

Overview: image and video coding standards

- JPEG
- MPEG-1 and MPEG-2
- H.261 and H.263
- Progress in video compression



JPEG: background

- JPEG = Joint Photographic Experts Group: Joint standards committee of ITU-T and ISO
- Flexible standard for monochrome and color image compression: “Digital Compression and Coding of Continuous-tone Still Images”
- Intraframe coding scheme, optimized for still images
- Flexible picture size
- Coding of color components separately, arbitrary color spaces possible, best compression for Y/R-Y/B-Y
- Variable compression ratio
- Compression 24:1 for ITU-R 601 images without loss of quality

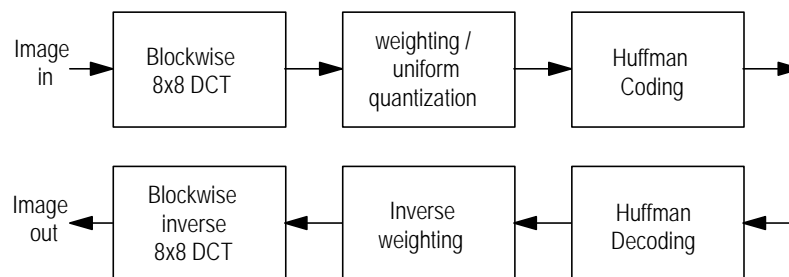


JPEG derived industry standards

- JFIF (JPEG File Interchange Format, <xxxx.jpg>)
- JTIP (JPEG Tiled, Pyramid Format)
- TIFF (Tagged Image File Format)
- SPIFF (Still Picture Interchange File Format, JPEG Part 3)
- FlashPix
 - Developed by Kodak, Hewlett- Packard, Microsoft (1996)
 - Widely used in digital still cameras



JPEG: baseline algorithm



JPEG: quantizer stepsize

- Different weighting matrices are standardized, adapted to human visual contrast sensitivity
- Example: Inverse weighting for ITU-R 601 images

Luminance

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Chrominance

17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99



JPEG: coding of DCT coefficients

- Differential coding of DC coefficient (0,0)
- Zig-zag-scan and run-level-coding of AC coefficients
- Two options for Huffman coding:
 - with predefined code tables (one-pass system)
 - code tables optimized for individual image (two-pass system)

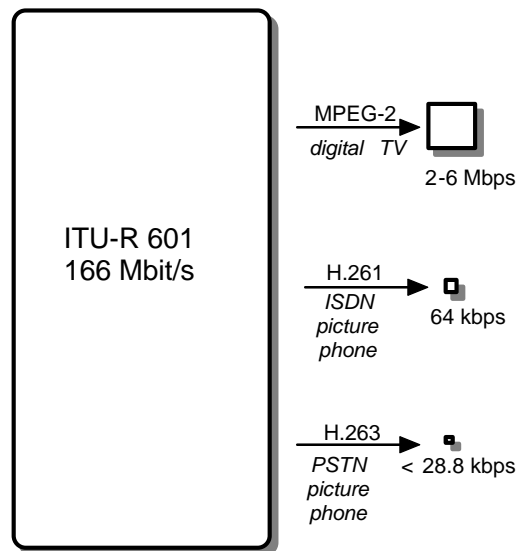


JPEG-2000

- New generation JPEG standard, recently finalized.
- Discrete wavelet transform
- Embedded scalar quantization with deadzone
- Entropy-coding: bit-plane arithmetic coding with „context modeling“
- Typically 30% lower bit-rate than old JPEG at the same image quality



Video coding standards



Generic encoder block diagram for H.261, H.263, and MPEG

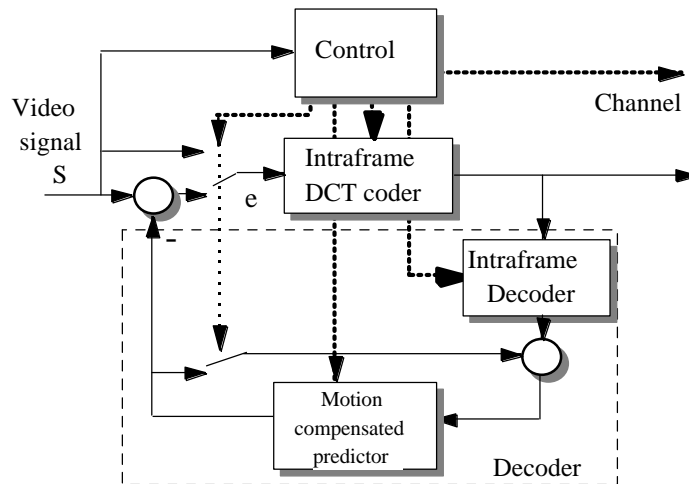
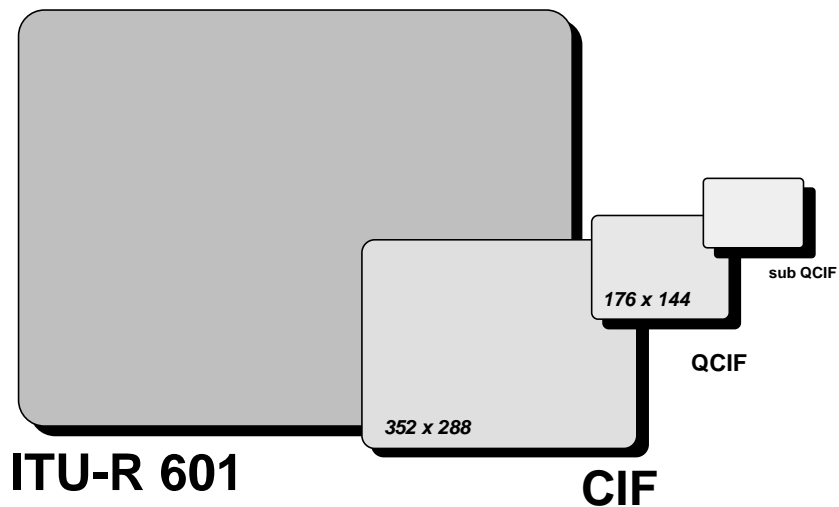


Image formats



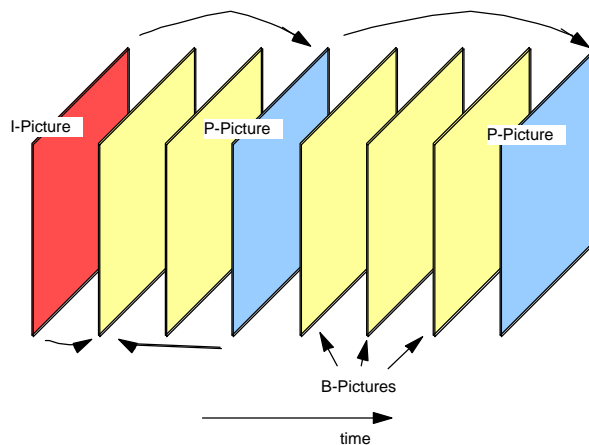
ISO MPEG

- MPEG-1 Standard (1991)
 - Target bit-rate about 1.5 Mbit/s
 - Typical image format CIF, no interlace
 - Frame rate 24 ... 30 fps
 - Main application: video storage for multimedia (e.g., on CD-ROM)
- MPEG-2 Standard (1994)
 - Extension for interlace, optimized for TV resolution (NTSC: 704 x 480 Pixel)
 - Image quality similar to NTSC, PAL, SECAM at 4 - 8 Mbit/s
 - HDTV at 20 Mbit/s



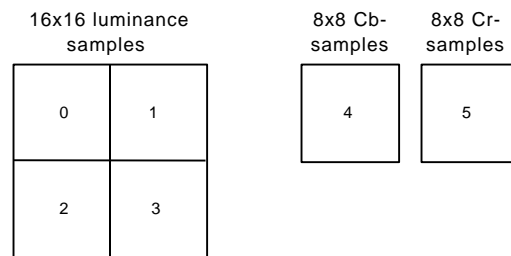
MPEG: hierarchical syntax I

- "Video Sequence"
- "Group of Pictures" = "GOP", GOP structure is very flexible



MPEG: hierarchical syntax II

- "Picture": $N \times M$ luminance samples, $N/2 \times M/2$ Cb- and Cr-samples
- "Slice": Sequence of Macroblocks
- "Macroblock"



- "Block": 8x8 samples



MPEG: coding of I-pictures

- I-pictures: intraframe coded
- 8x8 DCT
- Arbitrary weighting matrix for coefficients
- Differential coding of DC-coefficients
- Uniform quantization
- Zig-zag-scan, run-level-coding
- Entropy coding
- Unfortunately, not quite JPEG



MPEG: coding of P-pictures

- Motion-compensated prediction from an encoded I-picture or P-picture (DPCM)
- Half-pel accuracy of motion compensation, bilinear interpolation
- One displacement vector per macroblock
- Differential coding of displacement vectors
- Coding of prediction error with 8x8-DCT, uniform threshold quantization, zig-zag-scan as in I-pictures



MPEG: coding of B-pictures

- Motion-compensated prediction from two consecutive P- or I-pictures
 - **either**
 - only forward prediction (1 vector/macroblock)
 - **or**
 - only backward prediction (1 vector/macroblock)
 - **or**
 - Average of forward and backward prediction = interpolation (2 vectors/macroblock)
- Half-pel accuracy of motion compensation, bilinear interpolation
- Coding of prediction error with 8x8-DCT, uniform quantization, zig-zag-scan as in I-pictures



ITU-T Rec. H.261

- International standard for ISDN picture phones and for video conferencing systems (1990)
- Image format: CIF (352 x 288 Y samples) or QCIF (176 * 144 Y samples), frame rate 7.5 ... 30 fps
- Bit-rate: multiple of 64 kbps (= ISDN-channel), typically 128 kbps including audio.
- Picture quality: for 128 kbps acceptable with limited motion in the scene
- Stand-alone videoconferencing system or desk-top videoconferencing system, integrated with PC



ITU-T Rec. H.263

- International standard for picture phones over analog subscriber lines (1995)
- Image format usually CIF, QCIF or Sub-QCIF, frame rate usually below 10 fps
- Bit-rate: arbitrary, typically 20 kbps for PSTN
- Picture quality: with new options as good as H.261 (at half rate)
- Software-only PC video phone or TV set-top box
- Widely used as compression engine for Internet video streaming
- H.263 is also the compression core of the MPEG-4 standard

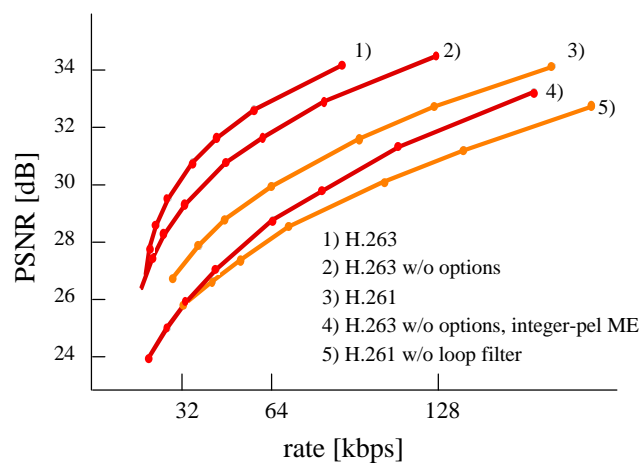


Motion compensation H.261 vs H.263

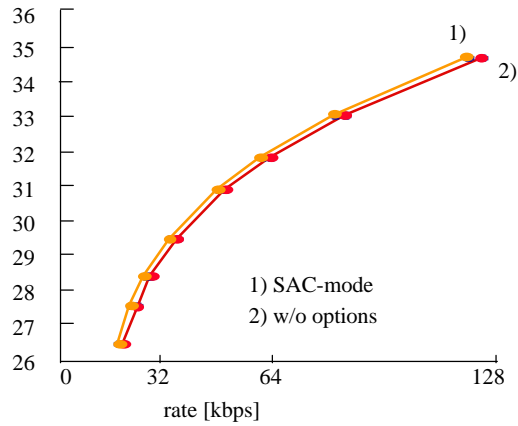
- H.261 (1990): integer-pel accuracy, loop filter, 1 motion vector per MB
- H.263 (1995): half-pel accuracy, no loop filter, 1 motion vector per MB
- H.263 option „Advanced Prediction Mode“
 - overlapped block motion compensation (OBMC),
 - switch between 1 or 4 motion vectors per MB
- H.263 option „PB frames“



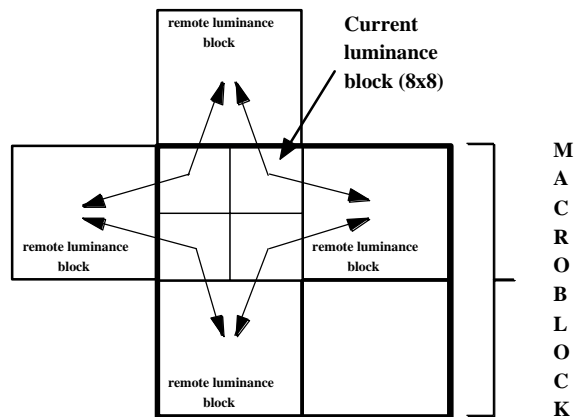
Performance of H.263 and H.261



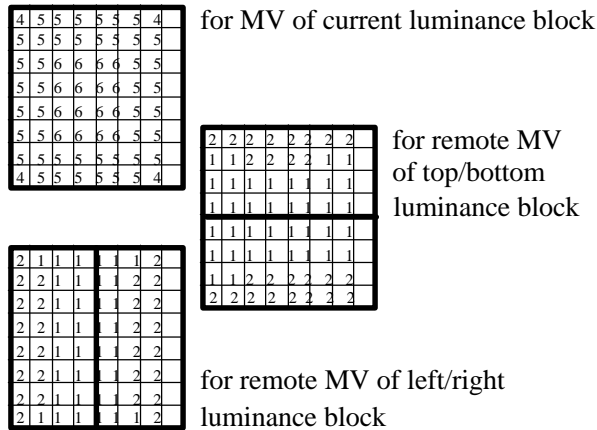
Performance of H.263 SAC mode



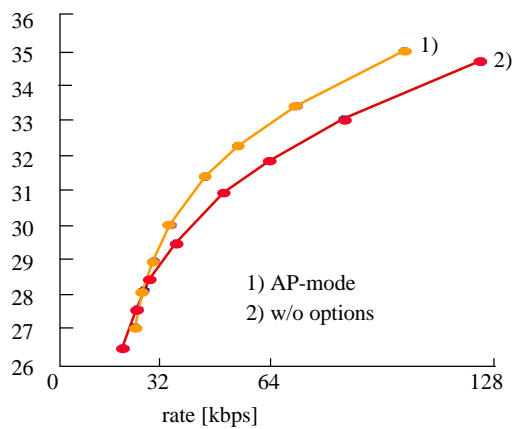
H.263: overlapped block motion compensation (OBMC)



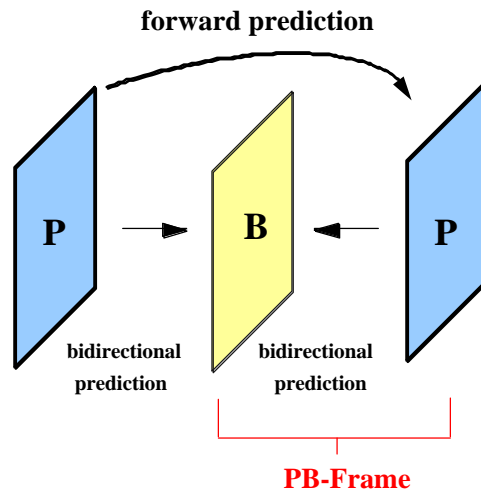
H.263: OBMC weights



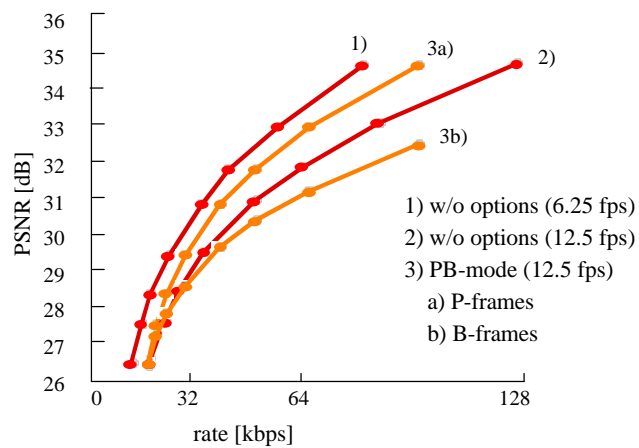
Performance of H.263 AP mode



H.263: PB-frames



Performance of H.263 PB-mode



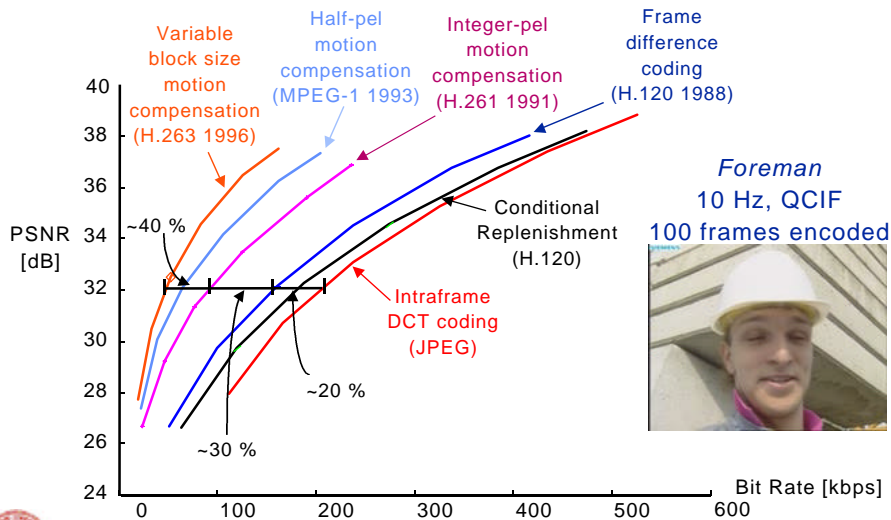
Video compression progress

- *Intraframe coding*: only spatial correlation exploited
 → DCT [Ahmed, Natarajan, Rao 1974], JPEG [1992]
- *Conditional replenishment, DPCM, scalar quantization*
 → H.120 [1984]
- *Frame difference coding*
 → H.120 Version 2 [1988]
- *Motion compensation: integer-pel accurate displacements*
 → H.261 [1991]
- *Half-pel accurate motion compensation*
 → MPEG-1 [1993], MPEG-2/H.262 [1994]
- *Variable block-size motion compensation*
 → H.263 [1996], MPEG-4 [1999]

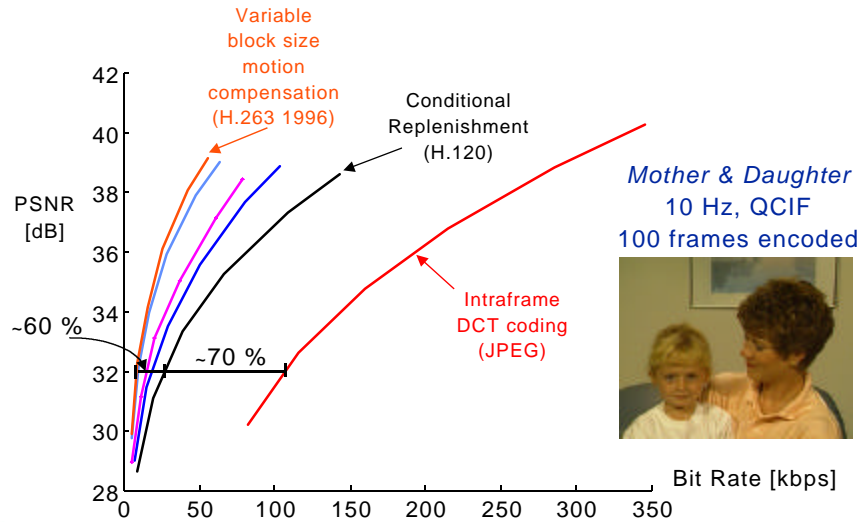
Complexity increases



Video compression progress



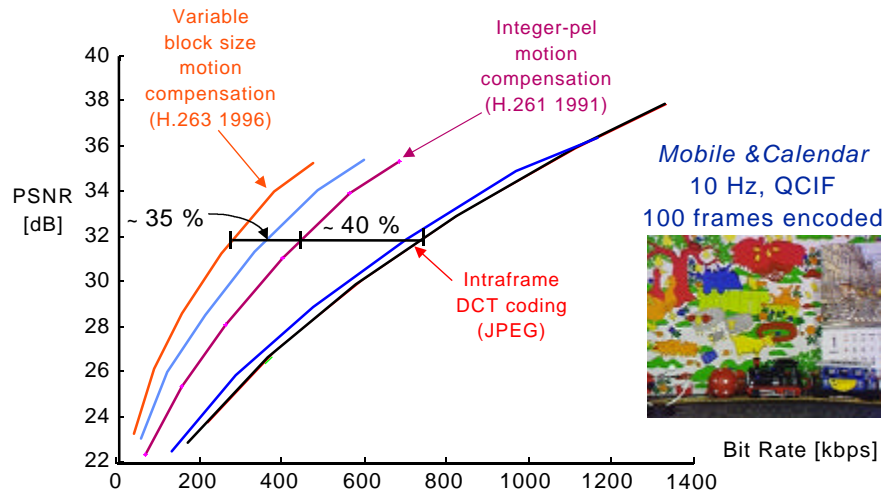
Video compression progress



Bernd Girod: EE368b Image and Video Compression

Coding Standards no. 29

Video compression progress



Bernd Girod: EE368b Image and Video Compression

Coding Standards no. 30