A Comparison of JEM and AV1 with HEVC: Coding Tools, Coding Efficiency and Complexity

Thorsten Laude, Yeremia Gunawan Adhisantoso, Jan Voges, Marco Munderloh, Jörn Ostermann

Leibniz Universität Hannover
Institut für Informationsverarbeitung
→ Next presentation: “An Overview of Core Coding Tools in the AV1 Video Codec”
→ Tomorrow afternoon: “Versatile Video Coding – Towards the Next Generation of Video Compression”

→ This presentation

→ This presentation
History of Video Codecs

ISO/IEC/ITU-T

1980s
- H.120
- H.261

1990s
- MPEG-1
- MPEG-2/H.262
- H.263
- MPEG-4 Part 2

2000s
- AVC (MPEG-4 Part 10/H.264)

2010s
- HEVC (MPEG-H Part 2/H.265)

Contenders

1980s
- TrueMotion S/RT/2
- Real Video

1990s
- Dirac
- VP3-7
- VP8
- Real Video

2000s
- VC-X

2010s
- VP9
- Daala
- AV1
- Thor
- Real Video

Comparison of the latest video codecs (JEM/AV1) with HEVC
On the Difficulty of Comparing Video Codecs

AV1 is up to 43% better than HEVC


“In terms of PSNR, the average BD-rate savings of AV1 relative to [...] x264 high [...] are [...] 45.8% [...] On the other hand, the encoding computational complexity [...] was increased by factors of [...] 5869.9x”

Source: Liu, “AV1 beats x264 and libvpx-vp9 in practical use cases”, Facebook Blog, 2018

HEVC is 30% better than AV1

Source: Grois et al., “Performance Comparison of AV1, JEM, VP9 and HEVC Encoders”, Proceedings of SPIE, 2017

Source: Akyazi and Ebrahimi, “Comparison of compression efficiency between HEVC/H.265 and VP9 based on subjective assessments”, QoMEX, 2018
On the Difficulty of Comparing Video Codecs

Codecs perform differently good for different content

- Standard vs. Encoder
  - Reference implementations (HM/JEM/aomenc)
  - Optimized encoders (x264/x265)

- Sequences

- Codec Comparison

- Codec Configurations
  - Computing resources
  - Applications: e.g. Broadcasting, VoD, Social Media
  - Tuning (e.g. PSNR, visual)

- Metrics
  - Luma BD-rates, weighted BD-rates
  - Quality metrics: PSNR, SSIM, VMAF
  - Subjective Tests

Thorsten Laude
laude@tnt.uni-hannover.de
## Test Conditions for this Paper

### Codec Comparison

#### Standard vs. Encoder

- Reference implementations (HM/JEM/aomenc)

#### Codec Configurations

- HM/JEM: Common Test Conditions (CTC)
- AV1
  ```
  ```

#### Metrics

- Luma BD-rates
- Quality metrics: PSNR

### Sequences

<table>
<thead>
<tr>
<th>Class</th>
<th>Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 (4K)</td>
<td>Tango2, Drums100, Campfire, ToddlerFountain2</td>
</tr>
<tr>
<td>A2 (4K)</td>
<td>CatRobot, TrafficFlow, DaylightRoad2, Rollercoaster2</td>
</tr>
<tr>
<td>B (1080p)</td>
<td>Kimono, ParkScene, Cactus, BasketballDrive, BQTerrace</td>
</tr>
<tr>
<td>C (WVGA)</td>
<td>BasketballDrive, BQMall, PartyScene, RaceHorses</td>
</tr>
<tr>
<td>D (WQVGA)</td>
<td>BasketballPass, BQSquare, BlowingBubbles, RaceHorses</td>
</tr>
<tr>
<td>E (720p)</td>
<td>FourPeople, Johnny, KristenAndSara</td>
</tr>
<tr>
<td>F (Screen/Mixed Content)</td>
<td>BasketballDrillText, ChinaSpeed, SlideEditing, SlideShow</td>
</tr>
</tbody>
</table>
Coding Tools

JEM

- **Partitioning**
  - Quaternary and binary splits
  - Bigger block size

- **Inter coding**
  - Overlapped block motion compensation
  - Higher order motion model
  - Sub-CU MV prediction

- **Intra coding**
  - Additional directions
  - Cross-component linear model

- **Transform coding**
  - Adaptive multiple transforms
  - Non-separable secondary transform
  - Signal-dependent transform

AV1

- **Partitioning**
  - Quaternary and binary splits
  - Bigger block size

- **Inter coding**
  - Overlapped block motion compensation
  - Higher order motion models
  - Wedge mode partitioning
  - Compound intra-inter prediction

- **Intra coding**
  - Directional, Paeth, Smooth prediction
  - Intra block copy
  - Palette mode

- **Transform coding**
  - DCT, DST, Identity
  - Independent horizontal/vertical transforms

Thorsten Laude
laude@tnt.uni-hannover.de
Coding Efficiency

-65%  -45%  -25%  -5%  15%  35%  55%  75%

JEM vs. HM  JEM vs. AV1  AV1 vs. HM  JEM vs. HM  JEM vs. AV1  AV1 vs. HM

Better

BD-rate

Thorsten Laude
laude@tnt.uni-hannover.de
Encoder Runtimes

Relative factors to HM, i.e. HM=1

Total CPU time: \(\approx 1\) decade

e.g. 10 frames/day
Relative factors to HM, i.e. HM=1
Runtime-memory Complexity

Elapsed run time [min]

Memory usage [GB]

- AV1 all-intra
- AV1 random access
- HM all-intra
- HM low-delay B
- HM random access
- JEM all-intra
- JEM low-delay B
- JEM random access

Thorsten Laude
laude@tnt.uni-hannover.de
Trade-off Coding Efficiency vs. Complexity

Better

Compression factor

AUC [GB*min]

Better

Thorsten Laude
laude@tnt.uni-hannover.de
Coding Efficiency

Comparison vs. HM

All intra (AI)
JEM: 20% gain
AV1: 4% gain

Random Access (RA)
JEM: 28% gain
AV1: 38% loss

Runtimes

Comparison vs. HM

Encoder
JEM: $39 \times (AI)/10 \times (RA)$ slower
AV1: $9 \times (AI)/32 \times (RA)$ slower

Decoder
JEM: $3 \times (AI)/7 \times (RA)$ slower
AV1: 2 × faster (AI)/same (RA)

Closing remarks

• Results are a snapshot of summer 2017 → AV1 finalization in March 2018 and JVET CfP evaluation in April 2018
  • Since last summer, AV1 has gained additional 5% (based on 80 preliminary data points)
• Complexity: Reference implementations vs. product implementations