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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IETF 100 – Singapore, SG – November 2017
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 $\leftrightarrow$ deblocking only:

- **Low complexity, low delay:**
  
  \[
  \begin{array}{cccccc}
  \text{PSNR} & \text{PSNR Cb} & \text{PSNR Cr} & \text{PSNR HVS} & \text{SSIM} & \text{MS SSIM} & \text{CIEDE 2000} \\
  \end{array}
  \]

- **Low complexity, high delay:**
  
  \[
  \begin{array}{cccccc}
  \text{PSNR} & \text{PSNR Cb} & \text{PSNR Cr} & \text{PSNR HVS} & \text{SSIM} & \text{MS SSIM} & \text{CIEDE 2000} \\
  \end{array}
  \]

- **Medium complexity, low delay:**
  
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  \text{PSNR} & \text{PSNR Cb} & \text{PSNR Cr} & \text{PSNR HVS} & \text{SSIM} & \text{MS SSIM} & \text{CIEDE 2000} \\
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  \end{array}
  \]

- **High efficiency, high delay:**
  
  \[
  \begin{array}{cccccc}
  \text{PSNR} & \text{PSNR Cb} & \text{PSNR Cr} & \text{PSNR HVS} & \text{SSIM} & \text{MS SSIM} & \text{CIEDE 2000} \\
  -2.2629 & -2.7290 & -2.5596 & -0.4865 & -2.7491 & -1.3874 & -3.1324 \\
  \end{array}
  \]

CDEF gains in Thor (AWCY)

Gains for replacing CLPF with CDEF:

- **Low complexity, low delay:**
  
<table>
<thead>
<tr>
<th>PSNR</th>
<th>PSNR Cb</th>
<th>PSNR Cr</th>
<th>PSNR HVS</th>
<th>SSIM</th>
<th>MS SSIM</th>
<th>CIEDE 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.8304</td>
<td>-4.0167</td>
<td>-3.6906</td>
<td>-0.7987</td>
<td>-1.3478</td>
<td>-1.1405</td>
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</thead>
<tbody>
<tr>
<td>-0.9475</td>
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<td>-2.4094</td>
<td>-0.7117</td>
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<td>-0.7862</td>
<td>-1.8283</td>
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<tr>
<td>-0.8560</td>
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<td>-3.1839</td>
<td>-0.7653</td>
<td>-1.2580</td>
<td>-1.0508</td>
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<tr>
<td>-0.7082</td>
<td>-2.5633</td>
<td>-2.3938</td>
<td>-0.7030</td>
<td>-1.0557</td>
<td>-0.9237</td>
<td>-1.4765</td>
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</thead>
<tbody>
<tr>
<td>-0.5777</td>
<td>-2.6286</td>
<td>-2.3601</td>
<td>-0.5300</td>
<td>-1.0664</td>
<td>-0.8435</td>
<td>-1.5601</td>
</tr>
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</thead>
<tbody>
<tr>
<td>-0.4942</td>
<td>-1.6534</td>
<td>-1.5278</td>
<td>-0.4858</td>
<td>-0.9091</td>
<td>-0.7584</td>
<td>-1.0541</td>
</tr>
</tbody>
</table>
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