Video Coding Standards: Up to H.264

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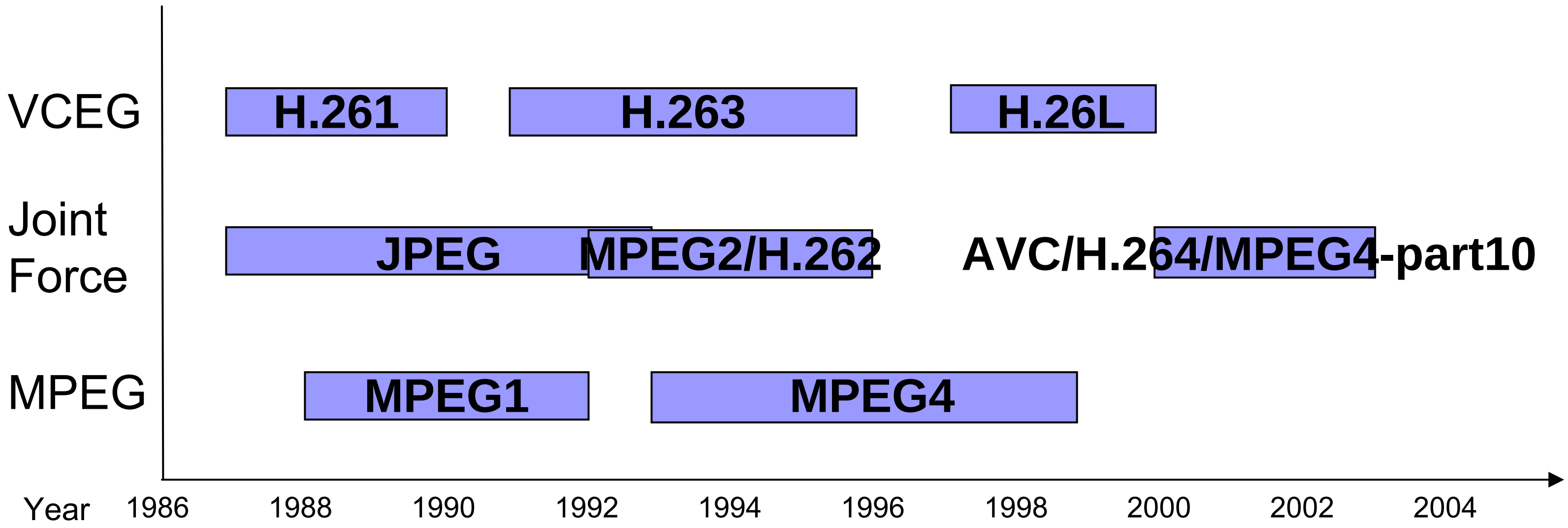
Time table



- Two organizations dominate video compression standardization:
  - ITU-T Video Coding Experts Group (VCEG): International Telecommunications Union – Telecommunications Standardization Sector (ITU-T, a United Nations Organization, formerly CCITT), Study Group 16, Question 6
  - ISO/IEC Moving Picture Experts Group (MPEG): International Standardization Organization and International Electro-technical Commission, Joint Technical Committee Number 1, Subcommittee 29, Working Group 11

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Joint(ITU+ISO) Photographic Experts Group (JPEG)

- JPEG targets:

8 bits/pixel monochrome images	→		
		0.083 bits/pixel as	"recognizable"
		0.25	"useful"
		0.75	"excellent"
		2.25	"indistinguishable"

- Color treatments:

Red	→	Luminance (Y)	**Two modes:**
Green		Color difference B-Y (C_B)	4:2:2
Blue		Color difference R-Y (C_R)	4:2:0

- JPEG coder
  - 8×8 DCT (why DCT?)
  - Quantization (Two tables by Lohscheller 1984)
  - Zig-zag scanning and run-level description
  - Entropy coding (Huffman and arithmetic coding)
- Motion JPEG (Video coded as sequences of JPEG images)

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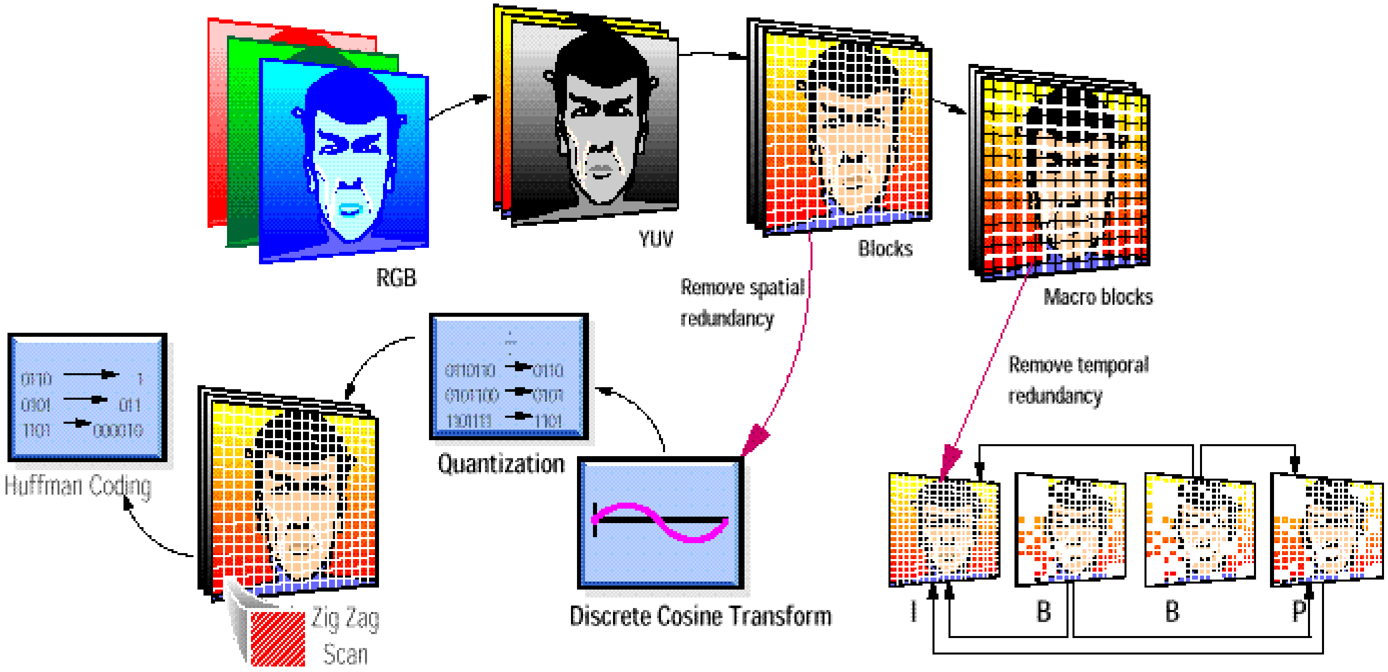
Motion JPEG

- Disadvantages
  - Loss of temporal compression capability
  - There is no document that defines a single exact format that is universally recognized as a complete specification of "Motion JPEG" for use in all contexts
- Advantages
  - Low processor overhead
  - Easy editing
- Applications
  - Digital cameras
  - Surveillance cameras

MPEG – Generic Encoder



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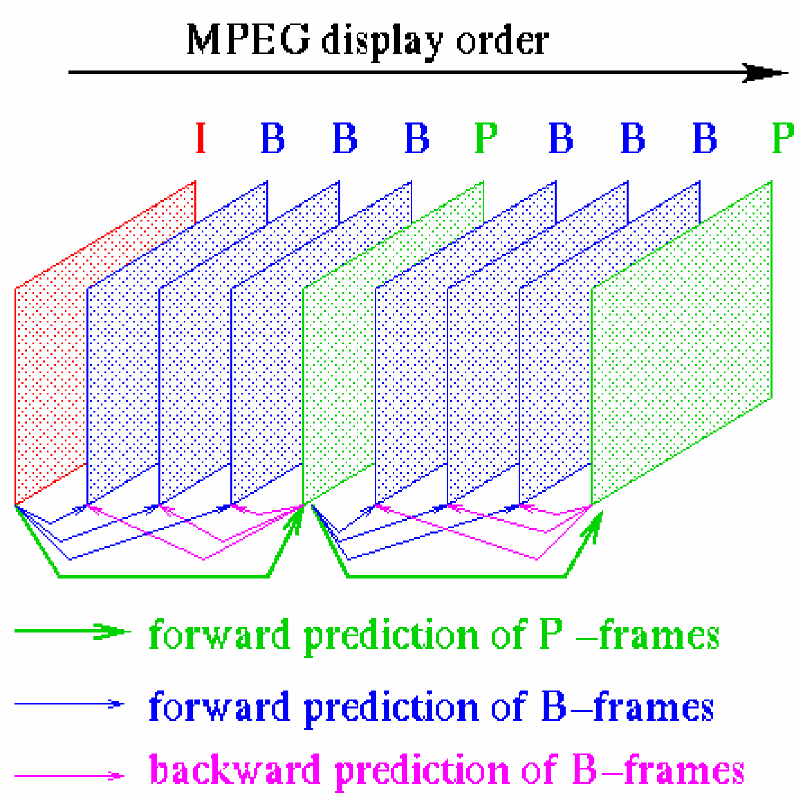
MPEG-1 = JPEG + Motion Prediction + Rate Control

- Early motivation: to encode motion video at 1.5Mbits/s for transport over T1 data circuits and for replay from CD-ROM
- Defines the decoder but not the encoder
- Frames (pictures)
  - Intra-coded using JPEG
  - Inter-coded using (interpolated) motion estimation & compensation and JPEG for the residuals
    - Predicted and Bi-directional
- MacroBlocks (MBs)
  - 16×16 pixels block
- Rate control
  - buffer at each end
  - Test Model 5 (TM5)



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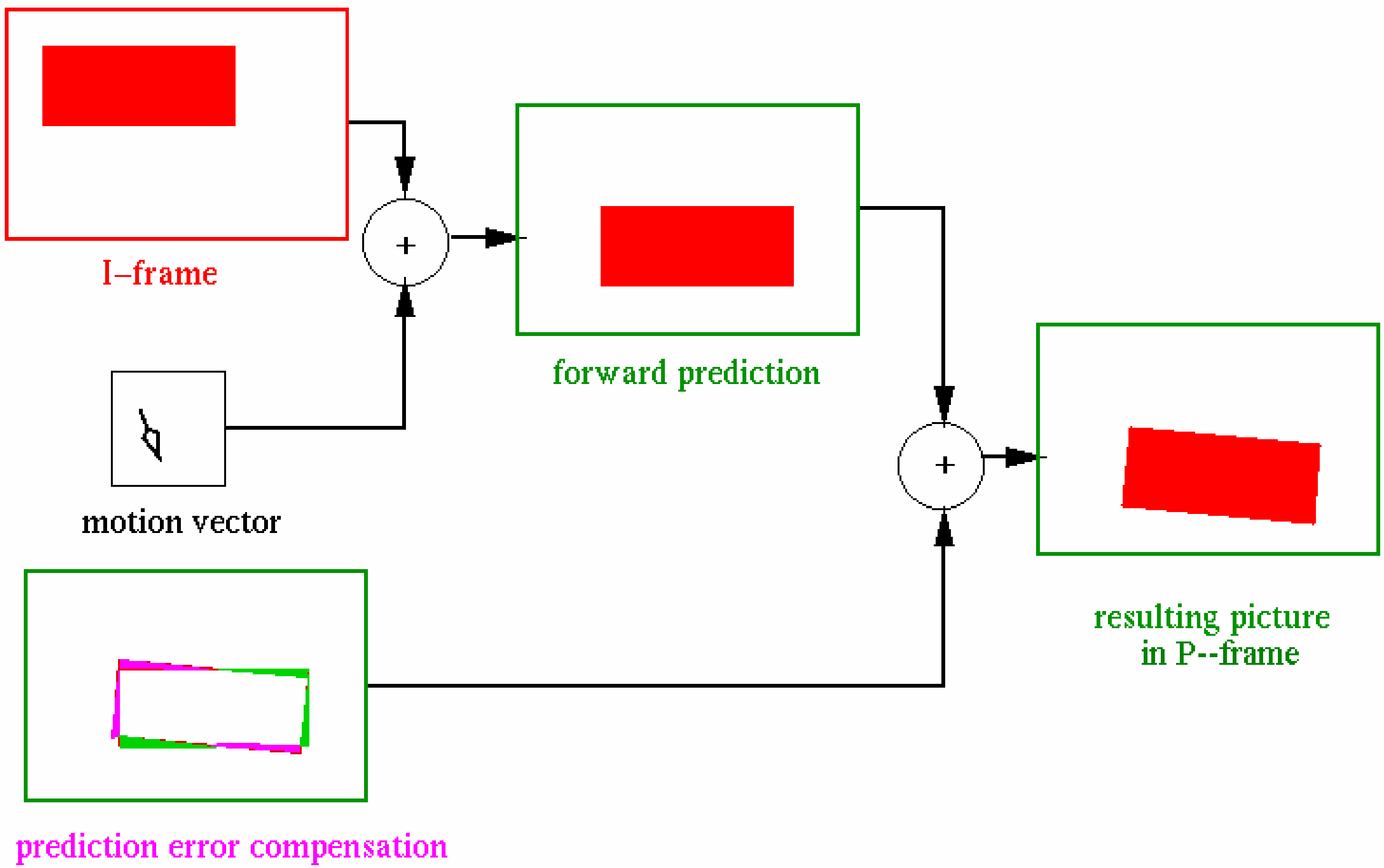
MPEG-1 – Motion Prediction

- Motion prediction = motion estimation + error compensation

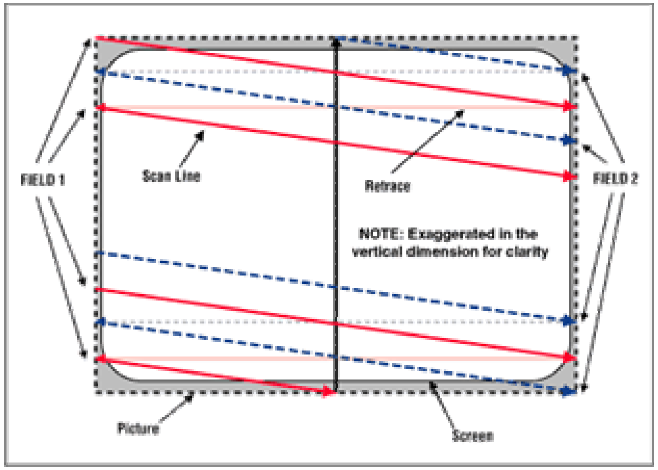


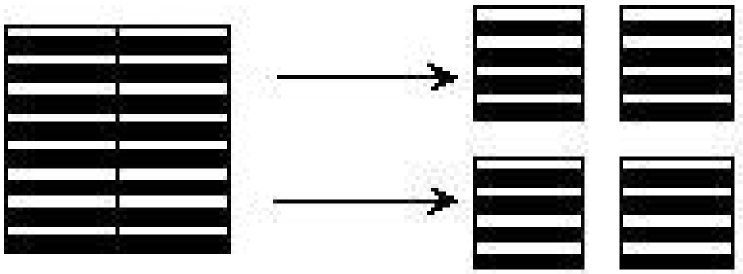
MPEG-2 = MPEG-1 +

- Improvements
  - Color space: could support 4:2:2 and 4:4:4 coding
  - Quantization: could have 9- or 10- bit precision for DC coefficients
  - Concealment motion vectors: used when an intra-MB is lost
  - Pan and Scan: supports display of different aspect ratios, e.g., 16:9
- Profiles and levels
  - Profiles: define the tools or syntactical elements
  - Levels: define the permissible ranges of parameters
- Interlace tools
- Scalable coding profiles
- System layer: define two bit stream constructs
  - Program stream (PS): modeled on MPEG-1 (backward compatibility)
  - Transport stream (TS): more robust, does not need a common time base, designed for use in error-prone environment.

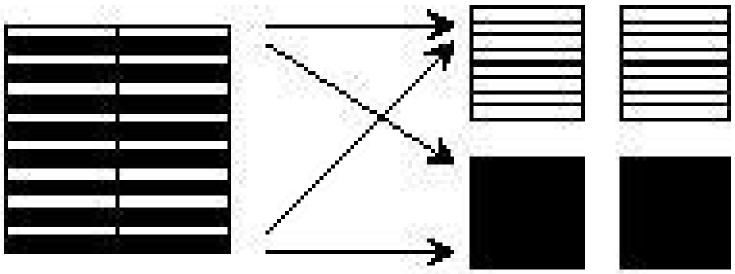
MPEG-2 – Interlace Tools

- Interlaced Scanning: Image flicker is less apparent because the image is painted twice as many times as what is in non-interlaced scanning.
- Frame Pictures and Field Pictures
  - two fields are processed sequentially or not
- Frame DCT and Field DCT
  - Field pictures usually use field DCT
  - Frame pictures use field DCT when there is obvious vertical motion
- Frame Prediction and Field Prediction





Frame DCT



Field DCT

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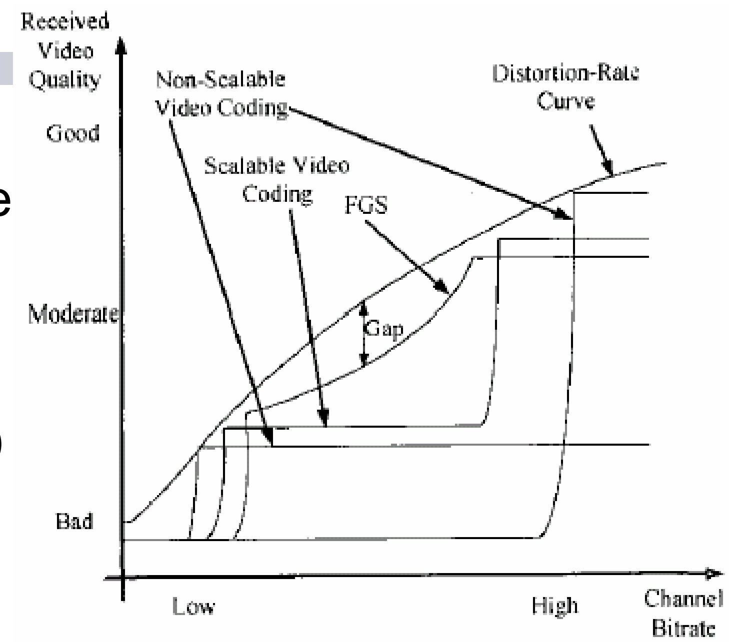
MPEG-4 = MPEG-2+Objects+Other Enhancements

- Objects (optional)
  - Video (texture+shape), image, audio, speech, text, etc.
  - Encoded using different techniques
  - Transmitted independently
  - Mixed at the decoder using Binary Format for Scenes (BIFS)
- Improvements in MPEG-4 version2
  - Global motion compensation (GMC)
    - Compensating the camera motion: panning, zooming, rotation
  - Quarter pixel motion compensation
  - Shape-adaptive DCT
- Why is MPEG-4 not a success as MPEG-2?
  - Not substantially better than MPEG-2
  - Suffers from its sheer size and flexibility
  - Issue of licensing

MPEG – Scalable Coding (SC)

- Non-scalable coding
  - Optimize video quality at a given bitrate
- MPEG-2 SC profiles
  - To optimize video quality at two given bit rates.
  - SNR SC (different quantization accuracy)
  - Temporal SC (different frame rates)
  - Spatial SC (different spatial resolution)
- Fine granularity scalability (FGS)
  - To optimize the video quality over a given bit rate range
  - Also has base layer and enhancement layer
  - Enhancement layer uses bit-plane coding
    - 10,0,6,0,0,3,0,2,2,0,0,2,0,0,1,0,……………,0,0 (absolute)
    - 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,……………..,0,0 (MSB)
      0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,……………..,0,0 (MSB-1)
      1,0,1,0,0,1,0,1,1,0,0,1,0,0,0,0,……………..,0,0 (MSB-2)
      0,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,……………..,0,0 (MSB-3)



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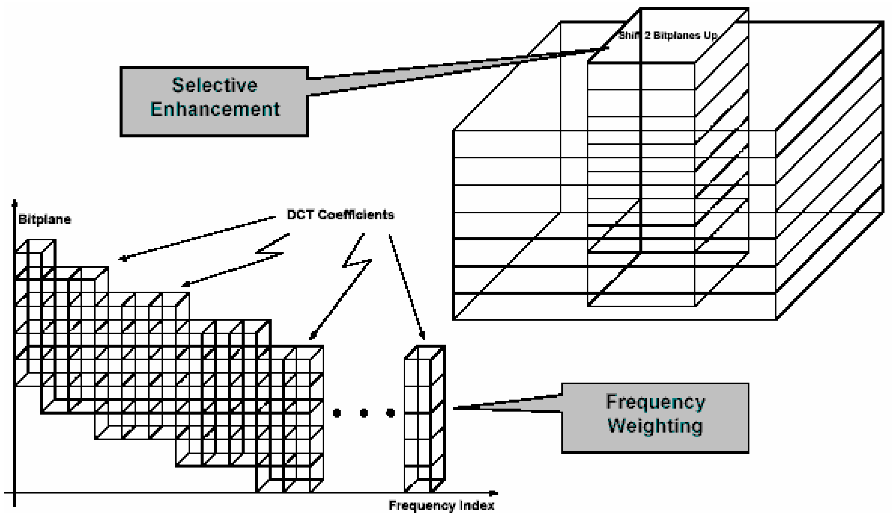
Fine granularity scalability (FGS)

- Frequency weighting and selective enhancement



- The coding efficiency of the FGS scheme is not as good as the traditional SNR scalability schemes
- Progressive FGS
  - Using as many predictions from the enhancement reference layers as possible (for coding efficiency)
  - Keeping a prediction path from the base layer to the highest quality layers across several frames (for error recovery and channel adaptation)

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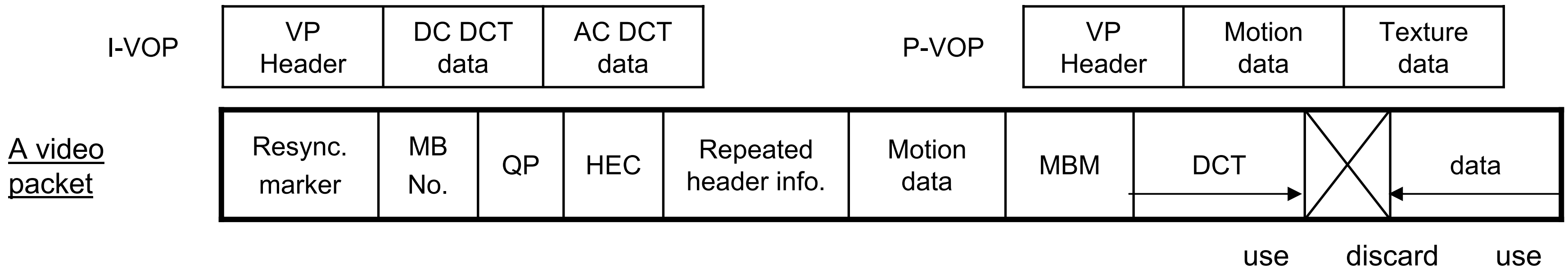
MPEG-4 – Error Resilience Tools

- Video packet resynchronization
  - Previous coding standards: Resynchronization markers are fixed at the beginning of each row of MBs
  - MPEG-4: Resynchronization markers are inserted at every K bits
- Data partitioning
  - Partitions the data in a video packet into a motion part and a texture part separated by a motion boundary marker (MBM)
- Reversible variable length codes (RVLC)
  - Finds the next resynchronization marker and decode backwards
- Header extension code (HEC)
  - The header information is repeated after the 1-bit HEC
- Unequal error protection technique (UEP)



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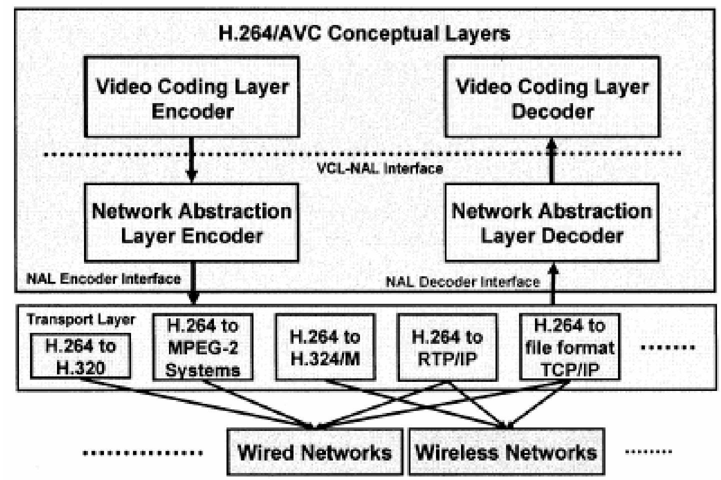
Advanced Video Coding/ ITU-T Recommendation H.264/ ISO/IEC MPEG-4 (Part 10)

- H.264 structure
  - Video coding layer (VCL)
  - Network abstraction layer (NAL)
- Possible applications of H.264
  - Conversational services operated below 1Mbps with low latency.
    - ISDN-based H.320
    - H.324/M in circuit-switched channels
    - H.323 in packet-switched networks

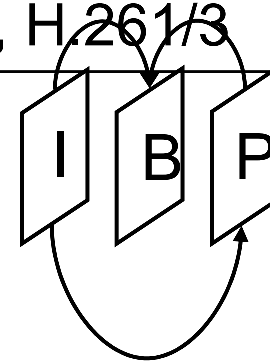


  - Entertainment services operated between 1-8+ Mbps with moderate latency such as 0.5-2s in modified MPEG-2/H.222.0 systems.
    - Broadcast via satellite, cable, terrestrial or DSL
    - DVD for standard and high-definition video
    - Video-on-demand via various channels
  - Streaming services operated at 50-1500kbps with 2s or more of latency.

Intra-Coded Macroblocks

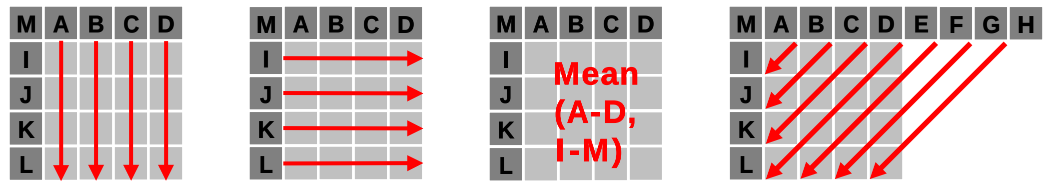
	H.264	MPEG-1/2/4, H.261/3
Prediction in space domain	■ Spatial prediction ■ Encode the prediction modes (Use predictive coding if 4x4 modes are used)	■ No spatial prediction
Transform	■ Integer transform of residue	■ 8x8 Discrete Cosine Transform (DCT) for pixel values
Quantization	■ Quantization including scaling	■ Quantization
Prediction in frequency domain	■ No coefficient prediction	■ Coefficient prediction (for DC values in MPEG-2 and AC values in the first row and column in MPEG-4)

Inter-Coded Macroblocks

	H.264	MPEG-1/2/4, H.261/3
References	■ Permits up to 15 (2 mostly used) reference pictures ■ Bi-predictive B-slices ■ A P-slice may reference a picture that has B-slices ■ Supports explicit weighting coefficients and (a+b)/2 type	■ A P-slice references only one I-picture ■ Bi-directional B-slices  ■ Only permit (a+b)/2 type prediction weighting
Block Sizes	■ Tree-structured (16x16 → 16x8, 8x16, 8x8 → 8x4, 4x8, 4x4)	■ Either 16x16 or 8x8
Motion Estimation	■ half or ¼-pixel accuracy ■ 6-point interpolation for half-pixel and 2-point linear interpolation for ¼-pixel	■ MPEG2 permits half-pixel accuracy and MPEG4 permits ¼-pixel accuracy ■2-point linear interpolation

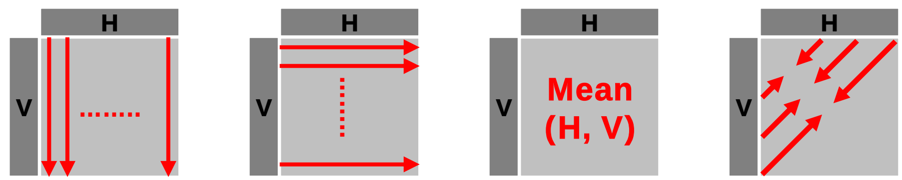
Spatial Prediction for Intra-Coded MBs

- luma
  - 4x4: 9 modes

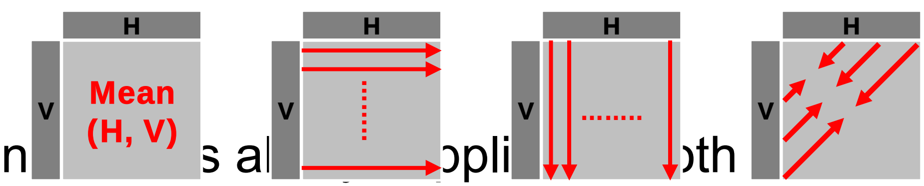


…

  - 16x16: 4 modes



- chroma
  - 8x8: 4modes

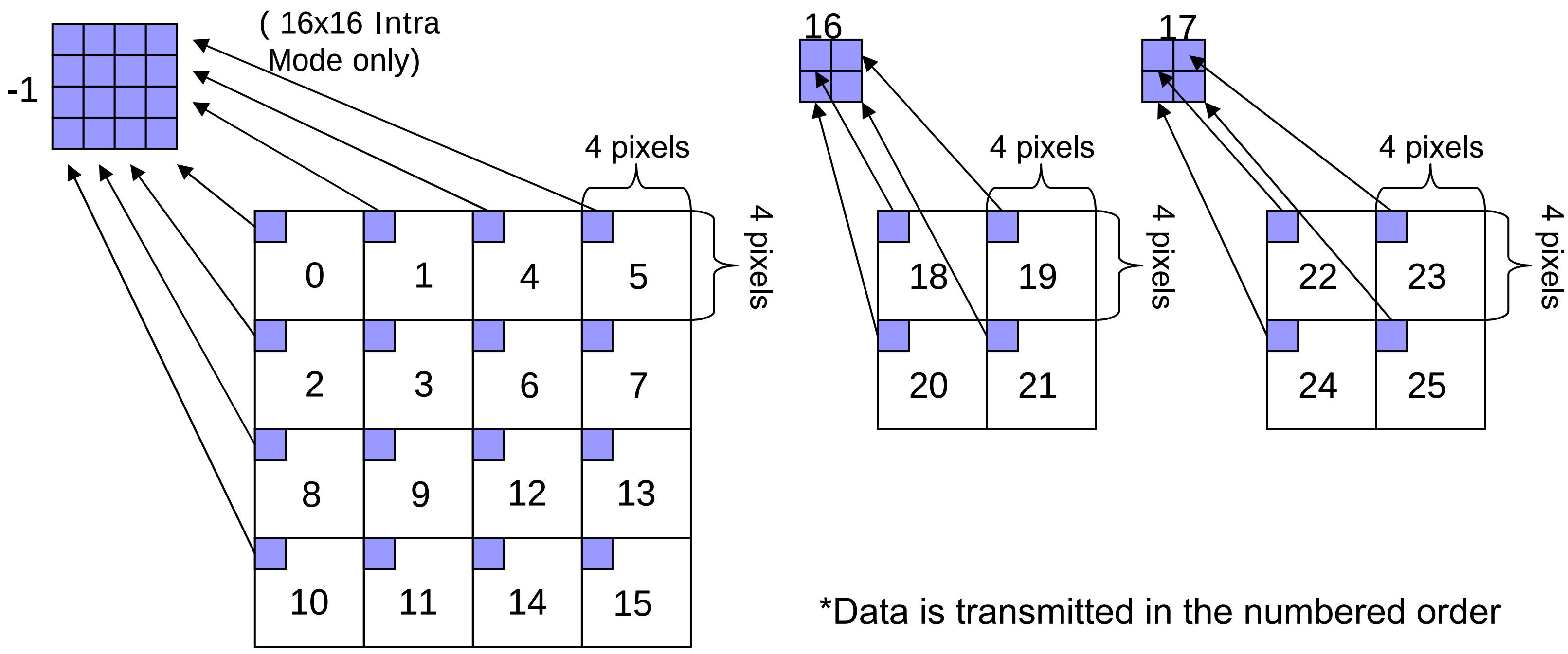


  - The same prediction … s al … ppli … oth … blocks

Transform and Quantization

- Three types of transform followed by quantization

  - **Type 1:** for the 4x4 array of luma DC coefficients in intra MBs predicted in 16x16 mode # -1
  - **Type 2:** for the 2x2 array of chroma DC coefficients #16-17
  - **Type 3:** for all other 4x4 blocks # 0-15, 18-25



*Data is transmitted in the numbered order

Transform and Quantization – Type 3

- 4×4 DCT (X – Input, Y – output)

$$\mathbf{Y}=\mathbf{AXA}^T=\begin{bmatrix} a & a & a & a \\ b & c & -c & -b \\ a & -a & -a & a \\ c & -b & b & -c \end{bmatrix} \begin{bmatrix} & & & \\ & \mathbf{X} & & \\ & & & \end{bmatrix} \begin{bmatrix} a & b & a & c \\ a & c & -a & -b \\ a & -c & -a & b \\ a & -b & a & -c \end{bmatrix}$$

$$a=\frac{1}{2}$$

$$b=\sqrt{\frac{1}{2}}\cos\left(\frac{\pi}{8}\right)$$

$$c=\sqrt{\frac{1}{2}}\cos\left(\frac{3\pi}{8}\right)$$

- 4×4 integer transform

- forward

$$\mathbf{Y}=\mathbf{C}_f\mathbf{X}\mathbf{C}_f^T\otimes\mathbf{E}_f=\left(\begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \begin{bmatrix} & & & \\ & \mathbf{X} & & \\ & & & \end{bmatrix} \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix}\right)\otimes\begin{bmatrix} a^2 & ab/2 & a^2 & ab/2 \\ ab/2 & b^2/4 & ab/2 & b^2/4 \\ a^2 & ab/2 & a^2 & ab/2 \\ ab/2 & b^2/4 & ab/2 & b^2/4 \end{bmatrix}$$

W

Post-scaling factor (PF)

- backward

$$\mathbf{X}'=\mathbf{C}_i^T(\mathbf{Y}\otimes\mathbf{E}_i)\mathbf{C}_i=\begin{bmatrix} 1 & 1 & 1 & 1/2 \\ 1 & 1/2 & -1 & -1 \\ 1 & -1/2 & -1 & 1 \\ 1 & -1 & 1 & -1/2 \end{bmatrix}\left(\begin{bmatrix} & & & \\ & \mathbf{Y} & & \\ & & & \end{bmatrix}\otimes\begin{bmatrix} a^2 & ab & a^2 & ab \\ ab & b^2 & ab & b^2 \\ a^2 & ab & a^2 & ab \\ ab & b^2 & ab & b^2 \end{bmatrix}\right)\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1/2 & -1/2 & -1 \\ 1 & -1 & -1 & 1 \\ 1/2 & -1 & 1 & -1/2 \end{bmatrix}$$

with $a=\frac{1}{2}, b=\sqrt{\frac{2}{5}}$

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Transform and Quantization – Type 3 (2)

- 52 quantization stepsizes (Qstep) indexed by quantization parameters (QP)

QP	0	1	2	3	4	5	6	7	8	9	10	11	12	….
QStep	0.625	0.6875	0.8125	0.875	1	1.125	1.25	1.375	1.625	1.75	2	2.25	2.5	….
QP	…	18	…	24	…	30	…	36	…	42	…	48	…	51
QStep		5		10		20		40		80		160		224

- Uniform Scalar Quantization

$$Z_{ij} = \text{round}\left(W_{ij} \cdot \frac{PF}{Qstep}\right) \;\Rightarrow\; Z_{ij} = \text{round}\left(W_{ij} \cdot \frac{MF}{2^{qbits}}\right)$$

where $\frac{MF}{2^{qbits}} = \frac{PF}{Qstep}$ and $qbits = 15 + \text{floor}(QP/6)$

- Integer arithmetic

$$|Z_{ij}| = (\,|W_{ij}|.MF + f\,) >> qbits$$
$$\text{sign}(Z_{ij}) = \text{sign}(W_{ij})$$

where $f=2^{qbits}/3$ for intra MBs and $2^{qbits}/6$ for inter MBs to control the quantization width near the origin (the "dead zone")

- The advantages of the new transform and quantization scheme:
  - Integer transform avoids the inverse-transform mismatch.
  - Smaller blocksize (4*4) leads to a significant reduction in blocking artifact.
  - No multiplication involved. Requires only 16-bit arithmetic.

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Entropy Coding

Parameters to be coded	entropy_coding_mode=0	entropy_coding_mode=1
Macroblock type (Intra/Inter)	Exponential Golomb codes (Exp_Golomb) Variable Length Coding (VLC)	Context-based Adaptive Binary Arithmetic Coding (CABAC)
Coded block pattern		
Quantizer parameter		
Reference frame index		
Motion vector		
Residual data	Context-adaptive variable length coding (CAVLC)	

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Exp-Golomb Entropy Coding

- Exp-Golomb codewords structure: [M zeros][1][M-bit info]

Code_num	Codeword
0	1
1	010
2	011
3	00100
4	00101
5	00110
6	00111
7	0001000
8	0001001
…	…

- Three ways of mapping parameter v to code_num:

1. Unsigned direct mapping: macroblock type, reference frame index and others
2. Signed mapping: motion vector difference, delta QP and others
3. Mapped symbols: coded block pattern parameter

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Context-adaptive variable length coding (CAVLC)

- Step0: Zig-zap ordering
- Step 1: Encode the number of non-zero coefficients and trailing ones in 4 tables based on the number of non-zero coefficients in upper and left-hand previously coded blocks N_u and N_l
- Step2: Encode the sign of each T1(0=+,1=-) in reverse order
- Step3: Encode the level of the remaining non-zero coefficients in 7 VLC tables in reverse order
- Step4: Encode the total number of zeros and each run of zeros

- 0, 3, 0, 1, -1, -1, 0, 1, 0, 0, …
- TotalCoeff = 5

  T1 = 3

  → 0000100

Example:

0	3	-1	0
0	-1	1	0
1	0	0	0
0	0	0	0

- +,-,- → 011
- 1 → 1, 3→0010
- TotalZeros = 3 → 111

  each run → 10 1 1 01

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Context-adaptive arithmetic coding (CABAC)

- Binarization: *to binarize a non-binary-valued symbol*
- Context probability model selection: *from available models based on the statistics of recently-coded data symbols*
- Binary Arithmetic encoding
- Probability update: *The selected context model is updated based on the actual coded value*

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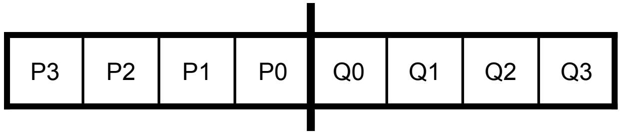
Deblocking Filters

- A boundary-strength (BS) parameter is assigned to every 4×4 block

Block modes and conditions	Boundary-Strength parameter (BS)
One of the blocks is intra-coded and the edge is a MB edge	4
One of the blocks is intra-coded	3
One of the blocks has coded residuals	2
Difference of block motion ≥ one luma sample distance	1
Motion compensation from different reference frames	1
Else	0

- BS = 0 ⟹ No filtering
  BS = 1-3 ⟹ Slight filtering
  BS = 4 ⟹ Strong filtering
- Filters only when
  - $|P_0 - Q_0| < \alpha$
  - $|P_1 - P_0| < \beta$
  - $|Q_1 - Q_0| < \beta$



- Thresholds α and β depend on the average quantization parameter (QP)
- The deblocking filtering accounts for 1/3 of the computational complexity of a decoder.

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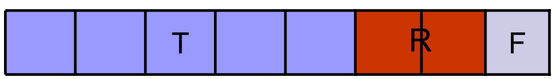
Contributions of the VCL Tools

Spatial Prediction for Intra-coded Macroblocks	Saves 6-9% bits
Temporal Prediction	Saves around 50% bits
Transforms	PSNR less than 0.02dB
Logarithmic Quantization	A change in step size by 12% also saves 12% bits
CAVLC	Saves 5-8% bits
CABAC	Saves 5-15% bits over CAVLC
Picture-adaptive frame/field (PAFF) coding	Saves 16%-20% bits
MB-adaptive frame/field (MBAFF) coding	Saves 14-16% bits over PAFF
Deblocking Filter	Saves 5-10% bits

H.264 Over IP

- Network Abstraction Layer Unit (NALU)
  - A byte stream of variable length
  - 1-byte header
    - NALU type (T)
    - NALU importance (R)
    - Error indication (F)



- RTP packetization
  - Simple packetization
    - One NALU in one RTP packet
    - NALU header as RTP header
  - NALU fragmentation
  - NALU aggregation

<table>
<tr><th>OSI/RM</th><th>Protocols and specifi-cations for H.264</th></tr>
<tr><td>Application Layer</td><td rowspan="3">■ RTP (Real-Time Transport Protocol)
Header size: IP/UDP/RTP = 20+8+12=40 bytes
Media-Unaware RTP payload specifications to reduce the loss rates observed by the decoder.
Packet duplication/Packet based FEC/Audio redundancy coding
■ Control protocols: H.245, SIP (Session Initiation Protocol), SDP (Session Description Protocol), RTSP (Real-Time Streaming Protocol)</td></tr>
<tr><td>Presentation Layer</td></tr>
<tr><td>Session Layer</td></tr>
<tr><td>Transport Layer</td><td>■ UDP (User Datagram Protocol)</td></tr>
<tr><td>Network Layer</td><td>■ IP: best effort service</td></tr>
<tr><td>Data Link Layer</td><td></td></tr>
<tr><td>Physical Layer</td><td></td></tr>
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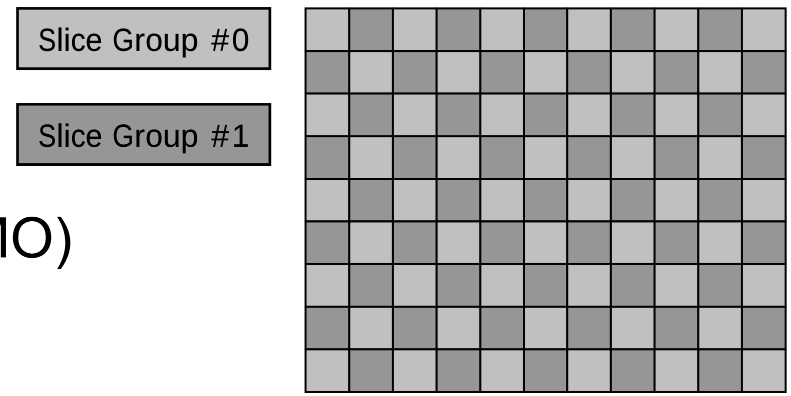
Error-Resilience Tools



- Parameter sets
  - Sequence parameter set
  - Picture parameter set
- Flexible macroblock ordering (FMO)
  - Allows to assign MBs to slices in an order other than scan order
- Arbitrary slice ordering (ASO)
  - Improved end-to-end delay in real-time applications
- Redundant slices (RS)
  - Redundant representations are coded using different coding parameters
- Data partitioning with Unequal Error Protection (UEP)
- Feedback from decoder to encoder
  - Acknowledging correctly received slices (ACK)
  - Not acknowledging message (NAK)

Complexity, Delay & Performance of H.264 codecs

	Baseline	Main	Extended
Profile IDC	66	77	88
Targeted applications	Real-time: to minimize complexity, and provide high robustness and flexibility	Broadcast and storage: to emphasize on compression coding efficiency	Others: to combine the robustness of the Baseline profile with a higher degree of coding efficiency and extra modes
I/P/B frames	IPPP…	IBPBPBI…	IBP(SP,SI)BPBPBP...
# of frames skipped	0	1	1
# of previous frames used for inter motion search*	10	5	5
Entropy coding	CAVLC	CABAC	CAVLC
Advanced error resilience tools	FMO(flexible macroblock ordering), ASO(arbitrary slice ordering), RS		FMO, ASO, RS, DP(data partitioning)

* Can be adjusted for each application

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Complexity, Delay & Performance of H.264 codecs

- Software: AVC/H.264 reference software JM9.3 (not optimized)
- Video clips:
  - football.cif 90 frames @ 30 frames/sec (fast motion)
  - paris.cif 90 frames @ 30 frames/sec (slow motion)
- Coding parameters

Max search range	16
Various block sizes for ME	All sizes enabled
Fast ME used?	No
SP picture	Not used
Weighted prediction	Not used
R-d optimization	On
Data partition	Not used
Slice modes	Not used

High quality	Profiles tested	B,M,E
	Video clips	Football.cif
	QP	I28/P28/B30
Low quality	Profiles tested	B
	Video clips	Football.cif & paris.cif
	QP	I30/P31

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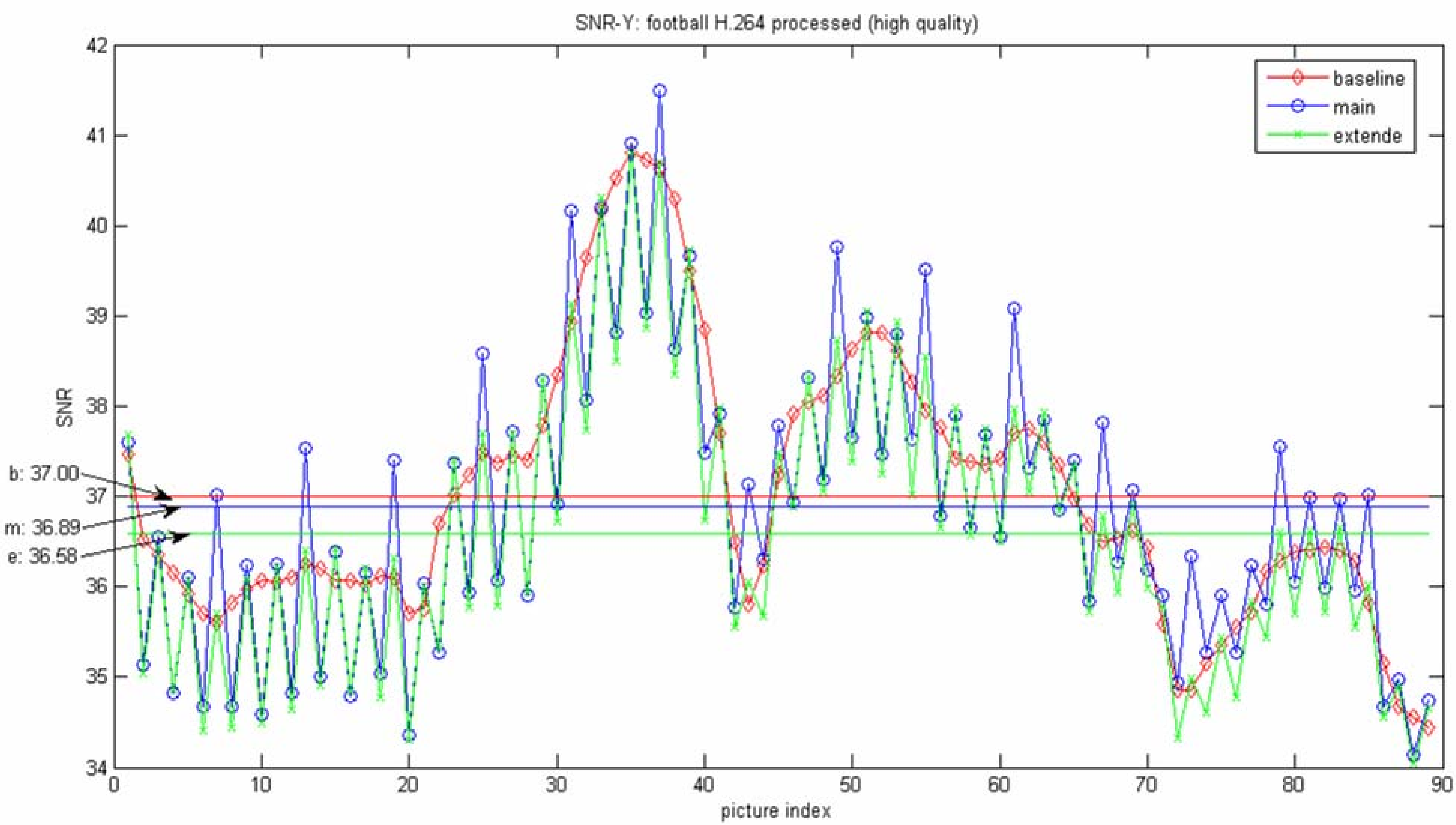

SNR-Y: football H.264 processed (high quality)
baseline
main
extende
SNR
picture index
b: 37.00
m: 36.89
e: 36.58
42
41
40
39
38
37
36
35
34
0
10
20
30
40
50
60
70
80
90

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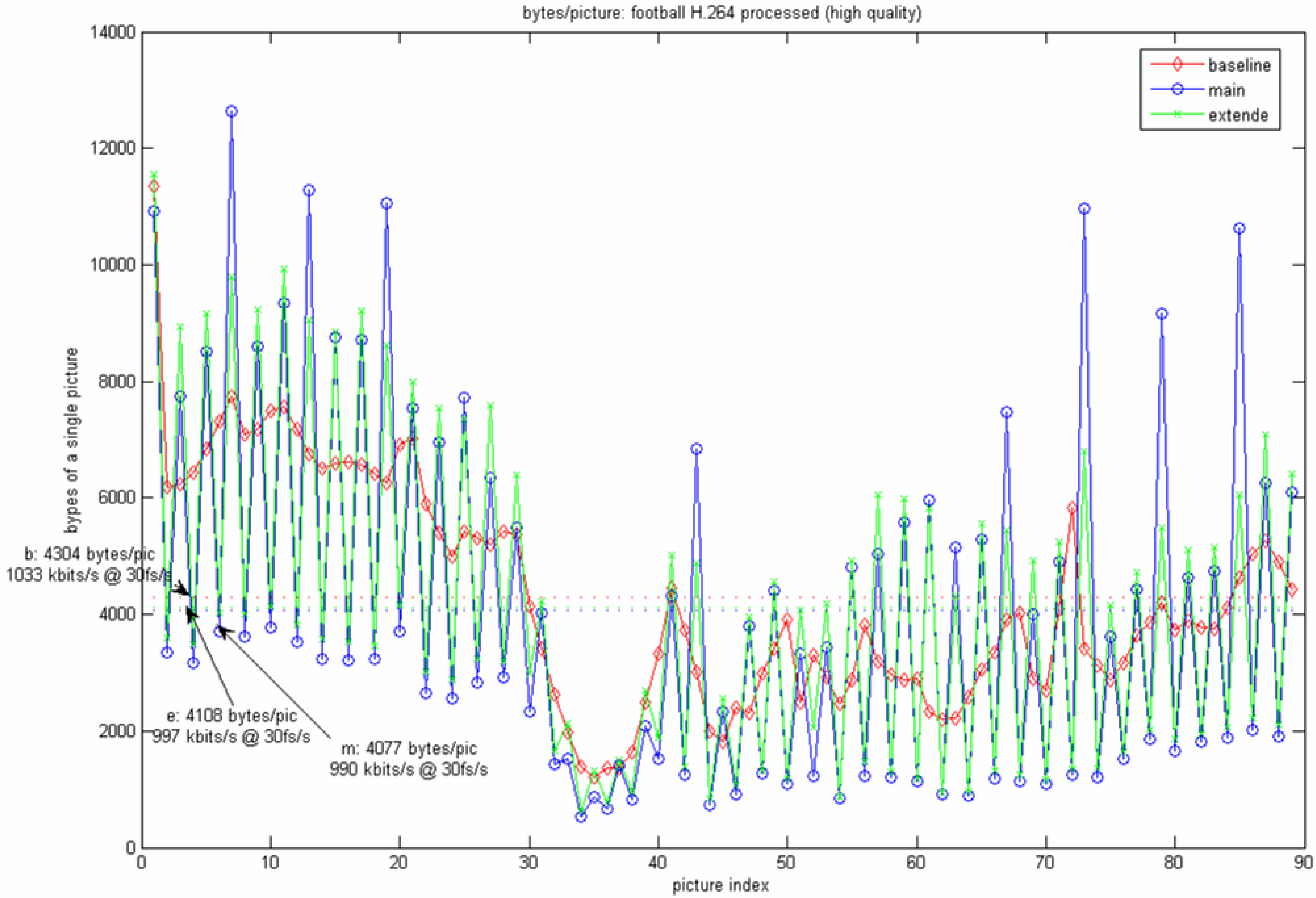
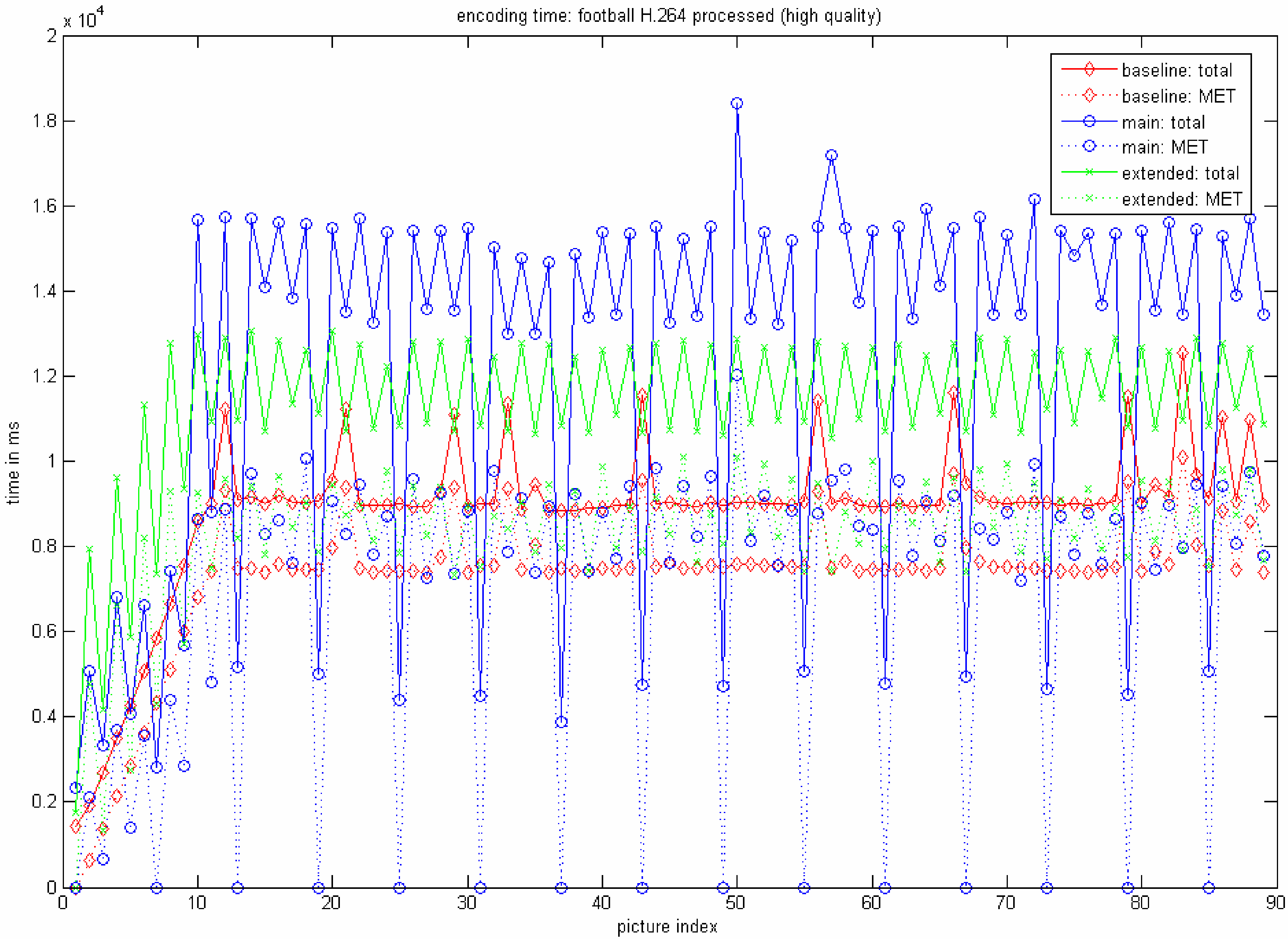
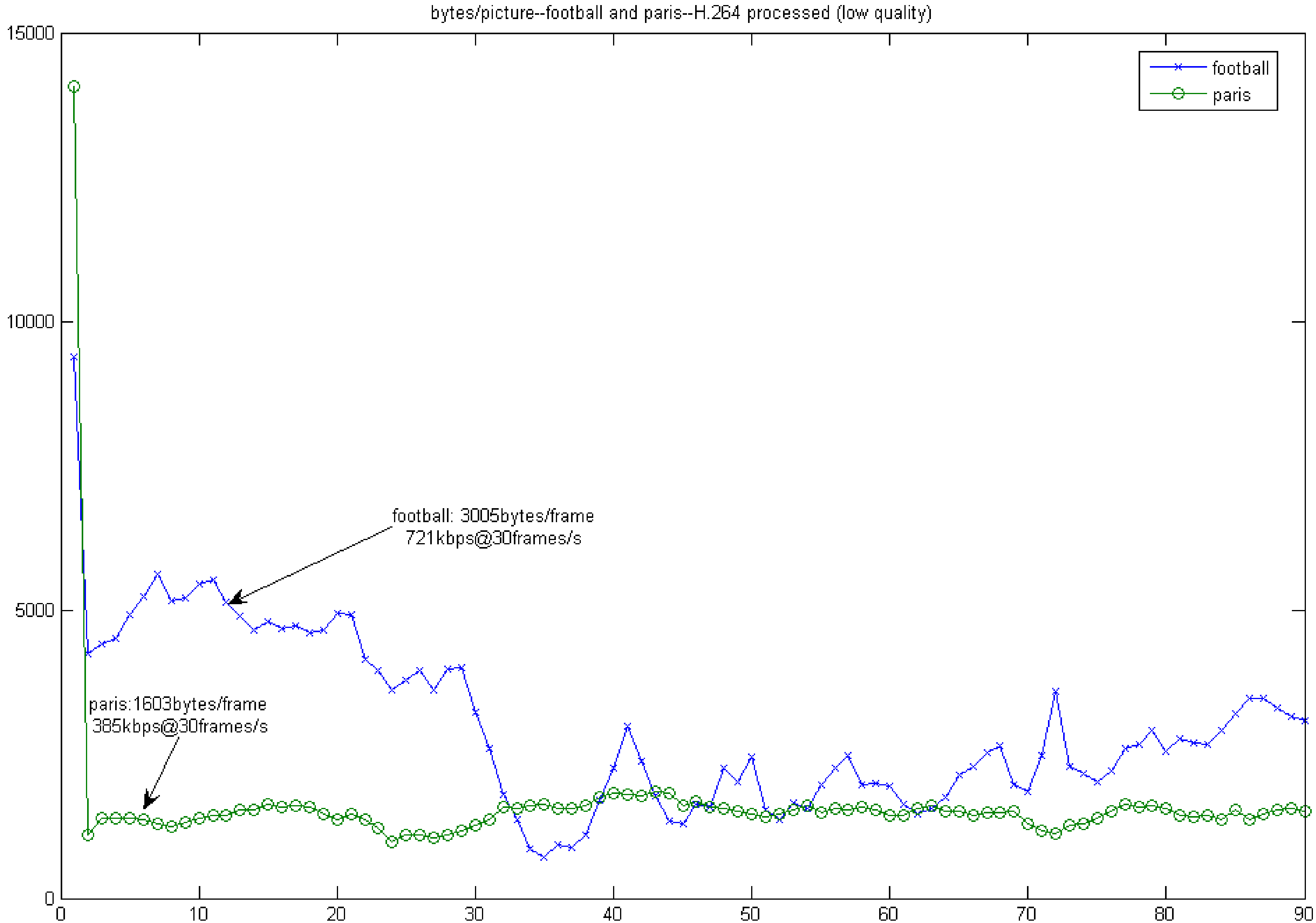

bytes/picture: football H.264 processed (high quality)
baseline
main
extende
bypes of a single picture
picture index
b: 4304 bytes/pic
1033 kbits/s @ 30fs/s
e: 4108 bytes/pic
997 kbits/s @ 30fs/s
m: 4077 bytes/pic
990 kbits/s @ 30fs/s

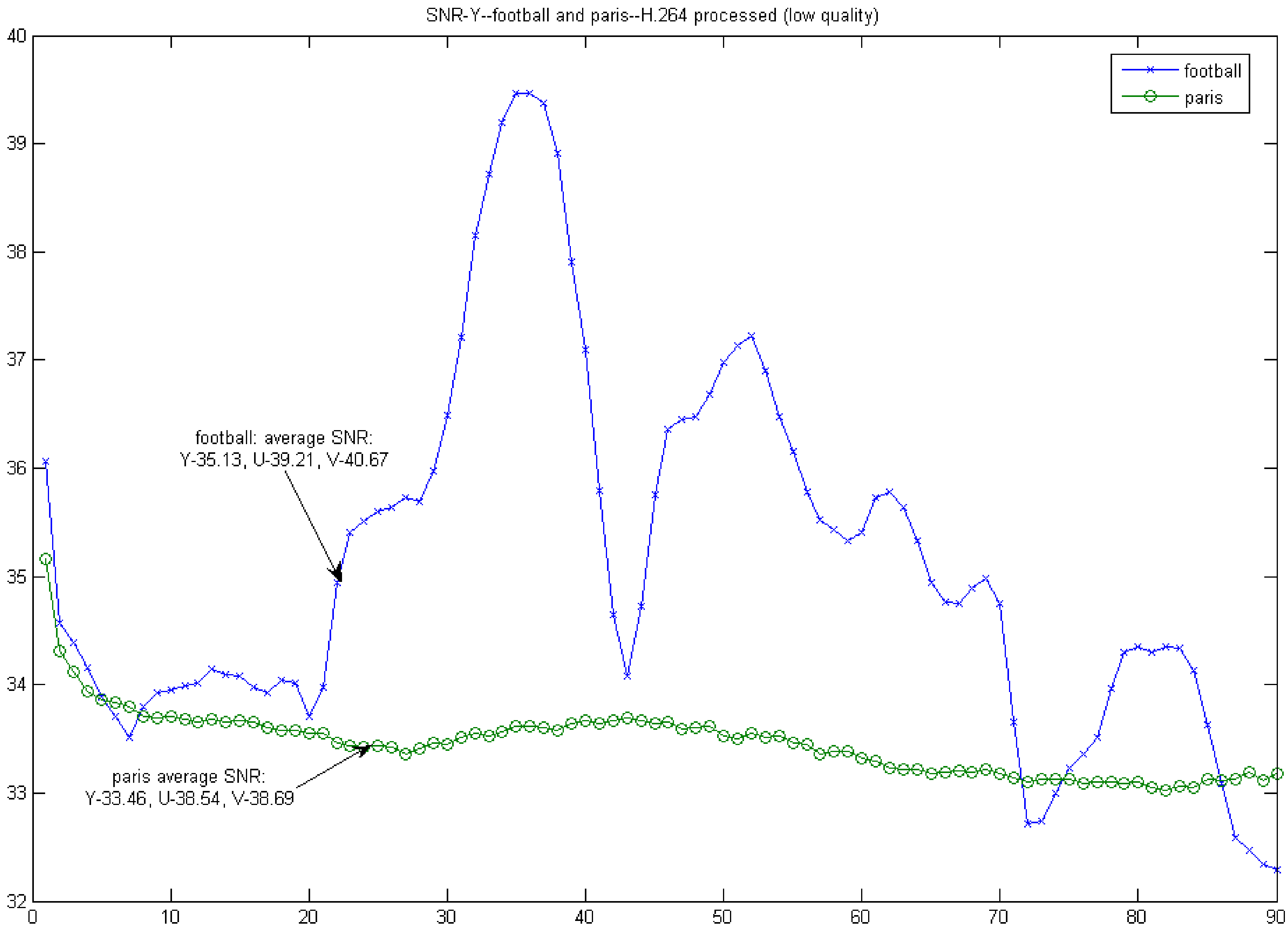
UCSB


encoding time: football H.264 processed (high quality)
x 10^4
time in ms
picture index
baseline: total
baseline: MET
main: total
main: MET
extended: total
extended: MET
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
10
20
30
40
50
60
70
80
90

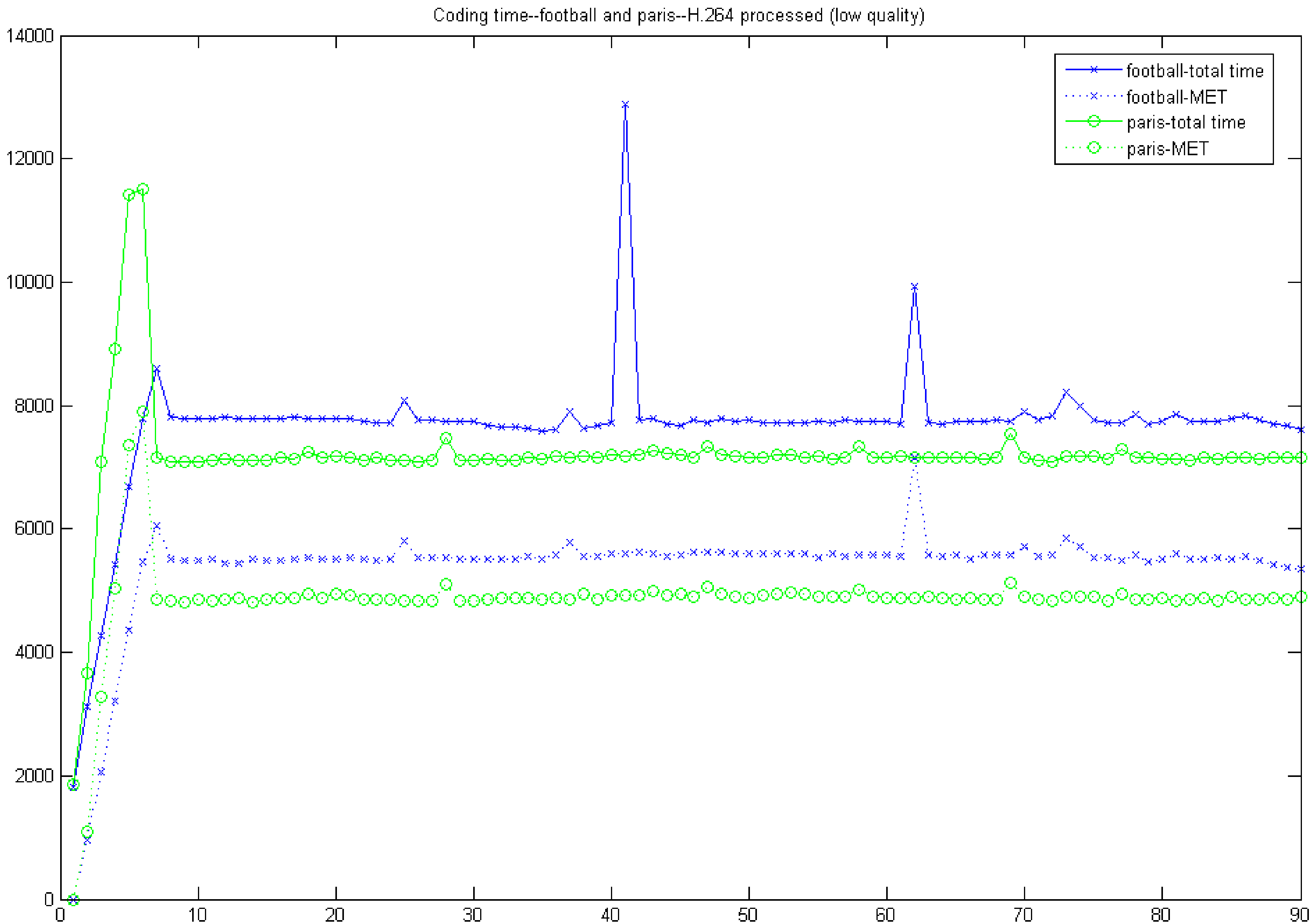
UCSB


bytes/picture--football and paris--H.264 processed (low quality)
football
paris
football: 3005bytes/frame
721kbps@30frames/s
paris:1603bytes/frame
385kbps@30frames/s
15000
10000
5000
0
0
10
20
30
40
50
60
70
80
90

UCSB


SNR-Y--football and paris--H.264 processed (low quality)
football
paris
football: average SNR:
Y-35.13, U-39.21, V-40.67
paris average SNR:
Y-33.46, U-38.54, V-38.69
40
39
38
37
36
35
34
33
32
0
10
20
30
40
50
60
70
80
90

UCSB


Coding time--football and paris--H.264 processed (low quality)
14000
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
80
90
football-total time
football-MET
paris-total time
paris-MET

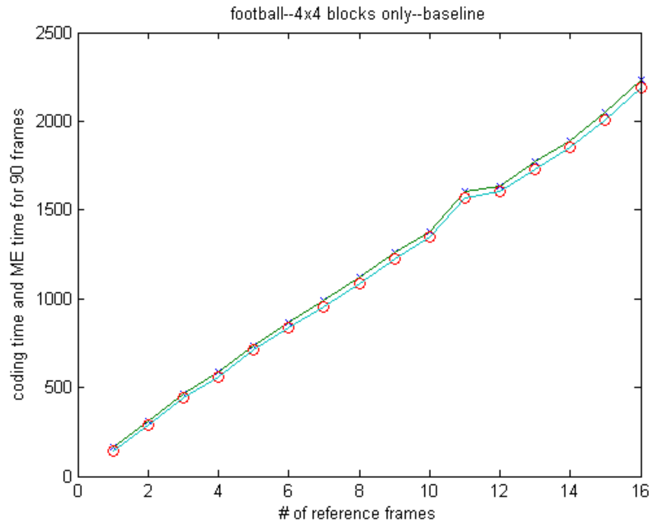
Complexity, Delay & Performance of H.264 codecs

- "*The JVT Advance Video Coding Standard: Complexity and Performance Analysis on a Tool-by-Tool Basis*", S. Saponara, C. Blanch, K. Denolf and J. Bormans, 2003
  - H.264 has a complexity increase of more than one order of magnitude at the encoder and a factor 2 for the decoder than MPEG-4 (Simple Profile)
  - The complexity, delay and performance of H.264 codecs varies largely when different tools are chosen

		MD		FOR1		FOR2		MC	
		Min	Max	Min	Max	Min	Max	Min	Max
	PSNR –Y	36.24	36.77	35.19	36.00	35.77	36.51	37.30	37.90
	Kbps	24.80	33.29	96.14	145.80	276.89	435.45	1305.20	2243.93
Encoder	Peak memory (Mbytes)	2.19	15.60	2.19	15.60	7.31	26.87	7.31	26.87
Encoder	Accesses (10^9/s)	1.40	79.92	1.18	65.78	4.60	258.01	2.75	134.26
Encoder	Relative time	6.48	409.12	5.40	330.87	21.70	1117.48	12.98	567.37
Decoder	Peak memory (Mbytes)	1.06	1.38	1.06	1.38	2.91	4.15	2.91	4.15
Decoder	Accesses (10^6/s)	61.10	104.41	90.16	153.88	385.21	636.90	287.10	492.54
Decoder	Relative time	0.30	0.69	0.58	1.30	3.04	5.51	2.33	4.26

Complexity, Delay & Performance of H.264 codecs

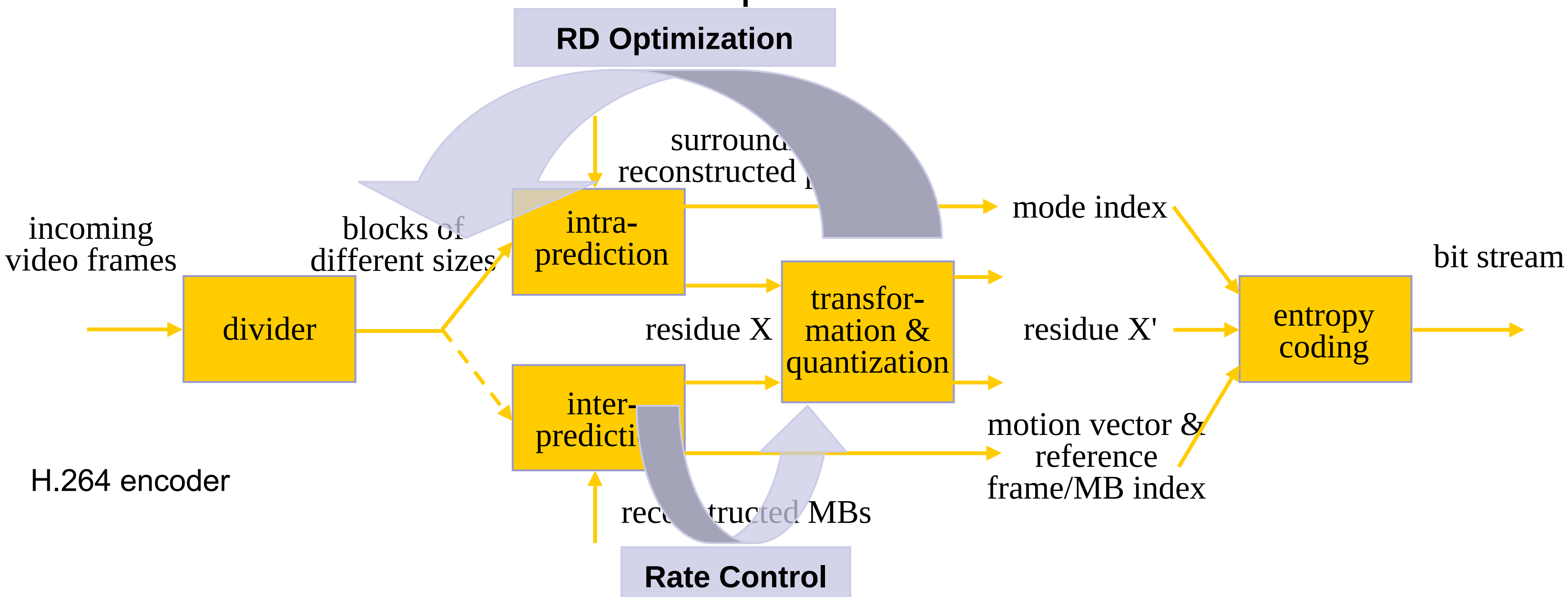
- Contributing to most of encoding delay
  - Motion estimation
    - Around 90% of total computation
  - DCT and IDCT
  - Pixel interpolation
- Contributing to most of decoding delay
  - Deblocking filtering
    - Around 30% of total computation



- How fast can the H.264 codecs in the market perform?
  - Most vendors have recently claimed simultaneous H.264 codecs for CIF videos at 30frames/second
  - Decoding time is on the order of 1% of encoding time.

Research Problems in H.264 (to name a few)

- Rate control and rate distortion optimization



- Fast algorithm and architecture design of low-power motion estimation
- Cross-layer design of video over IP networks
- Perceptual coding in AVC/H.264

What’s next? H.265?

- ITU-T Study Group 16 **Multimedia terminals, systems and applications** - Question 6/16 **Video coding** (Study Period 2005-2008)
- Study Items
  - New coding methods in order to achieve the following objectives:
    - improvements in compression efficiency;
    - robust operation in error/loss-prone environments (e.g. non-guaranteed-bandwidth packet networks or mobile wireless communication);
    - reduction of real-time delay;
    - reduction of channel acquisition time and random access latency;
    - reduction of complexity;
  - Organization of the compressed data format to support packetization and streaming;
  - Methods to allow streams to be easily mixed by MCUs or terminals;
  - Techniques to permit networks or terminals to adjust the bit rate of video streams efficiently;
  - Techniques for object coding and multiview operation;
  - Techniques for efficient compressed-digital to compressed-digital processing (including transcoding).
  - The impact of colorimetry, video quality assessment, and quality control requirements on video codec development.
- Final Rec. H.265: expected 2008-2010.

H.265 – Technology Contenders

- Introduction of Wavelets in video coding
- New ways of distributed source video coding.
- Intelligent decoders & encoder – Computer Vision tools
- Development of new transforms
- New scalability schemes.
- Switch to progressive (no interlaced) only tools.
- Better Data-partitioning and Error-concealment techniques.

References

- Peter Symes, Digital Video Compression, McGraw-Hill, 2003.
- Joan L. Mitchell, MPEG Video Compression Standard, Chapman & Hall : International Thomson, 1996.
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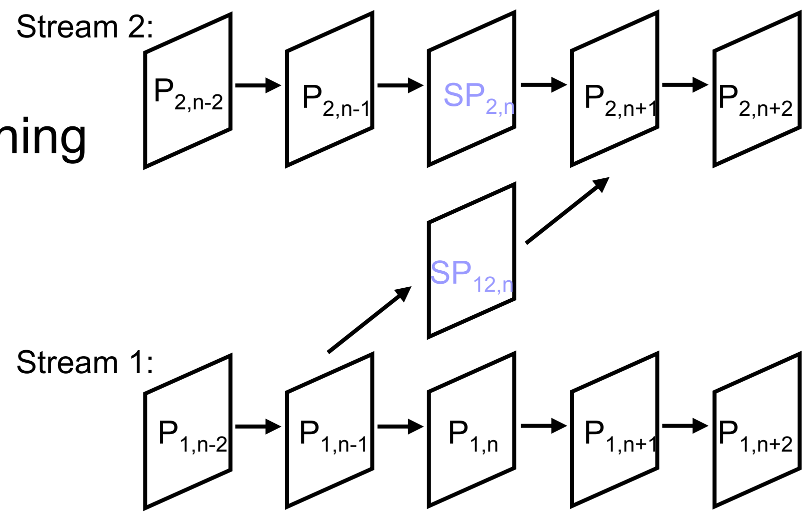
- H.264/MPEG-4 Part 10 White Paper, www.vcodex.com
- IEEE Transactions on Circuits and Systems for Video Technology, Special Issue on the H.264/AVC Video Coding Standard, Vol. 13, No. 7, July 2003.
- B. Yan and K.W. Ng, A Survey on the Techniques for the Transport of MPEG-4 Video Over Wireless Networks, IEEE Transactions on Consumer Electronics, Vol. 48, No. 4, November 2002.
- MPEG Video Compression Technique, http://rnvs.informatik.tu-chemnitz.de/~jan/MPEG/HTML/mpeg_tech.html
- P. Hoyingcharoen and C. Schmidt, Overview of H.264/AVC, Signal Compression Lab, UCSB.

SP and SI-Frame Design

- SP and SI-frames
  - allow identical reconstruction when coded using different references
  - Subtract the reference in the coder and add it back in the decoder
  - Coding efficiency of the SP-frame is worse than that of P-frames but much better than the I-frame
  - Coding efficiency of the SI-frame is worse than that of I-frames
- Bitstream switching
  - In previous coding standards: perfect (mismatch-free) switching only happens at Intra-frames.



- Other applications
  - Bitstream splicing
  - Error recovery/resilience
  - Video redundancy coding

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