

2. Review of Video Coding Standards

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Outline

- JPEG, H.261, MPEG-1, MPEG-2, H.262, H.263, H.263+, MPEG-4, MPEG-7, H.264
- Trends in video coding standards
- Is video compression dead?
- Trends of video compression technologies

Video Coding Standards

- Every standard was developed with an initial driving-application which may be different from the current driving applications
- The requirements from the driving-applications determined how the standard was developed
- Current driving applications determine how the standards will evolve
- The application ultimately determines if the standard will be successful
- ITU-T vs. ISO

Video Compression Standards Evolution

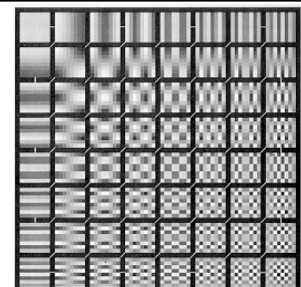
- JPEG (mid 80's)
- H.261 (mid 80's, ~2x improvement compared to JPEG)
- MPEG-1 (late 80's)
- MPEG-2/H.262 (late 80's to early 90's, ~2x improvement compared to H.261)
- H.263 (early to mid 90's)
- MPEG-4 ASP (mid to late 90's, ~1.5x improvement compared to MPEG-2)
- MPEG-4 AVC/H.264 (00's, ~3x improvement compared to MPEG-2)

JPEG

- Driving application: image compression for storage
- Technology: Integration of existing techniques
Discrete Cosine Transform (DCT) and Entropy coding

Discrete Cosine Transform (DCT)

8x8 DCT
Basis Functions



Entropy Coding

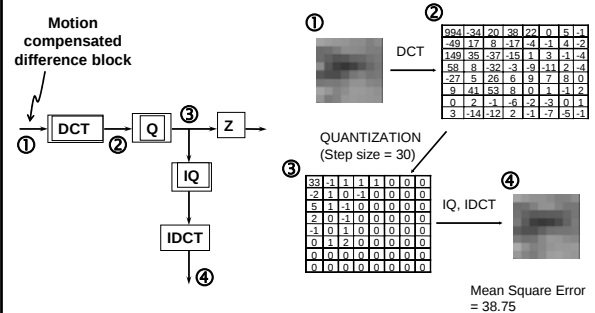
Run-length Coding:

Input sequence:
0,0,-3,5,1,0,-2,0,0,0,2,
-4,3,-2,0,0,0,1,0,0,-2

Run-length sequence:
(2,-3)(0,5)(0,1)(1,-2)(4,2)
(0,-4)(0,3)(0,-2)(3,1)(2,-2)

Symbol s_i	p_i	l_i	Codeword
0	0.28200	2	11
1	0.27860	2	10
2	0.14190	3	011
3	0.13890	3	010
4	0.05140	4	0011
5	0.05130	4	0010
6	0.01530	5	00011
7	0.01530	5	00010
8	0.00720	6	000011
9	0.00680	6	000010
10	0.00380	7	0000011
11	0.00320	7	0000010
12	0.00190	7	0000001
13	0.00130	8	00000001
14	0.00070	9	000000001
15	0.00040	9	000000000

JPEG: DCT + Quantization + Entropy Coding

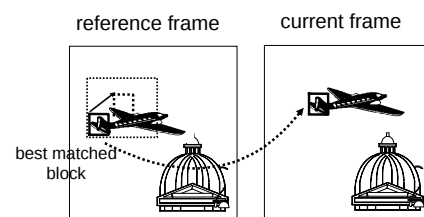


H.261

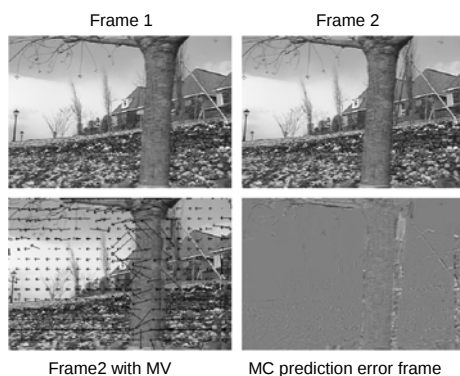
- Initial driving application: ISDN videoconferencing
- New technology used:
Motion compensated predictive coding

H.261

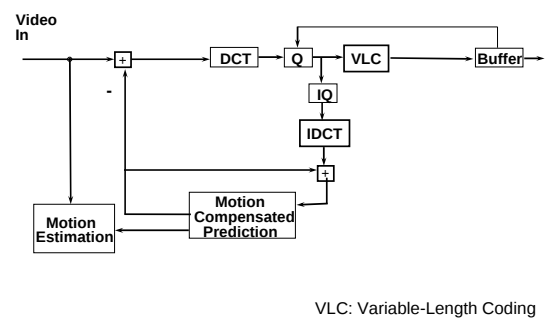
JPEG + Motion Compensated Predictive Coding (MCPC)



Motion Compensated Predictive Coding



H.261 Video Codec

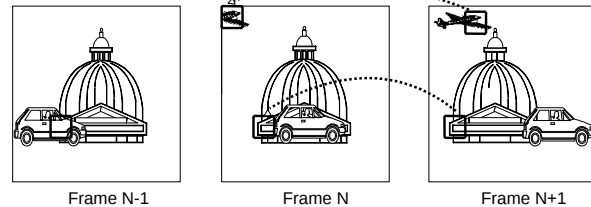


MPEG-1

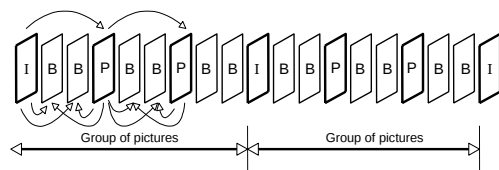
- Initial driving application: Video CD
- New concepts:
Bi-directional motion estimation with half-pixel accuracy

MPEG-1

H.261 + Half-pixel bi-directional MCPC



Group of Picture



I = **Intra-Picture** Coding, allow random access, for reference
P = **Predictive** coding, causal prediction only, can be referenced
B = **Bi-directional** coding, noncausal prediction, never referenced

MPEG-2

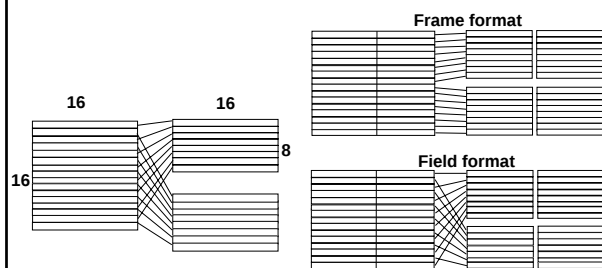
- Initial driving application: Video-On-Demand over HFC (Hybrid Fiber Coaxial) networks
- Main new concepts:
 - * Frame-field adaptive DCT and Motion Estimation
 - * Profiles and Levels
 - * Scalable coding
- The most successful video standard for high quality applications (DVD, Digital TV, HDTV, ...)
- Not suitable for low-bit-rate applications due to the overheads

Profiles and Levels

Level	Profile				
	Simple	Main	SNR Scalable	Spatially Scalable	High
High 1920x1152 (60 frames/s)		62.7 Ms/s 80 Mbit/s			100 Mbit/s for 3 layers
High-1440 1440x1152 (60 frames/s)		47 Ms/s 60 Mbit/s		47 Ms/s 60 Mbit/s for 3 layers	80 Mbit/s for 3 layers
Main 720x576 (30 frames/s)	10.4 Ms/s 15 Mbit/s	10.4 Ms/s 15 Mbit/s	10.4 Ms/s 15 Mbit/s for 2 layers		20 Mbit/s for 3 layers
Low 352x288 (30 frames/s)		3.04 Ms/s 4 Mbit/s	3.04 Ms/s 4 Mbit/s for 2 layers		

* numbers in the table are maximum allowed

Frame/Field Adaptive Coding



H.263

- Initial driving application: Videophone / Wireless video
- New technologies: 4 optional modes
- Suitable for low-bit-rate applications due to the optimized overheads
- Current driving applications: Internet / Wireless Video

Four Negotiable Options

- Annex D: Unrestricted Motion Vector
Motion vectors can point outside the picture, maximum range for motion vectors: -31,5 to 31.5 instead of -16 to 15.5 (useful in case of higher resolution format and movement along the edge of the picture and camera movement)
- Annex F: Advanced Prediction Mode
8x8 motion vectors, overlapped block motion compensation (OBMC), motion vector can point outside the picture
- Annex E: Syntax-based Arithmetic coding
About 5% decrease in bit-rate
- Annex G: PB-frame mode

H.263+ / H.263 Version 2

- Annex D: New Unrestricted Motion Vector Mode (use RVLC, motion vector range up to +/- 256)
 - Annex I: Advanced Intra Coding Mode
 - Annex J: Deblocking Filter Mode
 - Annex L: Supplemental enhancement information specification
 - Annex M: Improved PB-Frame Mode
 - Annex O: Temporal, Spatial, and SNR Scalability Mode
 - Annex P: Reference Picture Resampling Mode
 - Annex Q: Reduced Resolution Update Mode
 - Annex S: Alternative Inter VLC Mode
 - Annex T: Modified Quantization Mode
- Error resilience:
- Annex K: Slice Structured Mode
 - Annex R: Independent Segment Decoding Mode
 - Annex N: Reference Picture Selection Mode

MPEG-4

- Initial driving application:
 1. Next generation video coding for very low bit-rate video
 2. Object based manipulation
 - New concepts: Object-based coding
- Current driving application:

MPEG-4 attempts to become *THE* standard for streaming AV media on the Internet and via wireless networks

 - Error-resilience features, Optimized for low-bit-rate applications, Fine granular scalability coding
 - MPEG-4 File Format defines first standard for streaming AV media on the Internet

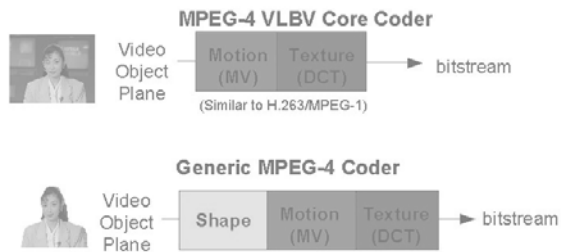
MPEG-4 Video Object Plane (VOP)



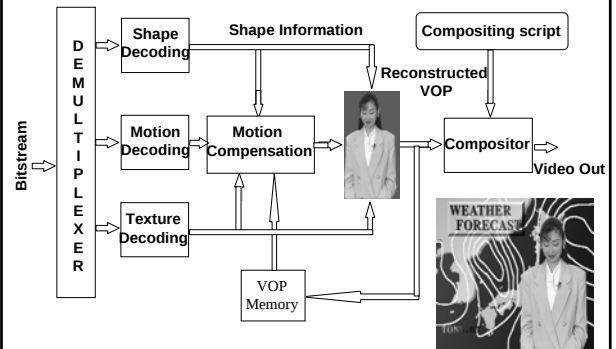
Synthetic and Natural Hybrid Coding (SNHC)



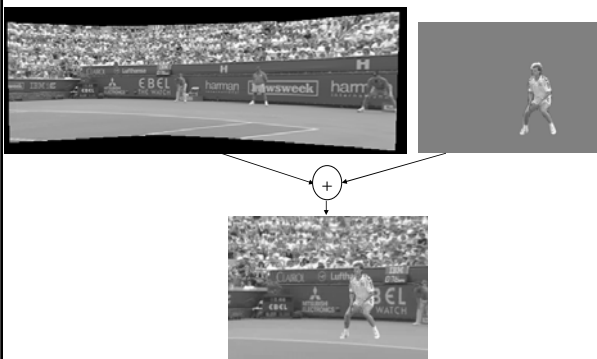
MPEG-4 Texture and Shape Coding



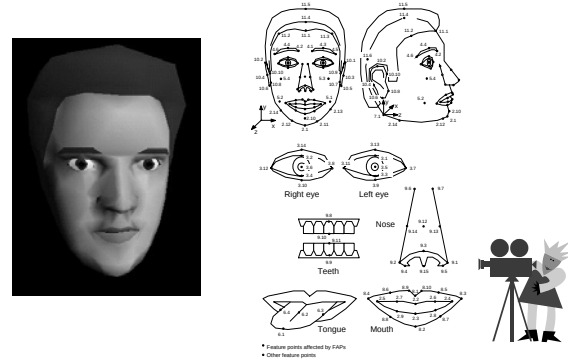
MPEG-4 VOP Decoder



Sprite Coding

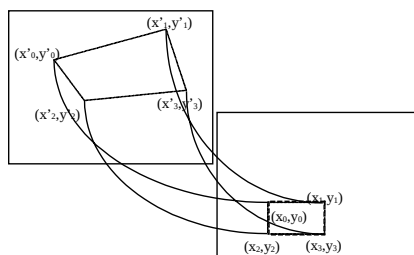


MPEG-4 Visual Face Animation

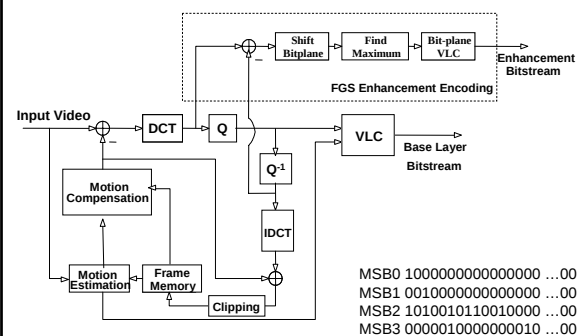


MPEG-4 ASP (Advanced Simple Profile)

Previous techniques + $\frac{1}{4}$ -pixel ME + Global ME

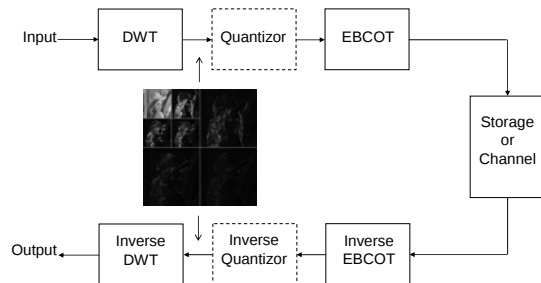


MPEG-4 FGS (Fine Granularity Scalability)



JPEG-2000 vs. JPEG (1/2)

JPEG-2000: Discrete Wavelet Transform (DWT) + Embedded Block Coding with Optimum Truncation (EBCOT)



JPEG-2000 vs. JPEG (1/3)



0.125bpp, JPEG

0.125bpp, JPEG-2000

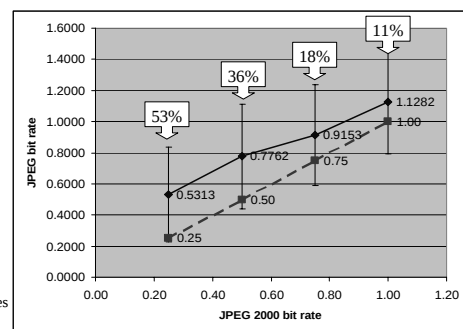
JPEG-2000 vs. JPEG (2/3)



0.25bpp, JPEG

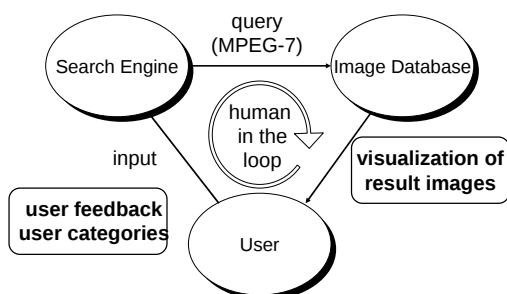
0.25bpp, JPEG-2000

JPEG-2000 vs. JPEG (3/3)



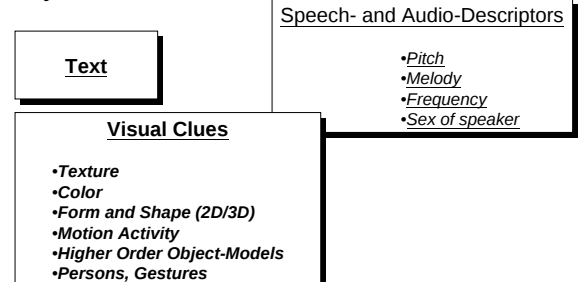
MPEG-7: Multimedia Content Description Interface

To define standardized solutions that allow users or agents to **Search, Browse, Filter** audiovisual content.

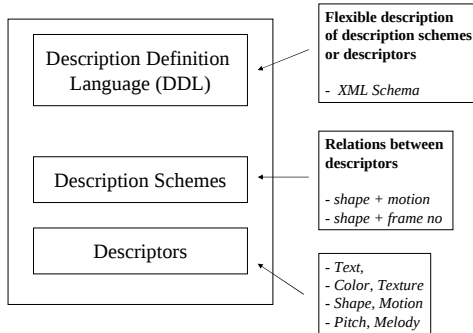


MPEG-7: Description of Multimedia Information

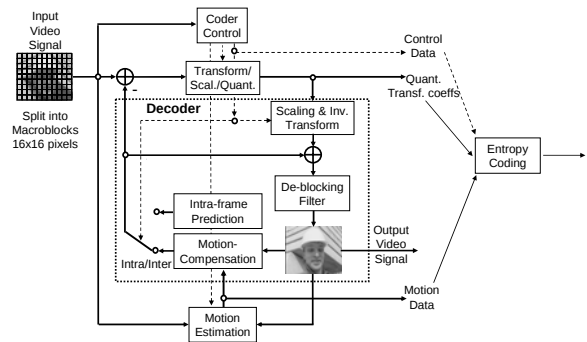
How can "Non-Text-Information" be described in a useful way?



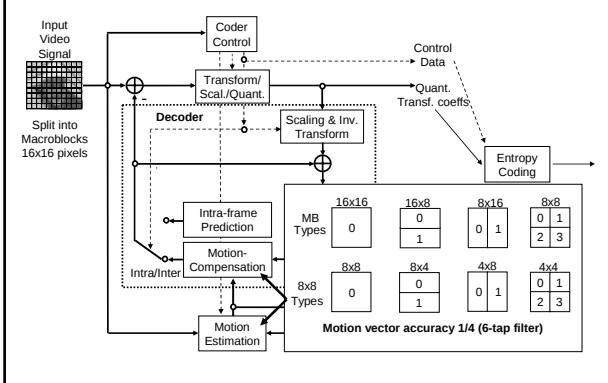
What MPEG-7 Standardize?



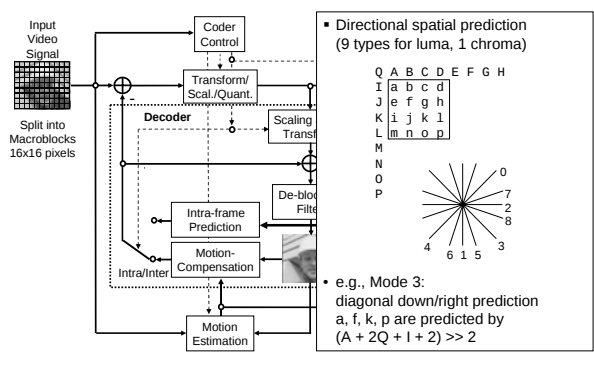
MPEG-4 AVC/H.264: Encoder Architecture



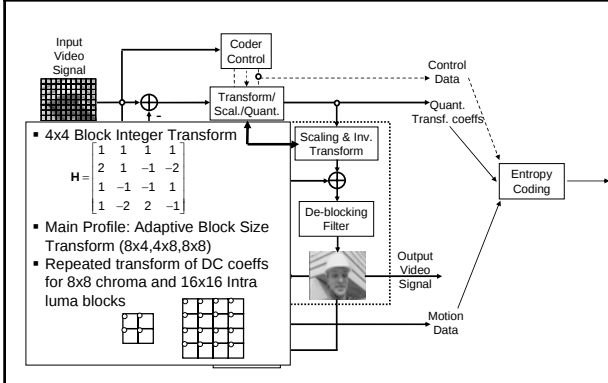
MPEG-4 AVC/H.264: Motion Compensation



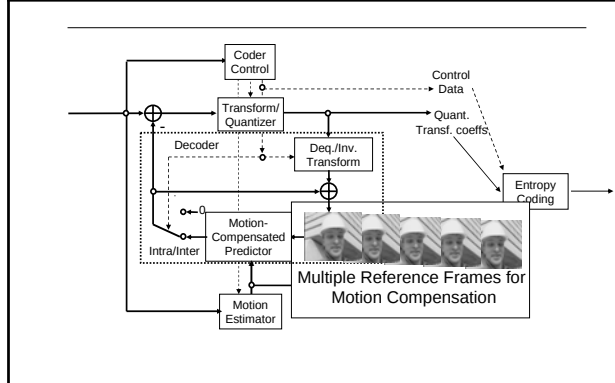
MPEG-4 AVC/H.264: Intra Prediction



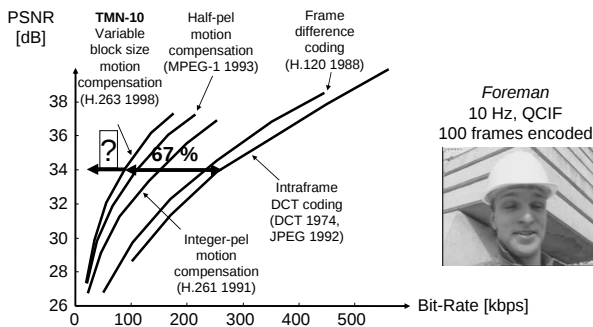
MPEG-4 AVC/H.264: Transform Coding



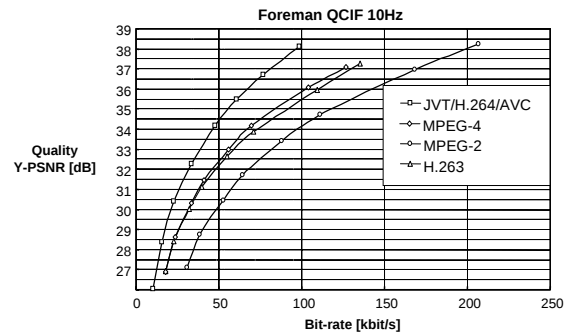
MPEG-4 AVC/H.264: Multiple Reference Frames



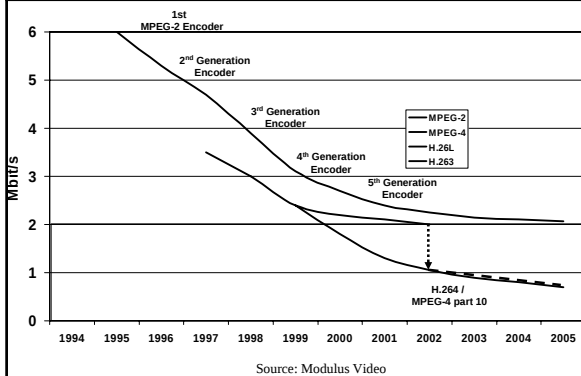
Coding Efficiency Comparison (1/3)



Coding Efficiency Comparison (2/3)



Coding Efficiency Comparison (3/3)



How were the Improvements Obtained

- It mainly comes from incremental improvements:
 - Better prediction
 - More computation
 - More memory
- No fundamental changes in the basic algorithm (DCT + MCPC)

Is Compression Dead? (1/2)

NO!!!

- Contrary to many people's thought that the compression has saturated, we actually have steady improvements over the last decade.
- Bandwidth is never sufficient: millions people may use streaming video, wireless video, games, HDTV, digital TV, 3-D TV, virtual reality, enhanced reality (needs multiple views), ...
- Every time you increase the bandwidth, people will always figure out innovative ways to fill up the bandwidth.

Is Compression Dead? (2/2)

- New applications need new compression algorithms for optimal performance
- Always need better quality
- As long as there are needs, people will eventually figure out better ways to do it
- Hardware and technology improvements will relax the constraints

What Aspects Can We Explore to Get Better Compression?

- Better prediction
- More memory
- More computation
- More content-aware
- More adaptive processing
- More delay
- Utilize human perception characteristics
- ...

Performance evaluation by PSNR?

What Else Besides Compression? (1/2)

- Networking (wired and wireless):
Scalable coding, Multiple description coding, Transcoding, Statistical multiplexing, Error-resilience coding, Error-concealment, Pre/post processing, Dynamic rate-control, Content-aware delivery, Joint source channel coding, Peer-to-peer streaming, Wireless games, ...

What Else Besides Compression? (2/2)

- Asynchronous applications may see more early success: needs authoring, retrieval, and content filtering tools
- Security: advanced video surveillance, face recognition, ...
- Content protection: IP Protection, encryption, watermarking, ...
- Implementation: for low-cost low-power high-performance devices, media processors