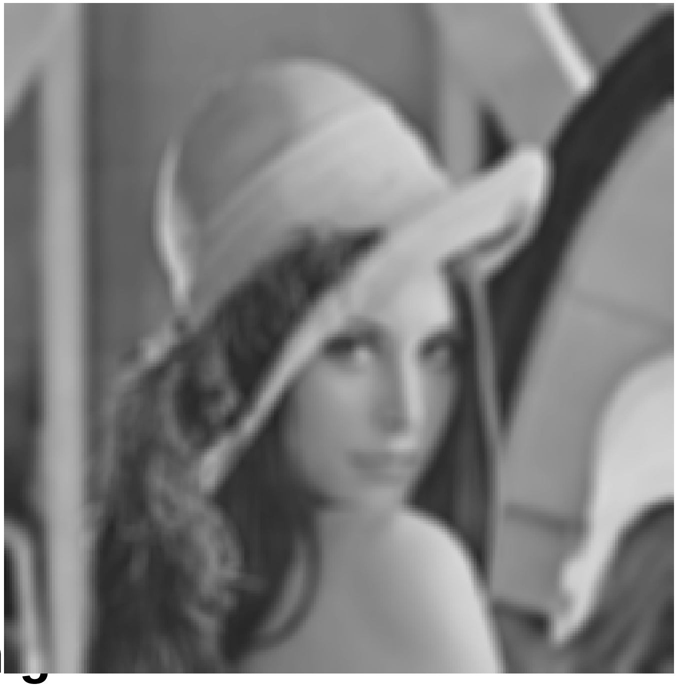
$$SNR = 10 \log \frac{\sum_n s^2[n]}{\sum_n (s[n] - \hat{s}[n])^2}$$

$$PSNR = 10 \log \frac{255^2}{\sum_n (s[n] - \hat{s}[n])^2}$$

PSNR:

~80% correlation with subjective evaluation results

Analytical Approaches to Evaluate Video Quality



Source: Zhou Wang, New York University

Both images have the <u>SAME</u> PSNR!

SAMVIQ – Test Organization

1. Sequence	Reference	Algo. 2	Algo. 1	Hidden Reference	Algo. 3
	ref	A	B	C	D
2. Sequence	Reference	Algo. 3	Hidden Reference	Algo. 1	Algo. 2
	ref	A	B	C	D
⋮					
k. Sequence	Reference	Hidden Reference	Algo. 1	Algo. 3	Algo. 2
	ref	A	B	C	D

For example: Algo. 1: MP4, QCIF,128kbps   Algo. 2: RV, QCIF, 500kbps

Video Coding in Production and Transmission

- **Relevance of clean production chains (change of codecs / parameters → transcoding)**
- **HD introduction**
- **Mapping to distribution channel**
  - Necessity to look at complete production and distribution chain
- **Heterogeneous transmission systems with different codecs**
  - Classical TV
  - IPTV
  - online

What Next?

- Not in all environments all devices need / support the identical resolution in space, time and quality

  → adaptation and transcoding

  → scalable coding

- Not all users are interested in the same content or watch the content in the same order (PVR)

  → individually control the handling of media

  → add functionality

  → complement coding with meta data

- 3D video coding (coding of stereoscopic images is a special case)

  → resolution of screen will continue to increase

  → gaming industry drives realistic 3D simulation engines

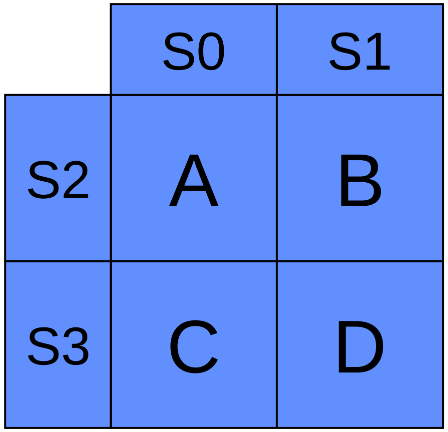
  → auto-stereoscopic 3D screens leave the stadium of prototypes

B A C K U P

Intra Prediction – Chrominanz

Chroma block

- 4 prediction modes are very similar to the 16x16 luma prediction modes
- DC prediction



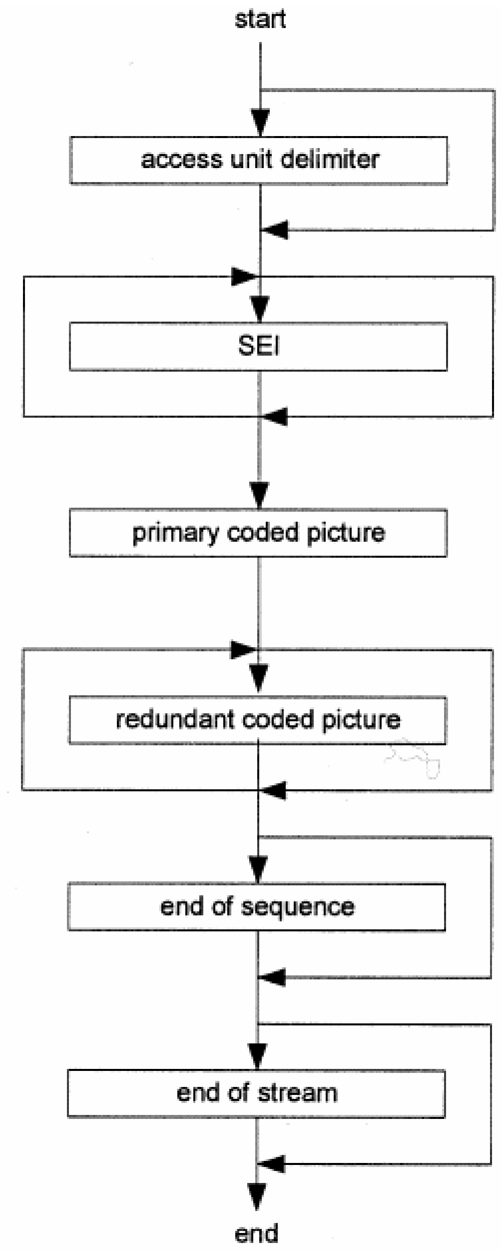
S0~S3:sum of bordering chroma pixels

- **Intra prediction across slice boundaries is not used**

Block	S0~S3 available	S0~S1 available	S2~S3 available	None available
A	(S0 + S2 + 4)/8	(S0 + 2)/4	(S2 + 2)/4	128
B	(S1 + 2)/4	(S1 + 2)/4	(S2 + 2)/4	128
C	(S3 + 2)/4	(S0 + 2)/4	(S3 + 2)/4	128
D	(S1 + S3 + 4)/8	(S1 + 2)/4	(S3 + 2)/4	128

NAL Struktur

- **NAL Units**
  - Organize the coded video data
  - Contain a header data
  - Two types: VCL NAL units and non-VCL units
  - In Byte-Stream Format Use
  - In Packet-Transport System Use
- **Parameter Sets**
  - Picture parameter sets
  - Sequence parameter sets
- **Access Units**
  - decoding of each results in one decoded picture
- **Coded Video Sequences**
  - a series of access units
  - only one sequence parameter set



MPEG-4 Versionen

H.263 bildet die Grundlage des Videocodierverfahrens von MPEG-4

- **Version 1 (Mai 1999)**
  - Simple Profile — ähnlich H.263: I/P-VOP,
  - Core Profile — arbitrary shaped objects, B-VOPs, temporal scalability
  - Main Profile — Alpha Plain, Interlaced, Sprites, Transparenz, ...
- **Version 2 (Feb. 2000)**
  - Skalierbarkeit
  - ACE Profile
- **Version 3 (April 2001)**
  - Bildgrößen bis 4096x4096, Bitraten bis 2.4 Gbit/s
- **H.264 / AVC (bis 2003)**
  - FRExt bis 2004