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Understanding the Video Codec Jungle: A Comparison of TCO and Compression Efficiency - Segunda Parte

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PSNR and VMAF Results

Figure 3 presents aggregated PSNR and VMAF BD-rate curves over all sequences for the four codecs. It shows AV1 gain over HEVC is reduced at a lower bitrate (at 2 Mbits/s only 3% in PSNR and 6% in VMAF).

Figure 4 displays PSNR and VMAF BD-rate curves by sequences.

Table 1 summarizes PSNR and VMAF BD rate delta values between codecs. For instance, the table shows that HM provides a 51% bitrate reduction compared with the JM for the same PSNR quality.

This paper provides a thorough comparison of different codec technologies, including Advanced Video Coding (AVC), HEVC, AV1, and Versatile Video Coding (VVC).

Expert Viewings

Subjective viewings with ten Harmonic and b‹›com experts were conducted for one bitrate point according to the test configuration shown in **Figure 5**. For each sequence, the bitrate was chosen to correspond to acceptable broadcast quality for the codec and also a realistic broadcast bitrate.

Viewers had to give their ranking between the four codecs. Globally, it was possible to conclude that JVET was always the best and H.264 was always behind. HEVC was judged on par with AV1 and, sometimes, was slightly better depending on the sequence. AVC was encoding at too low a bitrate for the chosen resolutions and, therefore, performed the worst subjectively. Subjectively, it was not possible to notice the PSNR and VMAF gains of AV1 over HEVC, as shown in **Table 2**. This may be due to the low bitrate point used for the subjective viewing (3-Mbits/s average). **Figure 3** shows that AV1's PSNR/ VMAF gain over HEVC is reduced at lower bitrates.

Other Codec Comparisons

In this section, an analysis is made between recent codec evaluations. Very often, comparisons are made with x265, which, first, is a commercial product; second, it has to be used in PSNR mode to make a fair comparison with other codecs; and third, should be used at least in placebo mode to exploit all the HEVC potential. In this study, the HM has been used.

Wiesbaden University presented a full subjective comparative study at EBU in January 2018.[21] It shows 25% bitrate gain for HM compared to AV1, but it is for ultrahigh definition (UHD) sequences, and it is based on an end-of-2017 AV1 release, while AV1 has made recent progress until the end of March 2018.

Bitmovin, in a recent comparative study,[22] showed higher bitrate gains for AV1 (+30% vs. x265 for 1080p) based on PSNR; however, it was a comparison with x265 (slow preset), which is not at the level of HM, and this study is PSNR-based only.

Moscow State University (MSU) released in Q1 of 2018 a report that compares AV1 to x265. Similar to the Bitmovin report, AV1 is ranked better than x265 by 18%, using its own subjective metric, which is very consistent with the findings of this study (7% on PSNR and 14% on VMAF).[23]

Ecole polytechnique fédérale de Lausanne (EPFL) conducted another complete subjective evaluation (with a recent AV1 release), and it shows a slight subjective bitrate gain (+3.2%) for HM compared to AV1.[24]

Facebook has conducted an objective comparison[25] of AV1, x264, and VP9. The results show that AV1 provides a 34% gain over VP9 and a 46% gain over x264 High profile. The other interesting aspect of this report is that it shows the complexity difference between AV1 and other codecs.

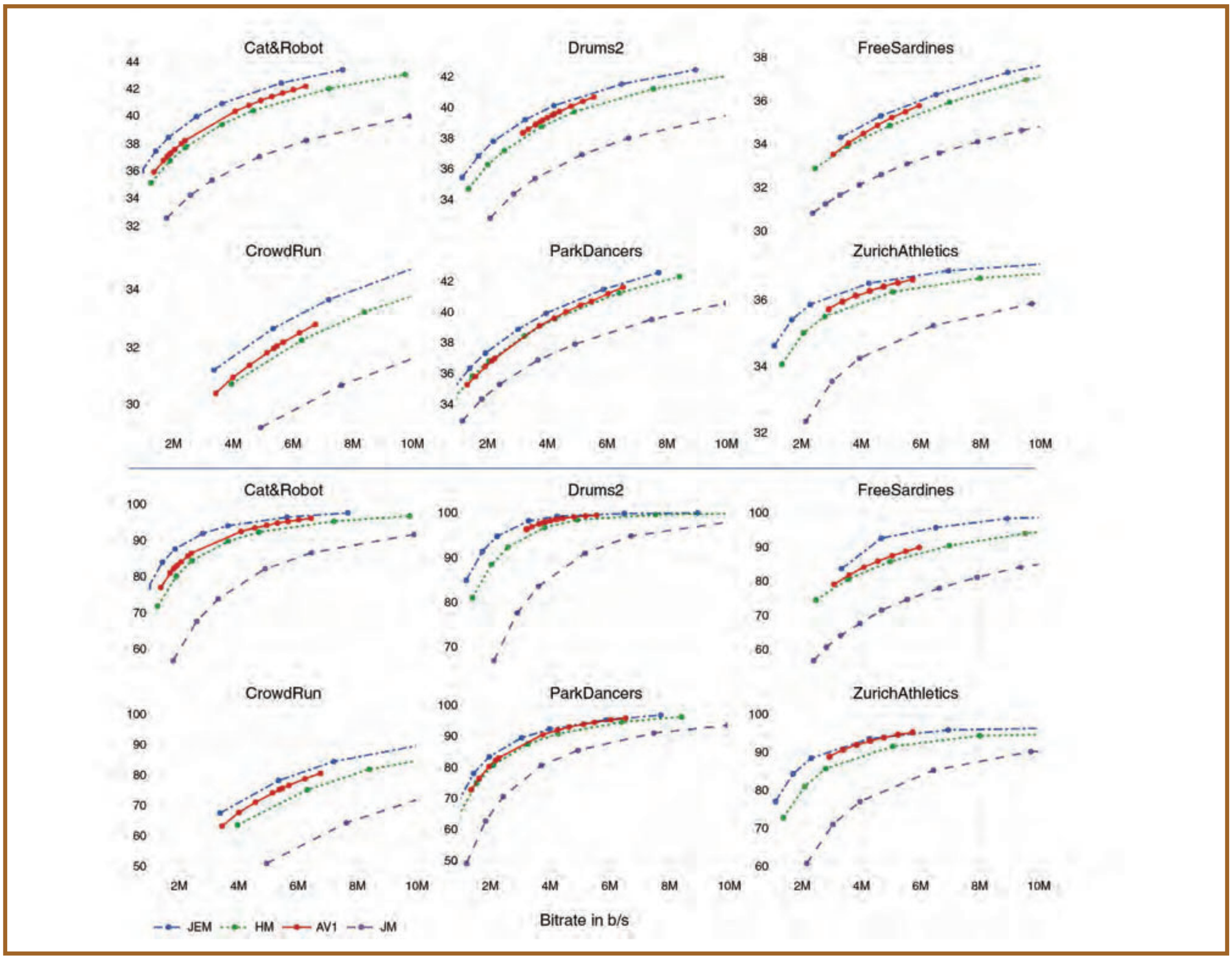

Figure 4. Sequence PSNR and VMAF BD-rate curves.

TABLE 1. PSNR/VMAF BD-rate deltas between codecs.

	PSNR (Reference Encoder in Column)				VMAF (Reference Encoder in Column)			
	JM	HM	AV1	JEM	JM	HM	AV1	JEM
JM		106%	131%	175%		103%	141%	200%
HM	–51%		8%	32%	–50%		17%	46%
AV1	–56%	–7%		25%	–58%	–14%		23%
JEM	–63%	–24%	–20%		–65%	–30%	–18%	

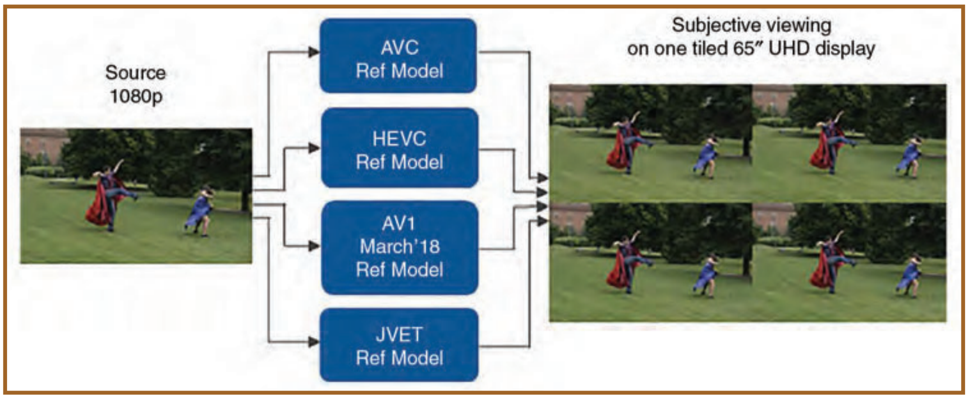

Figure 5. Expert viewing setup.

TABLE 2. Expert viewing sequence bitrate.

Cat & Robot	Crowd-Run	Park-Dancers	Zurich-Athletics	Drums	Free-Sardines
1.9Mb	5.4Mb	2.0Mb	2.4Mb	3.4Mb	3.6Mb

The AOMedia members, in a recent comparative study,[26] showed AV1 gains compared to HEVC (+22.75% vs. x265 for 1080p and PSNR-Y). However, it was a comparison with x265 (placebo preset), which is still not at the level of the HM. This study is PSNR-based.

Summary

Table 3 summarizes the different comparisons found between HEVC (HM or x265) and AV1. No conclusion can be drawn, as the companies do not use the same encoder and configuration for AV1 and HEVC. Convergence can be seen on the objective testing with the use of BD PSNR or VMAF. Subjective testing is the next point of convergence that heavily will rely on selected test sequences. Harmonic and b‹›com are going to drive such a convergence moving forward to have a more homogenous set of comparisons between different codecs and avoid another level of confusion in operators' minds. As subjective testing seems to be the most important for operators, the next step would ideally be to do a joint BT 500 subjective testing, on agreed materials and bitrates to compare all those codecs with all the interested research institutes in one single experiment.

Complexity

The codec performance is only one element of the codec comparison. Encoder and decoder complexities also need to be considered. Commercial implementations have not been compared, as they are at different stages for the different codecs. The study compares each codec single-threaded software implementation and the computation time for all mentioned codecs. **Figure 6** shows the comparison of encoding and decoding times, by taking the HM as reference.

An AV1 encoder is about 130 times more complex to encode than HEVC when comparing reference models. On the decoder side, no difference has been noticed.

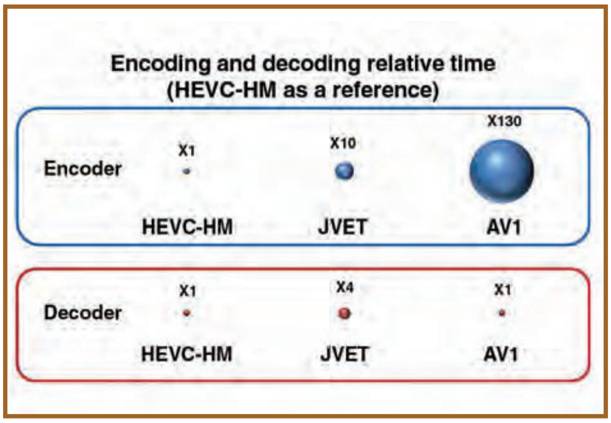

Figure 6. Codec encoding/decoding time comparison.

Today, JEM is 10× more complex to encode than HEVC and 4x more complex to decode.

Moving forward, AV1 is expected to be optimized in speed. Over the last few years, HEVC encoding time has been reduced by a factor of 10 while maintaining the quality at a similar level, when using the comparison reference model and commercial live implementation. To reach real time for AV1 at any resolution (including UHD), the source has to be sliced, and each chunk has to be encoded on a separate node, so if realtime is around the corner, the question will be more about the total cost of ownership (TCO). If it costs 10, 20, or 30x more in hardware to encode live AV1, operators might not use AV1, and stay with HEVC.

On the decode side, chip companies are used to building multi-codec decoders. Today's standard decoders support AVC, HEVC, and VP9. Adding AV1 will introduce complexity, but will not be prohibitive as it is on the encode side.

Conclusion

This paper provided a thorough comparison of AVC, HEVC, AV1, and VVC. The findings are that AV1 is not more advantageous today than HEVC on the compression side and much more complex to encode than HEVC, adding reasonable complexity to the HEVC decoder. On the bright side, it comes with more attractive licensing terms. Of course, the royalty cost, which is not in the scope of this paper, needs to be considered.

TABLE 3. Codec evaluation comparison.

	Harmonic & b<>com	Wiesbaden	Bitmovin	MSU	EPFL	Facebook	AOM
Objective Result	AV1 slightly better than HM	NA	AV1 better than x265	AV1 better than x265	HM better than AV1	NA	AV1 better than x265
Subjective Result	On par	HM better than AV1	NA	NA	HM better than AV1	NA	NA
Performance Comparison	AV1 much slower than HM	NA	NA	NA	NA	AV1 much slower than AVC	NA

VVC is by far the most powerful technology today. It will be standardized by ISO and ITU by 2020. It is expected to draw a lot of attention on the technical side; however, similar to HEVC, it will not be a success unless the licensing situation is resolved upfront. There are initiatives that have started in this direction recently that make the industry believe the MPEG path might still be an option by 2020.

In this time of climate warming, where datacentres have a bigger carbon footprint than aviation, it would be inconsistent to neglect the complexity of video coding and only consider licensing costs. Hopefully, the future generation of the codec will combine high efficiency and reasonable costs in terms of licensing and energy consumption. The industry is certainly working hard at achieving this goal. ■

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AUTHORS

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