Updates on Thor, AV1 and CDEF

High Efficiency, Moderate Complexity

Video Codec using only RF IPR

(https://datatracker.ietf.org/ipr/2636/)

draft-fuldseth-netvc-thor-03

draft-midtskogen-netvc-cdef-00

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Thor status

- Since IETF99 support for CDEF has been added
- The single-pass version of CDEF was adopted in AV1, and Thor only supports that version
- Thor uses a faster and simpler RDO for CDEF
  - Can be improved further for a better compression/complexity trade-off for real-time encoders
  - Thor is much faster than the AV1 reference codec, so CDEF experimentation is more convenient in Thor, and improvements can easily be backported to AV1
- Support for Daala EC not yet completed

Some minor CDEF changes

- New skip block test
  - **Before**: No filtering only if all coding blocks within the 64x64 filter block were “skip” (i.e. no coded residual)
  - The CDEF preset had to be signalled at the end of the superblock since the test needed to know about partitioning
  - **Now**: No filtering if the coding block size is 64x64 (i.e. no partitioning) and the coding block is “skip”.
  - This allows the CDEF preset to be signalled right after the first skip bit, making it possible to apply the filter once a coding block has been decoded
  - Adds a slight coding overhead (fewer blocks are implicitly not filtered), and a slight complexity increase (but not for the worst case). But the loss is < 0.1%.

Some minor CDEF changes

- Adaptation for 128x128 superblocks
  - AV1 now supports 128x128 superblocks with the EXT_PARTITION experiment
  - CDEF still needs to signal at 64x64 resolution
  - So for 128x128 up to four CDEF presets must be signalled
  - The details not yet decided
  - Investigating possible compression impact

CDEF in Thor

- Running CDEF instead of CLPF gives objective gains
  - 0.5 – 2.2% – full results will follow on a separate slide
  - Fairly large gains for chroma (up to 4%)
- CDEF adds complexity, though
- Running CLPF on top of CDEF gives little gain
  - If the CDEF RDO is greatly simplified, CLPF does give gains
  - Adds a risk of over-filtering despite objective results
  - Adds buffering requirements
- Is CLPF still attractive for fast real-time encoders?
  - May be hard to make the CDEF RDO as fast as CLPF RDO, but it should be possible to come close.

Loop filter integration in AV1

- Three loop filters in AV1 applied in cascade (in this order):
  - Deblocking
  - CDEF
  - Loop restoration
- Without integration this cascade requires a line buffer of **30 lines** (for filterering a frame in a single pass). This is a significant hardware cost.
- Proposal from ARM (with contributions from Intel, Google and Mozilla) can reduce this to **16 lines**

Loop filter integration in AV1

- Basic ideas:
  - Outside the superblock, loop restoration (LR) will read the deblocked output rather than the CDEF output
  - Shift the CDEF/LR filtering to align with the output from the deblock filter
- Requires no normative changes to CDEF
- No impact on AWCY results (-0.01 – 0.03%)
- Makes the line buffer requirements for AV1 the same as for VP9.
- Will probably be adopted along with LR

CDEF encoder complexity

- CDEF works well even with greatly simplified rate-distortion optimisation (RDO)
- Even restricting the filter to do no block level signalling gives similar objective gains as CLPF
  - The encoder must still select the optimal CDEF parameters for every frame, but the search space becomes small
- Simplifications that work well:
  - Damping selected can be based on frame QP
  - The number of bits to signal per block can be selected based on frame type and bitrate
- Still many ways to improve the CDEF RDO

CDEF gains in Thor (AWCY)

Gains for deblocking + CDEF ← deblocking only:

- Low complexity, low delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-6.1689	-10.4772	-11.2394	-4.1280	-7.6027	-6.1057	-10.3280

- Low complexity, high delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-4.0168	-6.3353	-6.6232	-1.6408	-5.3347	-2.9643	-6.3557

- Medium complexity, low delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-4.8637	-7.8556	-8.0799	-2.6514	-5.5668	-4.0526	-7.6489

- Medium complexity, high delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-3.9115	-5.1303	-4.9574	-1.6244	-5.1654	-2.9807	-5.3456

- High efficiency, low delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-3.1898	-5.2852	-5.4605	-1.3447	-3.3103	-2.2294	-5.1828

- High efficiency, high delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-2.2629	-2.7290	-2.5596	-0.4865	-2.7491	-1.3874	-3.1324

CDEF gains in Thor (AWCY)

Gains for replacing CLPF with CDEF:

- Low complexity, low delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-0.8304	-4.0167	-3.6906	-0.7987	-1.3478	-1.1405	-2.1609

- Low complexity, high delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-0.9475	-2.8048	-2.4094	-0.7117	-0.9714	-0.7862	-1.8283

- Medium complexity, low delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-0.8560	-3.5034	-3.1839	-0.7653	-1.2580	-1.0508	-1.9946

- Medium complexity, high delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-0.7082	-2.5633	-2.3938	-0.7030	-1.0557	-0.9237	-1.4765

- High efficiency, low delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-0.5777	-2.6286	-2.3601	-0.5300	-1.0664	-0.8435	-1.5601

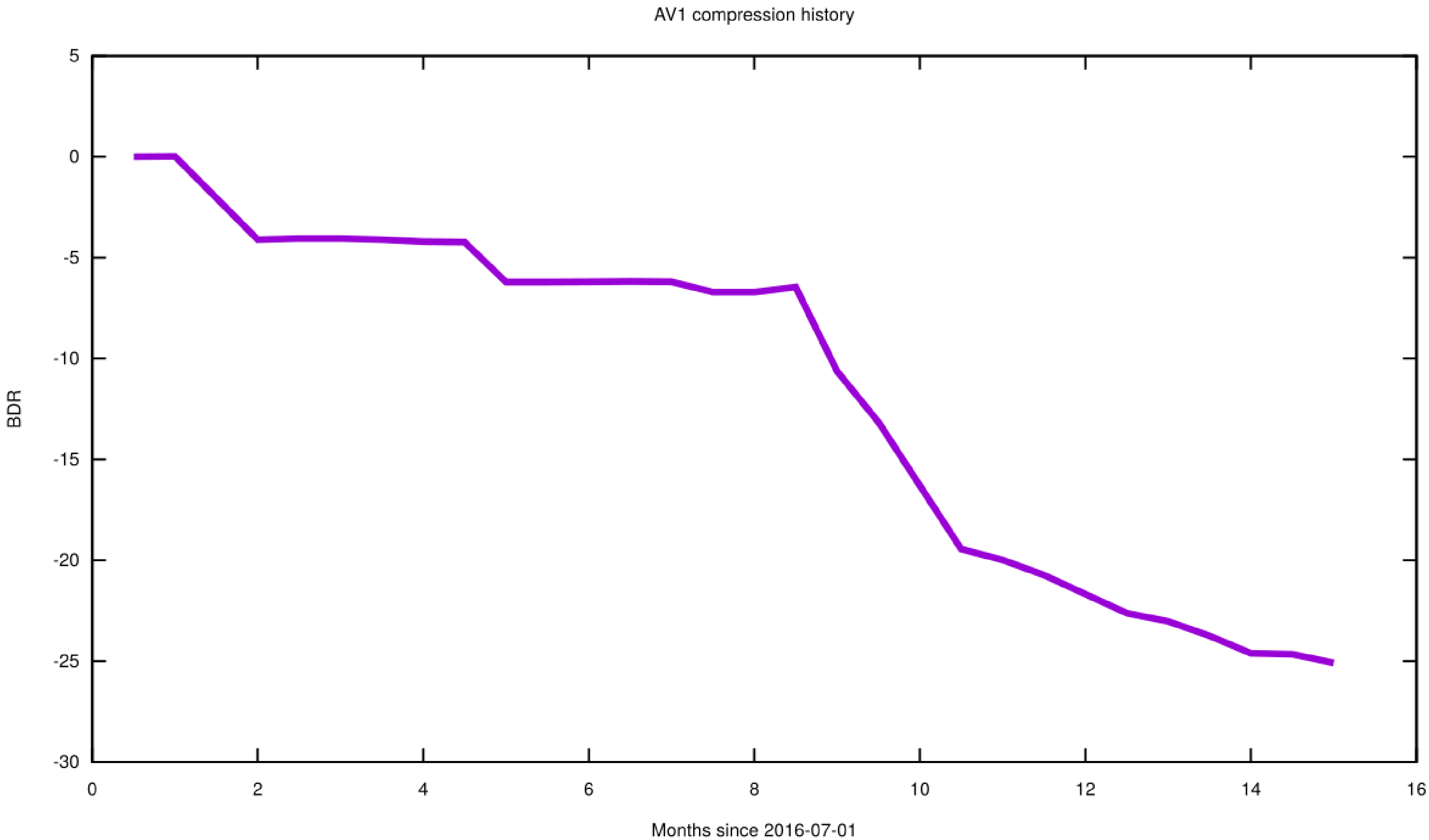
- High efficiency, high delay:

PSNR	PSNR Cb	PSNR Cr	PSNR HVS	SSIM	MS SSIM	CIEDE 2000
-0.4942	-1.6534	-1.5278	-0.4858	-0.9091	-0.7584	-1.0541

AV1 compression history

- Compression/speed relationships measured using AWCY
  - Mixed content: objective-1-fast
  - About 5% improvement since IETF99 and 2x complexity
- Low delay configuration
- BDR anchor is AV1 in July 2016, roughly equivalent to VP9
- Note that the speed axis is logarithmic

AV1 compression history



AV1 complexity history