A Comparison of JEM and AV1 with HEVC

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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
- Thor
- AV1

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


HEVC is 30% better than AV1

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

“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

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

Codec Comparison

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

Sequences

- 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

Codecs perform differently good for different content
Test Conditions for this Comparison

<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>BasketballDrill, 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>

Sequences

- Reference implementations (HM/JEM/aomenc)
- HM/JEM: Common Test Conditions (CTC)
- AV1
  --auto-alt-ref=1 --psnr --tune=psnr --i420 -p 1 -t 1 --fps=<> --bit-depth=<> --input-bit-depth=<> --cq-level=<> --kf-min-dist=<> --kf-max-dist=<> -w <> -h <>

Codec Configurations

- Luma BD-rates
- Quality metrics: PSNR
## 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
Coding Efficiency

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

JEM vs. HM  JEM vs. AV1  AV1 vs. HM  JEM vs. HM  JEM vs. AV1  AV1 vs. HM
All-intra  Random Access

BD-rate

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

Total CPU time: ≈ 1 decade

e.g. 10 frames/day
Decoder Runtimes

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

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Runtime-memory Complexity

Elapped run time [min] vs 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
Trade-off Coding Efficiency vs. Complexity

Better

Compression factor

AUC [GB*min]

AV1

HM

JEM

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

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Summary

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 × (AI)/10 × (RA) slower
AV1: 9 × (AI)/32 × (RA) slower

Decoder
JEM: 3 × (AI)/7 × (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