Multimedia Video Coding & Architectures (5LSE0), Module 10

MPEG-1/2 Standards: Motion-compensated video coding

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Part 1

MPEG Motion Compensation and Video Coding

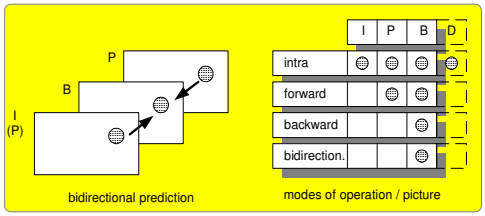
MPEG Video / Temporal Prediction – (1)

Temporal redundancy reduction

* **1. By single-sided prediction**
  - motion compensation should cover large area
  - (due to intermediate B pictures)
  - fallback coding required (for excessive motion or uncovered background)
* **2. Bidirectional motion compensation (interpolation)**
  - assume linear interpolation of surrounding pictures
  - bidirectional prediction is more efficient than single-sided
  - more possibilities with uncovered objects
  - not used as reference for further coding: no error propagation in temporal coding

MPEG Video / Temporal Prediction – (2)

Table of coding modes



MPEG Video / Quantizer inter block – (1)

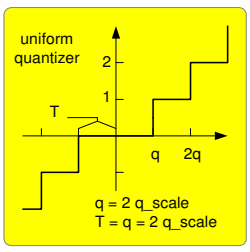
MPEG Quantization interframe data (predictive MBs)

* **DC coefficients**
  - Differential DC coefficients
  - Quantized and coded as AC coefficients
* **AC coefficients**
  - MPEG-1 decoder fomula
  - $F(u,v) = 2\ (QF(u,v)+k)\ q\_scale\ W(u,v)\ /\ 16$
  - $W(u,v) = 16$ default, but new matrix can be loaded
  - $k = sign(QF(u,v))$ for inter-blocks
  - Mismatch control: if $F(u,v)$ even => $F(u,v)=F(u,v)-sign(F(u,v))$ value closest to zero

MPEG Video/ Quantizer inter-blocks – (2)

MPEG Quantization interframe data (predictive MBs)

* AC coefficients (cont.) for MPEG-2
  - MPEG-2 is more precise with normalization factor 32
  - MPEG-2 special mismatch control
  - Quantizer is uniform, but larger dead zone



MPEG Video / Coding modes P&B – (1)

MPEG-1/2 coding modes for inter-coded images (P, B)

Predictive (P)	Bidirectional (B)
Motion, no motion	Forward, from past, Backward, from future, interpolated (from both sides)
Intra (fallback), or non-intra (regular case)	Intra (fallback), or non-intra (regular case)
Coded (regular), or not-coded (skipped block)	Coded (regular), or not-coded (skipped)
Default quantization, new q-scale	Default quantization, new q-scale

MPEG Video / Coding modes P&B – (2)

MPEG-2 extensions for compensated coding modes

- **Frame-based prediction (in both standards)**
  - Equal to MPEG-1 (16x16 compensation blocks)
  - In a frame picture, either frame- or field-based prediction on MB level
- **Field-based prediction (MPEG-2)**
  - Results from interlaced pictures
- **16x8 motion compensation (MPEG-2)**
  - Requires two motion vectors (1 for top- and 1 for bottom field)
  - In B interlaced pictures, even 4 vectors can be used

MPEG Video / Modes for P&B MBs – (3)

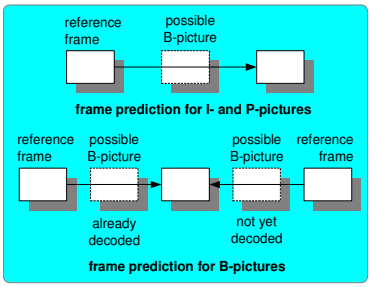
MPEG-2 extensions for compensated coding modes

- **Special: Dual-prime prediction**
  - 1 Motion Vector is coded in full resolution, 1 motion vector is a small differential vector (the dmv)
  - **Field-based prediction**: 2 vectors are derived from this information. The obtained fields are averaged to get the final prediction
  - **Frame-based pictures**: the averaging is done for both fields, yielding 4 field predictions.
  - This mode is only used for P-pictures, without B-pictures in between.

MPEG Video / Modes for P&B MBs – (4)

MPEG-2 extensions for compensated coding modes

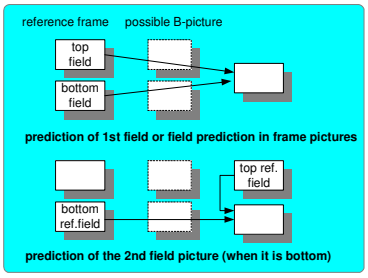
- **Frame-based prediction**
  - 1 mv for P
  - 2 mv for B



MPEG Video / Modes for P&B MBs – (5)

MPEG-2 extensions for compensated coding modes

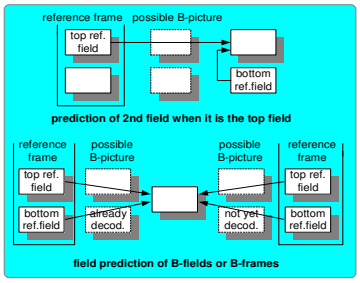
- **Field-based prediction**
  - 2 mv for field to frame for P
  - 2 mv for field to field **for full interlacing P**



MPEG Video / Modes for P&B MBs – (6)

MPEG-2 extensions for compensated coding modes

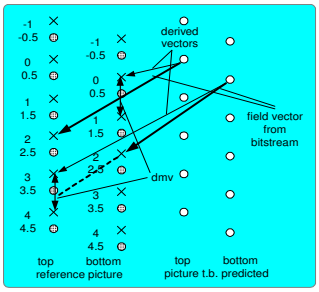
- **Field-based prediction (continued)**
  - 2 mv for P
  - 4 mv for B



MPEG Video / Modes for P&B MBs – (7)

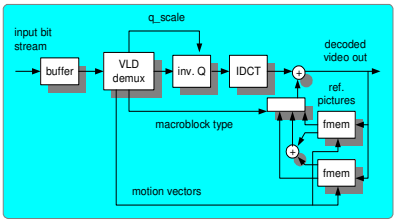
MPEG-2 extensions for MC-coding

* **Special field-based prediction: dual prime**
  - Main and dmv vector
  - Scaling of vectors for dual prime prediction



MPEG Video / Decoder structure

* **MPEG-2 Video decoder hardware**
  - MPEG strongly asymmetric, follows encoder decisions
  - Decoder has no ME, only MC, saves factor 3-4 in complexity



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Part 2

MPEG Flexibility and Programmability

MPEG Video / Flexibility parameters

MPEG Video: Flexibility w.r.t. system parameters

* **Video sequence parameters in sequence header**
  - Pixels/line, lines per picture
  - Pixel aspect ratio
  - Frame rate, bit rate
  - Required buffer size
* **Conclusion MPEG-1**
  - MPEG allows for a wide range of input formats
  - However, MPEG-1 is tuned to be optimal for 1.5 Mbit/s bit rate, spatial resolutions of approx. 350x250 pixels, picture rate of 20-30 frame/s, and non-interlaced pictures

MPEG Video / MPEG-1 core param'ts

* **MPEG Video core parameters, purpose**
  - guaranteed exchange of MPEG-coded data, which should be decodable on different systems
  - also important: bounding of encoder complexity
* **MPEG-1 Core parameters**
  - Pixels/line <= 720
  - Lines/frame <= 576
  - Frame rate <= 30 Hz
  - Macroblock/picture <= 396
  - Macroblock rate <= 396 x 25 Hz = 330 x 30 Hz = 9,900 Hz
  - Bit rate <= 1.86 Mbit/s
  - Buffer <= 376,832 bits

MPEG Video / Flexibility Layer Level

* **GOP**
  - Frame structure I,B,P, and GOP size
* **Frame types**
  - Intraframe I, predictive P, bidirectional B
* **Slice**
  - Slice size, fixed/adaptive partitioning, quantization block/size
* **Macroblock coding**
  - Coded/skipped, motion/ no motion, intra or predicted
* **Macroblock quantizaton**
  - Adaptive or default, weighting function default or adaptive
* **Motion vectors**
  - One-sided, two-sided, motion estimation algorithm

MPEG Video / MPEG-2 Flexibility – (1)

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- **MPEG-2 extensions on flexibility**
  - MPEG-2 should give a more generic set of tools for a wider range of applications
- **MPEG-2 Picture formats**
  - Color formats 4:2:0, 4:2:2, 4:4:4
  - Progressive, interlaced
  - More flexible frame size, more flexible pixel aspect ratio
- **MPEG-2 Bit rates**
  - „Composite" quality CCIR-601 at 3-5 Mbit/s
  - Component quality CCIR-601 at 8-10 Mbit/s
  - Variable bit rate, constant bit rate
  - Coded/skipped, motion/ no motion, intra or predicted

MPEG-V. / MPEG-2 Flexibility Extens. – (2)

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- **Random access**
  - On slice basis, independent slice processing
- **Bit stream scalability**
  - Additional layering of information (partitioning)
- **Compatibility**
  - Backwards to MPEG-1
- **Editing**
  - Possible in bit stream domain
- **Stability**
  - Repeated coding resilience

MPEG V. / MPEG-2 Video extensions – (1)

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- **Interlaced video**
  - Frame or field-based pictures
  - In frame case: extra MB coding options (such as frame/field motion compensation, frame or field DCT
- **Hierarchical/scalable coding (optional)**
  - HDTV / TV compatibility
  - MPEG-2 / MPEG-1 compatibility
  - Graceful degradation
  - Solutions: frequency scalability, spatial scalability
- **Picture format**
  - Parametric specification of colour sampling, colour space

MPEG V. / MPEG-2 Video extensions – (2)

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- MPEG-2 extensions (cont.)

- **Coding**
  - Alternate quantization tables
  - Alternate VLC tables
  - Added MB types
  - Extended precision for high-quality PQ up to HDTV

MPEG / MPEG-2 Profiles & Levels – (1)

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- **MPEG-2 Profiles / Levels**
  - Implementation of full specification of MPEG-2 too difficult
  - Profiles serve as limited number of subsets of MPEG-2
  - Bounding of encoder/decoder complexity
- **Profile**
  - Limited subset of entire bit stream syntax
  - Different profiles support different features (applications)
- **Level**
  - Defined set of constraints imposed on the parameters in the profile bit stream

MPEG / MPEG-2 Profiles & Levels – (2)

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- **MPEG-2 profiles / levels**
  - **Example: MP@ML**

- **Main Profile**
  - sampling 720 x 576, 4:2:0 standard
  - DCT based, frame/field DCT, frame/field MC, B frames
- **Simple profile**
  - no B pictures are used
- **Next profile**
  - scalability
  - 4:2:0 or 4:2:2 sampling

MPEG Video / MPEG-2 Profile Table

	Profile				
syntactic element	**Simple**	**Main**	**SNR**	**Spatial**	**High**
chroma format	4:2:0	4:2:0	4:2:0	4:2:0	4:2:0, 4:2:2
frame rate extens. n	0	0	0	0	0
frame rate extens. d	0	0	0	0	0
picture coding type	I, P	I, P, B	I, P, B	I, P, B	I, P, B
repeat first field	constrained	constrained	no constr.	no constr.	no constr.
sequence table extens.	No	No	Yes	Yes	Yes
scalable mode	-	-	SNR	SNR, spatial	SNR, spatial
spatial scalable extens.	No	No	No	Yes	Yes
intra dc precision	8,9,10	8,9,10	8,9,10	8,9,10	8,9,10,11
slice structure	restricted	restricted	restricted	restricted	restricted

MPEG Video / MPEG-2 Level Table

	Level			
syntactic element	**Low**	**Main**	**High-1440**	**High**
horizontal vector range	-512, +511.5	-1024, +1023.5	-2048, +2047.5	-2048, +2047.5
vertical vector rang (fra.)	-64, +63.5	-128,+127.5	-128,+127.5	-128,+127.5
vertical range (field)	-32, +31.5	-64, +63.5	-64, +63.5	-64, +63.5
max. sample / line	352	720	1440	1920
max. lines / frame	288	576	1152	1152
max. frame / second	30	30	60	60
Y sample rate (Msam/s)	3.041	10.368	47.002	62.669
max. bit rate (Mbit/s)	4	15	60	80
VBV buffer size (Mbit)	0.475	1.835	7.340	9.781

MPEG Video / MPEG-2 Profile-Level

Combined overview of MPEG-2 profiles and levels

	Profile				
Level	**Simple**	**Main**	**SNR**	**Spatial**	**High**
High		MP@HL			HP@HL
High-1440		MP@H-14			HP@H-14
Main	SP@ML	MP@ML	SNR@ML	Spatial@H-14	HP@ML
Low		MP@LL	SNR@LL		

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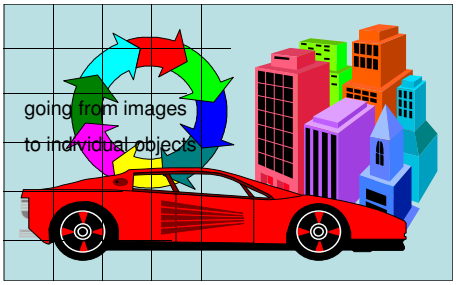
Part 3

Towards the future…,
Lower bit rate and Video Objects

MPEG Outlook / MPEG-4 – (1)

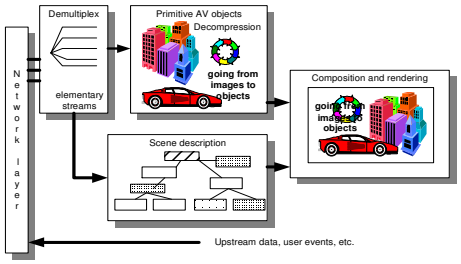
- **Not only bit streams and bit maps**
- **Abstract object-oriented multimedia**
- **A/V Programs as SW programs**
- **Elements can be described independently and combined only at playback time**
- **Elements can include stills, digital video, 3D graphics, text, speech**
- **Elements can be combined intelligently**
  - video texture on 3D objects

MPEG Outlook / MPEG-4 Objects – (2)



MPEG Outlook / MPEG-4 aspects – (3)

* System aspects and manipulation



MPEG Coding / Conclusions – (1)

* MPEG-1 provides a suitable platform for 1 Mbit/s applications, whereas MPEG-2 enables TV up till HDTV coding and contains may extensions for interlaced images
* MPEG Video Compression is based on motion-compensated DCT coding, with extensive VLC usage of various signal components
* The complete specification for audio, video and data, together with system has resulted in wide acceptance of MPEG-1 and MPEG-2 for many applications
* MPEG-4 will be the next important step and is based on several developments: Internet, Blu-ray disc, mobile phone

MPEG Coding / Conclusions – (2)

* MPEG-4 has proven to be the next important step and is more pluriform
* Resulted in several standards due to Internet development
  - 1. MPEG-4 AVC / H.264 for HDTV-optimized coding on Blu-ray Disc (stream-based decoding)
    - Again Motion-Compensated DCT Coding but optimized
    - Halved bit rate of MPEG-2
  - 2. MPEG-4 Object-Oriented Coding, for low bit-rates and interactive or conditional access to individual parts
    - Objects on Internet (not yet broadly applied)