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 / 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 formula
    - \( F(u,v) = 2 (QF(u,v) + k) q_{\text{scale}} W(u,v) / 16 \)
  - \( W(u,v) = 16 \) default, but new matrix can be loaded
  - \( k = \text{sign}(QF(u,v)) \) for inter-blocks
  - Mismatch control: if \( F(u,v) \) even => \( F(u,v) = F(u,v) - \text{sign}(F(u,v)) \) value closest to zero

MPEG Video / Coding modes P&B – (1)

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

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

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 – (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

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 = 9,900 Hz
  – Bit rate <= 1.86 Mbit/s
  – Buffer <= 376,832 bits

MPEG Video / MPEG-2 Flexibility – (1)

* 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 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 quantization
  – Adaptive or default, weighting function default or adaptive

* Motion vectors
  – One-sided, two-sided, motion estimation algorithm

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

* 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)**

* 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)**

* 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)**

* 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)**

* 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

<table>
<thead>
<tr>
<th>syntactic element</th>
<th>Profile</th>
<th>4:2:0</th>
<th>4:2:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>chroma format</td>
<td>Simple</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>frame rate exts.</td>
<td>Main</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>d picture coding type</td>
<td>SNR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sequence table ext.</td>
<td>Spatial</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>scalable mode</td>
<td>High</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>spatial scalable exts.</td>
<td></td>
<td>8,9,10</td>
<td>8,9,10</td>
</tr>
<tr>
<td>intra dc: precision slice structure</td>
<td></td>
<td>restricted</td>
<td>restricted</td>
</tr>
</tbody>
</table>

MPEG Video / MPEG-2 Level Table

<table>
<thead>
<tr>
<th>syntactic element</th>
<th>Level</th>
<th>4:2:0</th>
<th>4:2:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>horizontal vector range</td>
<td>Low</td>
<td>-512</td>
<td>-1024</td>
</tr>
<tr>
<td>vertical vector range (fra.)</td>
<td>Main</td>
<td>-64, +128</td>
<td>-64, +128</td>
</tr>
<tr>
<td>vertical vector range (field)</td>
<td>SNR</td>
<td>-128, +256</td>
<td>-64, +128</td>
</tr>
<tr>
<td>max. sample / line</td>
<td>Main</td>
<td>-32, +64</td>
<td>-64, +128</td>
</tr>
<tr>
<td>max. lines / frame</td>
<td>Spatial</td>
<td>288, 288, 720</td>
<td>768, 1152</td>
</tr>
<tr>
<td>max. frame / second</td>
<td>SNR</td>
<td>288, 288, 720</td>
<td>768, 1152</td>
</tr>
<tr>
<td>Y sample rate (Msam/s)</td>
<td>Spatial</td>
<td>3.041</td>
<td>3.041</td>
</tr>
<tr>
<td>max. bit rate (Mb/s)</td>
<td>SNR</td>
<td>3.041</td>
<td>3.041</td>
</tr>
<tr>
<td>VBV buffer size (Mbit)</td>
<td>Main</td>
<td>4.675</td>
<td>1.825</td>
</tr>
<tr>
<td>VBV buffer size (Mbit)</td>
<td>High</td>
<td>4.675</td>
<td>1.825</td>
</tr>
</tbody>
</table>

Combined overview of MPEG-2 profiles and levels

5LSE0 - Mod 10
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)

- Going from images to individual objects

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 many 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)