Video Compression in the Studio

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Compression is all around us

- In production all cameras and recording devices use compression of some variety
- Typical production workflow goes through many stages
- Concatenation of single codec is a problem
- Concatenation of multiple codecs could be disastrous
- Where is the metadata to help codec concatenation?
  - e.g. The Mole
- Each compression system has different parameters
## Typical HD compressions

<table>
<thead>
<tr>
<th>Codec</th>
<th>Resolution</th>
<th>Bit-depth</th>
<th>Chroma Sampling</th>
<th>Bitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDCAM</td>
<td>1440x1080</td>
<td>8-bit</td>
<td>3:1:1</td>
<td>135 Mbps</td>
</tr>
<tr>
<td>HDCAM SR</td>
<td>1920x1080</td>
<td>10-bit</td>
<td>4:2:2 or 4:4:4</td>
<td>440 Mbps</td>
</tr>
<tr>
<td>DVCPRO HD</td>
<td>1440x1080</td>
<td>8-bit</td>
<td>4:2:2</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>HD D5</td>
<td>1920x1080</td>
<td>10-bit or 8-bit</td>
<td>4:2:2</td>
<td>235 Mbps</td>
</tr>
<tr>
<td>Avid DnxHD 145</td>
<td>1920x1080</td>
<td>8-bit</td>
<td>4:2:2</td>
<td>145 Mbps</td>
</tr>
<tr>
<td>Avid DnxHD 220</td>
<td>1920x1080</td>
<td>10-bit or 8-bit</td>
<td>4:2:2</td>
<td>220 Mbps</td>
</tr>
<tr>
<td>HDV</td>
<td>1440x1080</td>
<td>8-bit</td>
<td>4:2:0</td>
<td>25 Mbps</td>
</tr>
</tbody>
</table>
1080i v 720p debate is over (in the studio)

- Studio and location based production want the highest quality HD
- 1920 x 1080 progressive is the best we can currently achieve in television world
- Various frame-rates available for different “looks”
- European frame-rates:
  - 24P and 25P for the “film look”
  - 50P for content with high motion
1080p50 is an ideal acquisition format

- Easily converted to either 1080i or 720p for delivery
- Future-proof broadcasters’ archives

However

- High data rate around 3 Gbps
- How can we move that around the studio?
TV studios

• Large installed base of coaxial cable interconnections
1080p/50 needs 3 Gbit/s

Option 1:
- Dual link HD-SDI:
  - Inconvenient
  - Halves installed cabling capacity
1080p/50 needs 3 Gbit/s

Option 2:

• 3 Gbit/s over coax:
  – Uncertainty over distance achievable
  – Incompatible with existing routers
1080p/50 needs 3 Gbit/s

Options 3:

• Twisted pair:
  – Requires entire infrastructure replacement
1080p/50 needs 3 Gbit/s

Option 4:
• Optical:
  – Expensive
  – Limited routing capability.
Mild compression

‘Only’ 2:1 compression is needed to fit 1080p/50 into HD-SDI – the but requirements are tough:

• Perceptually lossless or very low loss
• Negligible additional loss on multi-generation compression
• Low delay
• Simple and cheap to implement in hardware.
BBC’s algorithm has the following properties:

- Total delay through codec of 8 lines at 1080p/50
- Compressed signal conforms to 1080i bit stream
- Small, intra-coded, picture blocks (16 pixels x 4 lines).
Picture split into macroblocks for coding
Macroblocks divided into 4x4 blocks
H.264 transform applied to each block

\[
\begin{bmatrix}
    r_{00} & r_{01} & r_{02} & r_{03} \\
    r_{10} & r_{11} & r_{12} & r_{13} \\
    r_{20} & r_{21} & r_{22} & r_{23} \\
    r_{30} & r_{31} & r_{32} & r_{33}
\end{bmatrix}
\begin{bmatrix}
    1 \\
    2 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    x_{00} \\
    x_{10} \\
    x_{20} \\
    x_{30}
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    1 \\
    2 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    x_{01} \\
    x_{11} \\
    x_{21} \\
    x_{31}
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    1 \\
    2
\end{bmatrix}
\begin{bmatrix}
    x_{02} \\
    x_{12} \\
    x_{22} \\
    x_{32}
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    2 \\
    1
\end{bmatrix}
\begin{bmatrix}
    x_{03} \\
    x_{13} \\
    x_{23} \\
    x_{33}
\end{bmatrix}
\begin{bmatrix}
    1 \\
    2 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    x_{04} \\
    x_{14} \\
    x_{24} \\
    x_{34}
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    1 \\
    1
\end{bmatrix}
\begin{bmatrix}
    1 \\
    1 \\
    1 \\
    1
\end{bmatrix}
\]
Quantising and variable-length coding

Hadamard transform for DC coefficients

5-bit quantisation parameter

512 bits available
Difference picture (gain x16)
Compressed data formatted as a 1080i signal

- Compressed data transported in the least significant 8-bits of each pixel
- Most significant 2-bits of each pixel contain ‘compatible’ interlaced version of original video
- Most significant 2-bits modified if necessary to eliminate forbidden TRS codes.
‘Compatible’ coded picture
Effect of halftone dither

- Original linear ramp
Effect of halftone dither

- Original linear ramp
- Quantise to 2 bits
Effect of halftone dither

- Original linear ramp

- Quantise to 2 bits

- 2D halftone dither
Effect of halftone dither

- Original linear ramp
- Quantise to 2 bits
- 2D halftone dither
- Random data in LSBs
‘Compatible’ coded picture
Multihop routing

- Programme making involves routing the signal several times round a site:

  - **DVE**
  - **camera**
  - **mixer**
  - **VTR**
7th generation decoded picture with pixel shifts
7th generation difference picture (gain x16)

With pixel shifts between each generation
Summary

• Compression is inevitable with HD
• Mezzanine coding system to carry 1080p in 1080i
• Low delay, simple to implement in hardware
• Existing 1.5 Gb/s routing infrastructure can be used
• Compatible picture for viewing on 1080i equipment
• Being considered by SMPTE Ad-Hoc group (C24-Mezz)
• Should we keep content in native formats or common studio format??
Thank You