Advanced Video Compression
Outline

- MPEG
- H.264/AVC
- AVC Extensions
  - Scalable Video Coding
  - Multi-view Video Coding
- High Efficiency Video Coding (HEVC, aka. H.265)
- 3D-TV Research
MPEG

- MPEG: Moving Picture Experts Group
  - Established in 1988
  - Standards for audio and video compression and transmission

- MPEG standards:
  - MPEG-1, MPEG-2, MPEG-3 (abandoned), MPEG-4 (AVC)
  - MPEG-7 (content description), MPEG-21 (framework)
  - MPEG-A~MPEG-E
  - MPEG-V, MPEG-M, MPEG-U, MPEG-H (HEVC), MPEG-DASH

- MP3?
  - MPEG-1 Audio Layer 3
MPEG-4

- Standard for a group of audio and video coding formats
- Part 1~29
  - Part 1: System
  - Part 2: Visual (ASP, Advanced Simple Profile)
  - Part 3: Audio (AAC, Advanced Audio Coding)
  - Part 10: Advanced Video Coding (H.264)
Core concept of Video Compression

Compressed Video (Residual) = Original Video – Prediction
Profiles of H.264

- Profile: set of capabilities
  - 21 profiles in total

- High profile
  - For Blu-ray

- Extension
  - Scalable Video Coding (SVC)
  - Multi-view Video Coding (MVC)
Frame types of H.264

- I-frame (Baseline Profile)
- P-frame (Baseline Profile)
- B-frame (Main Profile)
- SI-frame, SP-frame (Extended Profile)
Frame types of H.264

- I-frame (Baseline Profile)
- P-frame (Baseline Profile)
- B-frame (Main Profile)
- SI-frame, SP-frame (Extended Profile)
Frame types of H.264

- SI-frame, SP-frame (Extended Profile)
  - SI-frame (Switching streams using I-slices)
  - SP-frame (switching streams using P-slices)
H.264 Encoder
Intra Prediction

- Compressed Video (Residual) = Original Video – Prediction
- Intra prediction modes (4x4 block)
Intra Prediction

- Intra prediction modes (16x16 block)
H.264 Encoder
Inter Prediction

- **Macroblock Partitions:**

  - 16x16
  - 8x16
  - 16x8
  - 8x8

- **Sub-Macroblock Partitions:**

  - 8x8
  - 4x8
  - 8x4
  - 4x4
Inter Prediction
Inter Prediction

- Multiple reference frames
- Data needs to be compressed
  - Motion vector
  - Partition mode
  - Residual

- Further improvements
  - Sub-sample prediction
  - Motion vector prediction
Sub-sample prediction

- Integer and sub-sample prediction
Interpolation of half pixels

- Finite Impulse Response (FIR) filter is utilized.

\[ b = \text{round}\left(\frac{(E - 5F + 20G + 20H - 5I + J)}{32}\right) \]
Interpolation of quarter pixels

<table>
<thead>
<tr>
<th>G → a ← b → c ← H</th>
</tr>
</thead>
<tbody>
<tr>
<td>h → i ← j → k ← m</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>G</th>
<th>b</th>
<th>H</th>
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<tr>
<td>d</td>
<td>f</td>
<td>m</td>
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<tr>
<td>n</td>
<td>q</td>
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<tr>
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<td>g</td>
<td>m</td>
</tr>
<tr>
<td>p</td>
<td>r</td>
<td>s</td>
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<th>b</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>j</td>
<td>m</td>
</tr>
<tr>
<td>M</td>
<td>s</td>
<td>N</td>
</tr>
</tbody>
</table>
Motion Vector Prediction

- Except 16x8, 8x16, MVp (predicted mv) is median(A, B, C)
- For 8x16, left MVp = A, right MVp = C
- For 16x8, upper MVp = B, lower MVp = A
H.264 Encoder
Transform

- 3 Transforms
  - 4x4, 2x2 Hadamard transform
  - 4x4 DCT (approximated)

- 4x4 DCT in H.264
  - Integer transform
  - Can be implemented using only additions and shifts
  - Scaling multiplication is integrated into quantization
  - Zero mismatch between encoder and decoder is possible
Transform

- Luma block size: 16x16
- Cb, Cr block size: 8x8

4x4 Hadamard

2x2 Hadamard
Transform

- Block 0~15, 18~25: 4x4 DCT transform
Transform

- \( Y = AXA^T \)

\[
A = \begin{bmatrix}
\frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\
\sqrt{\frac{1}{2}} \cos\left(\frac{\pi}{8}\right) & \sqrt{\frac{1}{2}} \cos\left(\frac{3\pi}{8}\right) & -\sqrt{\frac{1}{2}} \cos\left(\frac{3\pi}{8}\right) & -\sqrt{\frac{1}{2}} \cos\left(\frac{\pi}{8}\right) \\
\frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & \frac{1}{2} \\
\sqrt{\frac{1}{2}} \cos\left(\frac{3\pi}{8}\right) & -\sqrt{\frac{1}{2}} \cos\left(\frac{\pi}{8}\right) & \sqrt{\frac{1}{2}} \cos\left(\frac{\pi}{8}\right) & -\sqrt{\frac{1}{2}} \cos\left(\frac{3\pi}{8}\right)
\end{bmatrix}
\]
Transform

\[ Y = AXA^T = \begin{bmatrix} a & a & a & a \\ b & c & -c & -b \\ a & -a & -a & a \\ c & -b & b & -c \end{bmatrix} \begin{bmatrix} a & b & a & c \\ a & c & -a & -b \\ a & -c & -a & b \\ a & -b & a & -c \end{bmatrix} \]

\[ a = \frac{1}{2}, \quad b = \sqrt{\frac{1}{2}} \cos \left( \frac{\pi}{8} \right), \quad c = \sqrt{\frac{1}{2}} \cos \left( \frac{3\pi}{8} \right) \]
**Transform**

- Factorization of $Y$: $(d = c/b \approx 0.414)$

$$a = \frac{1}{2}, \quad b = \sqrt{\frac{1}{2} \cos \left(\frac{\pi}{8}\right)}, \quad c = \sqrt{\frac{1}{2} \cos \left(\frac{3\pi}{8}\right)}$$

Scalar multiplication

\[
Y = (CXC^T) \otimes E = \begin{bmatrix}
1 & 1 & 1 & 1 \\
1 & d & -d & -1 \\
1 & -1 & -1 & 1 \\
d & -1 & 1 & -d
\end{bmatrix} \begin{bmatrix}
1 & 1 & 1 & 1 \\
1 & d & -1 & -1 \\
1 & -d & -1 & 1 \\
1 & -1 & 1 & -d
\end{bmatrix} \begin{bmatrix}
a^2 & ab & a^2 & ab \\
ab & b^2 & ab & b^2 \\
a^2 & ab & a^2 & ab \\
ab & b^2 & ab & b^2
\end{bmatrix}
\]

\[d = \frac{1}{2}\]

\[
Y = C_fX C_{f}^T \otimes E_f = \begin{bmatrix}
1 & 1 & 1 & 1 \\
2 & 1 & -1 & -2 \\
1 & -1 & -1 & 1 \\
1 & -2 & 2 & -1
\end{bmatrix} \begin{bmatrix}
1 & 2 & 1 & 1 \\
1 & 1 & -1 & -2 \\
1 & -1 & -1 & 2 \\
1 & -2 & 1 & -1
\end{bmatrix} \otimes \begin{bmatrix}
a^2 & \frac{ab}{2} & a^2 & \frac{ab}{2} \\
\frac{ab}{2} & \frac{b^2}{4} & \frac{ab}{2} & \frac{b^2}{4} \\
a^2 & \frac{ab}{2} & a^2 & \frac{ab}{2} \\
\frac{ab}{2} & \frac{b^2}{4} & \frac{ab}{2} & \frac{b^2}{4}
\end{bmatrix}
\]
Transform

- Comparison between the approximated and the exact DCT

<table>
<thead>
<tr>
<th>X:</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>i = 0</td>
<td>5</td>
<td>11</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>10</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>6</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

\[
Y = AXA^T = \begin{bmatrix}
35.0 & -0.079 & -1.5 & 1.115 \\
-3.299 & -4.768 & 0.443 & -9.010 \\
5.5 & 3.029 & 2.0 & 4.699 \\
\end{bmatrix}
\]

\[
Y' = (CXC^T) \otimes E_f = \begin{bmatrix}
35.0 & -0.158 & -1.5 & 1.107 \\
-3.004 & -3.900 & 1.107 & -9.200 \\
5.5 & 2.688 & 2.0 & 4.901 \\
\end{bmatrix}
\]

\[
Y - Y' = \begin{bmatrix}
0 & 0.079 & 0 & 0.008 \\
-0.295 & -0.868 & -0.664 & 0.190 \\
0 & 0.341 & 0 & -0.203 \\
0.224 & 0.190 & -0.055 & 0.868
\end{bmatrix}
\]
Quantization

\[ Z_{ij} = \text{round}(Y_{ij}/Q_{\text{step}}) \]

\[ Y = C_fX C_f^T \otimes E_f = \left( \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \right) \left( \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix} \right) \]

\[ W = C X C^T \]

\[ Z_{ij} = \text{round} \left( W_{ij} \cdot \frac{P F}{Q_{\text{step}}} \right) \]

<table>
<thead>
<tr>
<th>Position</th>
<th>PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,0), (2,0), (0,2) or (2,2)</td>
<td>(a^2)</td>
</tr>
<tr>
<td>(1,1), (1,3), (3,1) or (3,3)</td>
<td>(b^2/4)</td>
</tr>
<tr>
<td>other</td>
<td>(ab/2)</td>
</tr>
</tbody>
</table>
# Quantization

- QP vs. Qstep in H.264

| QP | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | ...
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---
| QStep | 0.625 | 0.6875 | 0.8125 | 0.875 | 1 | 1.125 | 1.25 | 1.375 | 1.625 | 1.75 | 2 | 2.25 | 2.5 | ...
| QP | ... | 18 | ... | 24 | ... | 30 | ... | 36 | ... | 42 | ... | 48 | ... | 51 |
| QStep | 5 | 10 | 20 | 40 | 80 | 160 | 224 |

\[ Z_{ij} = \text{round} \left( W_{ij} \cdot \frac{PF}{Q_{\text{step}}} \right) \]

\[ Z_{ij} = \text{round} \left( W_{ij} \cdot \frac{MF}{2^{q_{\text{bits}}}} \right) \]

\[ \frac{MF}{2^{q_{\text{bits}}}} = \frac{PF}{Q_{\text{step}}} \]

\[ q_{\text{bits}} = 15 + \text{floor}(Q_{P}/6) \]
Quantization

- Table of QP vs. MF

\[ Z_{ij} = \text{round} \left( W_{ij} \cdot \frac{MF}{2qbits} \right) \]

<table>
<thead>
<tr>
<th>QP</th>
<th>Positions (0,0),(2,0),(2,2),(0,2)</th>
<th>Positions (1,1),(1,3),(3,1),(3,3)</th>
<th>Other positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>13107</td>
<td>5243</td>
<td>8066</td>
</tr>
<tr>
<td>1</td>
<td>11916</td>
<td>4660</td>
<td>7490</td>
</tr>
<tr>
<td>2</td>
<td>10082</td>
<td>4194</td>
<td>6554</td>
</tr>
<tr>
<td>3</td>
<td>9362</td>
<td>3647</td>
<td>5825</td>
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<td>4</td>
<td>8192</td>
<td>3355</td>
<td>5243</td>
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<td>5</td>
<td>7282</td>
<td>2893</td>
<td>4559</td>
</tr>
</tbody>
</table>
H.264 Encoder

Input Video Signal

Split into Macroblocks 16x16 pixels

Coder Control

Transform/Scal./Quant.

Decoder

Scaling & Inv. Transform

Entropy Coding

Control Data

Quant. Transf. coeffs

Intra-frame Prediction

Motion Compensation

Deblocking Filter

Motion Estimation

Output Video Signal

Motion Data
De-blocking filter

- De-blocking filter
- Filter the blocking effect

1. $|p_0 - q_0| < \alpha(QP)$
2. $|p_1 - p_0| < \beta(QP)$
3. $|q_1 - q_0| < \beta(QP)$
H.264 Encoder

Input Video Signal

Split into Macroblocks 16x16 pixels

Coder Control

Transform/Scal./Quant.

Scaling & Inv. Transform

Deblocking Filter

Intra-frame Prediction

Motion Compensation

Motion Estimation

Output Video Signal

Control Data

Quant. Transf. coeffs

Entropy Coding

Motion Data
Entropy Coding

- Exp-Golomb Entropy Coding
  
  \[ [M \text{ zeros}] [1] [\text{INFO}] \]
  
  \[ M = \text{floor}(\log_2(\text{code\_num} + 1)) \]
  
  \[ \text{INFO} = \text{code\_num} + 1 - 2^M \]

- CAVLC (Context-based Adaptive VLC)

- CABAC (Context-based Adaptive Binary VLC)
  - The choice of look-up table depends on the number of nonzero coefficients in neighboring blocks
Performance Evaluation

\[ PSNR = 10 \cdot \log_{10} \left( \frac{MAX^2_I}{MSE} \right) \]
\[ = 20 \cdot \log_{10} \left( \frac{MAX_I}{\sqrt{MSE}} \right) \]
\[ = 20 \cdot \log_{10} (MAX_I) - 10 \cdot \log_{10} (MSE) \]
Performance Evaluation

- Quality metric: SSIM (Structural Similarity)

\[
SSIM(x, y) = \frac{(2\mu_x \mu_y + C_1)(2\sigma_{xy} + C_2)}{\left(\mu_x^2 + \mu_y^2 + C_1\right) \left(\sigma_x^2 + \sigma_y^2 + C_2\right)}
\]

(a) Original, MSSIM=1
(b) Contrast, MSSIM=0.9168
(c) Mean shift, MSSIM=0.99
(d) JPEG, MSSIM=0.6949
(e) Blurred, MSSIM=0.7052
(f) Salt noise, MSSIM=0.7748
Extensions of AVC

- Scalable Video Coding (SVC)
  - Simulcast
  - Scalability: Spatial, Temporal, Quality

- Multi-view Video Coding (MVC)
Extensions of AVC

- Compressed Video (Residual) = Original Video – Prediction
Extensions of AVC

- Simulcast
Extensions of AVC

- Spatial Scalable
Extensions of AVC

- Multi-view Video Coding (MVC)
**HEVC (H.265)**

- Official International Standard since Apr. 2013

<table>
<thead>
<tr>
<th>Tool \ Profile</th>
<th>Main Still Picture</th>
<th>Main</th>
<th>Main 10</th>
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<tbody>
<tr>
<td>Bit Depth</td>
<td>8</td>
<td>8</td>
<td>8, 9, 10</td>
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<tr>
<td>CU Size</td>
<td></td>
<td>16x16~64x64</td>
<td></td>
</tr>
<tr>
<td>PU Partition</td>
<td>Symmetric</td>
<td>Symmetric, <strong>Asymmetric</strong></td>
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</tr>
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<td>TU Partition</td>
<td>Residual Quad-tree Transform</td>
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<td></td>
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<tr>
<td>MV Prediction</td>
<td>-</td>
<td>AMVP, MRG, MRG-Skip</td>
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<tr>
<td>Interpolation Filter</td>
<td>-</td>
<td>DCT-IF</td>
<td></td>
</tr>
<tr>
<td>Intra Prediction</td>
<td>DC, Planar, <strong>33 Directions</strong>, DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transform</td>
<td>DCT 4x4~32x32, <strong>Skip 4x4</strong>, DST 4x4 (Intra)</td>
<td></td>
<td></td>
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<tr>
<td>In-loop Filter</td>
<td>De-blocking, <strong>SAO</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entropy Coding</td>
<td>CABAC (<strong>Tiles</strong>, <strong>Wavefront</strong>)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HEVC vs. AVC

Input Video Signal

Split into Largest Coding Unit 64x64 pixels

Coder Control

Transform/Scal./Quant.

Intra/Inter Coder Control

Motion Estimation

Entropy Coding

H.264: 8x4 to 16x16
HEVC: 16x16 to 64x64

H.264: primary 4x4 to 8x8 int. trans.
HEVC: DCT 4x4~32x32, Skip 4x4, DST 4x4

HEVC: Similar to H.264 (Tiles, Wavefront)

H.264: Similar to H.264

HEVC: Similar to H.264

Intra-frame Prediction

Filter

Motion Compensation

Filter

H.264: ¼-pel with 6-tap interpolation filter
HEVC: DCT-IF

H.264: Up to 9 directions
HEVC: Up to 33 directions

H.264: 4x4 to 16x16
HEVC: 16x16 to 64x64

H.264: 4x4 to 16x16
HEVC: 16x16 to 64x64

H.264: ¼-pel with 6-tap interpolation filter
HEVC: DCT-IF

H.264: 8-bit precision
HM3: up to 10-bit precision
HEVC (H.265) vs. AVC (H.264)

- Bit Rate Saving Comparison
  - HEVC: HM10.0, AVC: JM18.4

HEVC (H.265) vs. AVC (H.264)

- Encoding time comparison

Real-time Hardware Encoder

- By Mitsubishi & NHK (Jan. 2013)

<table>
<thead>
<tr>
<th>Source</th>
<th>1920x1080@60p, 10-bit YUV 4:2:0</th>
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</thead>
<tbody>
<tr>
<td>Profile</td>
<td>Main 10</td>
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<tr>
<td>GOP Structure</td>
<td>Hierarchical B (1 for L0, 1 for L1)</td>
</tr>
<tr>
<td>CU Size</td>
<td>64x64, 32x32, 16x16</td>
</tr>
<tr>
<td>Max TU Size</td>
<td>32x32 w/ RQT disabled</td>
</tr>
</tbody>
</table>

Related events

- Container formats vs. Video formats
Related events

- Video Tag in HTML5
  - H.264? WebM? Ogg Theora?

- License fee of H.264 for an enterprise
  - Free for free content
  - 6.5M USD per year (2011~2015)

- MPEG-LA
  - Not affiliated with MPEG
  - Maintain patent pool

- WebM from Google (free) vs. H.264
  - Patent issues

http://www.mpegla.com/main/programs/AVC/Pages/Agreement.aspx
MPEG-DASH

- Standard for Multimedia Streaming
  - RTP (Realtime Transport Protocol) vs. HTTP
  - CDN (Content Delivery Networks) usually don’t support RTP
- Dynamic Adaptive Streaming over HTTP (DASH)
Research of 3D-TV

- Some history

- Related research topics of 3D-TV
Research activities on 3D-TV
- History of 3D -

- 1692 French painter G. A. Bois-Clair
  - An antecessor of Auto-stereoscopic display
- 1838 Sir Charles Wheatstone
  - Mirrored stereoscope
- 1849 Sir David Brewster
  - First stereoscopic camera
- 1903 Lumiere brothers
  - First moving 3D pictures in Paris
- 1922 John Logie Baird
  - Full length 3D movie in LA
- 1986 IMAX 3D appears
Research activities on 3D-TV
- History of 3D -

• 1990s transition from analog to digital TV
  • European projects: DISTIMA, MIRAGE
• 1996 MPEG-2 Multi-View-Profile
• Late 1990s
  • It is essential to separate capture and display geometry by using emerging methods of CV
• 1998 European project: PANOROMA
  • One of the first research activities that demonstrated depth based process of stereo adaptation
Research activities on 3D-TV
- History of 3D -

- Late 1990s
  - European follow-up project ATTEST
  - 3D-TV processing chain, DIBR
  - Time-of-flight sensor
Related research topics of 3D-TV

- Stereoscopic vision

- 3D display technologies
  - Stereoscopic display
  - Auto-stereoscopic display
  - Volumetric
  - Holographic

- 3D data formats
Related research topics of 3D-TV

- Stereoscopic vision
Binocular Visual System

- Random Dot Stereogram
  - Discovered by Bela Julesz (1928-2003)
    - “Foundations of Cyclopean Perception”, 1971
    - the 100 most-influential cognitive science books in the 20th century
Comfort Zone of 3D Viewing (1/2)

- Focal distance vs. Vergence distance (disparity)
- Mismatch between these 2 distances: Discomfort

Comfort Zone of 3D Viewing (2/2)

![Graph showing the comfort zone of 3D viewing](image)

- **Zone of clear single binocular vision**
- **Minimum relative vergence**
- **Maximum relative vergence**
- **Natural viewing**

**Axes:**
- **Focal distance (D)**
- **Vergence distance (D)**
Related research topics of 3D-TV

- Stereoscopic display
- Anaglyph
Related research topics of 3D-TV

- Stereoscopic display
  - Active shutter
  - Polarized
Related research topics of 3D-TV

- Auto-stereoscopic display
Related research topics of 3D-TV

- Auto-stereoscopic display
  - Lens
  - Barrier
Related research topics of 3D-TV

- HDDP: 2D/3D mixed display

With this configuration, a 3D image can be localized in an area under a 2D image.
Related research topics of 3D-TV

- Volumetric 3D display
  
  Source: [http://www.youtube.com/watch?v=eNWJ9XtRhLw](http://www.youtube.com/watch?v=eNWJ9XtRhLw)
Related research topics of 3D-TV

- Touchable Holography http://www.youtube.com/watch?v=Y-P1zZAcPuw
Emerging 3D Viewing Devices

- Virtual Reality
  - Oculus VR: Acquired by FB for 2B USD
Emerging 3D Viewing Devices

- Next Generation Smart Glasses (e.g. Google Glasses)
- Epson Moverio BT-200
Related research topics of 3D-TV

- 3D data format

**2D + Depth Cameras**

- Large volume, low cost
Related research topics of 3D-TV

- RGB/depth frames
- Spatial resolution: 640x480
- Frame rate: 30 fps

Range: 1~10m
Depth resolution: < 1cm
Cost: $150
Related research topics of 3D-TV

- Multi-view 3D data
Related research topics of 3D-TV

- Profiles of MVC (Extension of AVC)
- Adopted in Blu-ray 3D
8 views (640×480), consider rate for all views
~25% bit rate savings over all views
Related research topics of 3D-TV

- Frame-compatible formats
Related research topics of 3D-TV

- 3D AHG (Ad Hoc Group) in MPEG

3DV should be compatible with:
- existing standards
- mono and stereo devices
- existing or planned infrastructure

Bit Rate

3D Rendering Capability

2D

2D+Depth

Simulcast

MVC

3DV
Related research topics of 3D-TV

- Coding tools for 3D data (e.g. Platelet Coding)

**Depth modeling functions**

[Image of depth modeling functions]

**Quadtree decomposition**
Each block/node approximated by a modeling function
Rate-distortion optimization procedure can be applied
Related research topics of 3D-TV

Typical Depth Coding Artifacts

Sample Synthesis Results

Better geometric representation of depth can lead to better coding and rendering results
Related research topics of 3D-TV

- Coding tools for 3D data
  - Some coding tools proposed during the development of MVC
  - Not adopted due to syntax compatibility

- Macroblock-level coding tools (AVC)
  - Illumination compensation
  - Motion skip mode
  - Adaptive reference filtering
  - View synthesis prediction
Related research topics of 3D-TV

- Illumination compensation
  - Compensate for illumination difference between views
Related research topics of 3D-TV

- Motion skip mode
- High correlation between motion vectors in different views

![Diagram showing motion vectors in different views and macroblocks]
Related research topics of 3D-TV

- Adaptive reference filtering
  - Filtering the mismatch between views (e.g. focus)
Related research topics of 3D-TV

- View synthesis prediction
3D HEVC

Limited Camera Inputs

Data Format

Constrained Rate (based on distribution)

Stereoscopic displays
- Variable stereo baseline
- Adjust depth perception

Left

Right

Data Format

Auto-stereoscopic N-view displays
- Wide viewing angle
- Large number of output views
3D HEVC

- Multi-view plus depth 3D data
3D HEVC

Limited Video Inputs (e.g., 2 or 3 views)

Depth Estimation → Video/Depth Codec → View Synthesis

Larger # Output Views

1010001010001

Binary Representation & Reconstruction Process
3D HEVC

2-view Configuration

Left

Depth Estimation

3D Video Codec

Multiview Rendering

Output to Stereo Display

Right

3-view Configuration

Left

Center

Right

Depth Estimation

3D Video Codec

Multiview Rendering

Output to Auto-Stereo
N-view Display

virtual views
Further Research of 3D-TV

- High-quality depth information acquisition and generation
- 3D Media Retrieval and Recommendation
- Quality Assessment of 3D Image/Video Compression
  - Frequency-Integrated PSNR (FI-PSNR)
- Perceptual-based 3D Image/Video Processing