

JCTVC-N0223 NON-RCE1: IN-LOOP CHROMA ENHANCEMENT FOR HEVC RANGE EXTENSIONS

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invention | collaboration | contribution

Introduction

- This contribution is proposed as an in-loop processing for HEVC RExt.
 - Goal: enhance the chroma planes of a reconstructed picture and the accuracy of future chroma MCP.
 - Methodology: enhance the chroma planes using the corresponding information from the luma plane.
 - Performed after SAO and before added to DPB
- Has been proposed to SHVC for inter-layer prediction in previous meetings
- Performance (use Random Access as an example)

| | RA Main-tier | | | RA High-tier | | |
|-----------|--------------|----------|----------|--------------|----------|----------|
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) |
| RGB 4:4:4 | -0.2% | -4.4% | -7.6% | -0.2% | -2.6% | -5.3% |
| YUV 4:4:4 | 0.6% | -4.3% | -8.4% | 0.2% | -3.3% | -8.3% |
| YUV 4:2:2 | 0.2% | -9.2% | -9.3% | 0.0% | -4.9% | -6.8% |

Overview of Chroma Enhancement Filtering

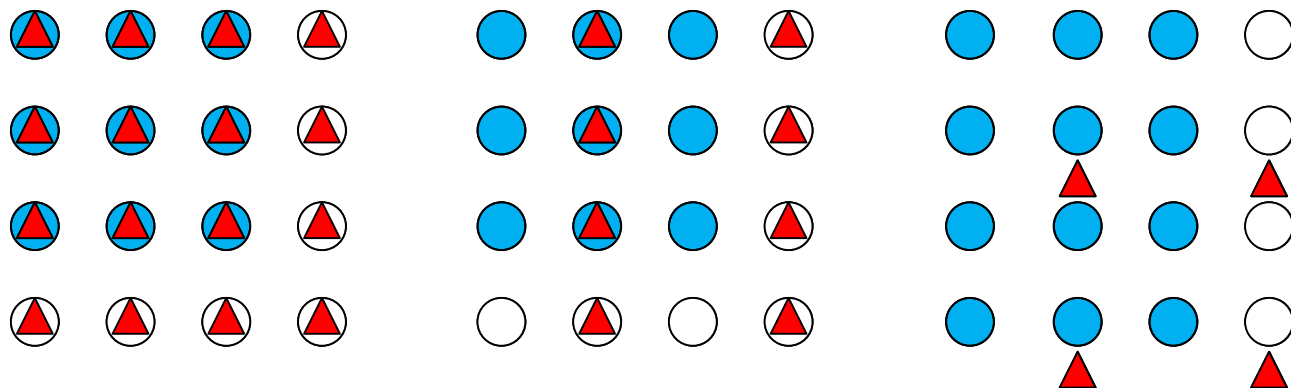
- Each chroma pixel is added by an offset

$$Cb_{enh}(x,y) = Cb(x,y) + o(x,y)$$

- Offset is the output of applying a high-pass filter f_{Cb} to the surrounding $W \times H$ luma pixels (W and H are signaled in bitstream)

$$o(x,y) = \sum_{j=-H/2}^{H/2} \sum_{i=-W/2}^{W/2} f_{Cb}(i,j) Y(s_x x - i, s_y y - j)$$

(s_x, s_y) equal to (1, 1), (2, 1), and (2, 2) for 4:4:4, 4:2:2, and 4:2:0, respectively.



4:4:4

4:2:2

4:2:0

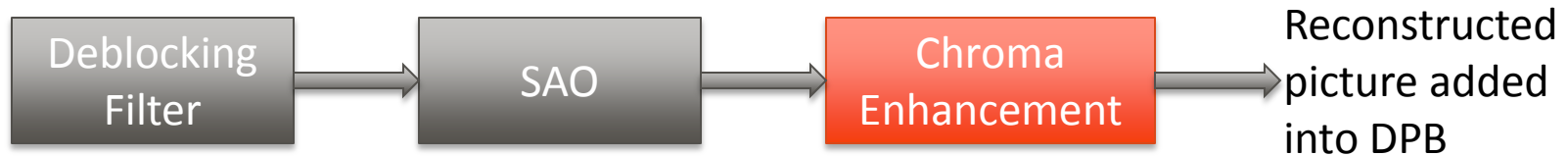
○ Luma sample

▲ Chroma sample

Filter Training and Signaling

- Filter derivation on the encoder side
 - Use Least Minimum MSE (LMMSE) estimator to minimize the MSE between the reconstructed and original chroma planes
- Quantization:
 - 16-level uniform quantizer
 - Quantization stepsize: $Q_{Cb}/2^{N_{Cb}}$
- $$h_{Cb,opt}(i, j) = f_{Cb}(i, j) \times \frac{Q_{Cb}}{2^{N_{Cb}}}$$
- Signaling
 - Slice header
 - W and H : coded using ue(v)
 - Flag indicating On/Off for certain chroma plane: 1-bit
 - $(W-1) \times (H-1)$ filter coefficients: 4 bits each, the rest one is derived based on zero-sum constraint
 - Q_{Cb} : 11 bits (10 bits for magnitude and 1 bit for sign)
 - N_{Cb} : 5 bits
 - SPS
 - 1-bit flag: indicating On/Off for the coded video sequence

Process of Chroma Enhancement



- Filter the surrounding $W \times H$ luma pixels to get the scaled offset $z(x,y)$

$$z(x, y) = \sum_{j=-H/2}^{H/2} \sum_{i=-W/2}^{W/2} f_{Cb}(i, j) Y(s_x x - i, s_y y - j)$$

- Normalize and round $z(x,y)$ to $o(x,y)$

$$o(x,y) = \text{Sign}(z(x,y) \gg Q_{Cb}) \left((\text{Abs}(z(x,y) \gg Q_{Cb}) + (1 \ll (N_{Cb}-1))) \gg N_{Cb} \right)$$

- Add offset $o(x,y)$

$$Cb_{enh}(x,y) = Cb(x,y) + o(x,y)$$

BD-Rate Compared with HEVC RExt. (W H = 5 5)

| | AI Main-tier | | | AI High-tier | | | AI Super-High-tier | | |
|-----------|----------------|----------|----------|----------------|----------|----------|--------------------|----------|----------|
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) |
| RGB 4:4:4 | 0.0% | -0.9% | -1.8% | 0.0% | -0.5% | -1.1% | 0.0% | -0.2% | -0.6% |
| YUV 4:4:4 | 0.0% | -3.0% | -6.0% | 0.0% | -1.8% | -4.8% | 0.0% | -0.9% | -3.1% |
| YUV 4:2:2 | 0.0% | -5.2% | -7.0% | 0.0% | -2.1% | -3.7% | 0.0% | -0.7% | -1.5% |
| | RA Main-tier | | | RA High-tier | | | | | |
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) | | | |
| RGB 4:4:4 | -0.2% | -4.4% | -7.6% | -0.2% | -2.6% | -5.3% | | | |
| YUV 4:4:4 | 0.6% | -4.3% | -8.4% | 0.2% | -3.3% | -8.3% | | | |
| YUV 4:2:2 | 0.2% | -9.2% | -9.3% | 0.0% | -4.9% | -6.8% | | | |
| | LD-B Main-tier | | | LD-B High-tier | | | | | |
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) | | | |
| RGB 4:4:4 | -1.3% | -4.1% | -7.1% | -0.7% | -2.2% | -4.6% | | | |
| YUV 4:4:4 | 0.7% | -3.0% | -7.1% | 0.0% | -2.0% | -6.5% | | | |
| YUV 4:2:2 | 0.2% | -6.7% | -5.8% | 0.0% | -3.8% | -4.2% | | | |

BD-Rate Compared with HEVC RExt. (W H = 3 3)

| | AI Main-tier | | | AI High-tier | | | AI Super-High-tier | | |
|-----------|----------------|----------|----------|----------------|----------|----------|--------------------|----------|----------|
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) |
| RGB 4:4:4 | 0.0% | -0.8% | -1.3% | 0.0% | -0.5% | -0.9% | 0.0% | -0.2% | -0.5% |
| YUV 4:4:4 | 0.0% | -2.0% | -5.2% | 0.0% | -1.2% | -4.3% | 0.0% | -0.7% | -2.9% |
| YUV 4:2:2 | 0.0% | -3.6% | -5.5% | 0.0% | -1.4% | -2.7% | 0.0% | -0.5% | -1.0% |
| | RA Main-tier | | | RA High-tier | | | | | |
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) | | | |
| RGB 4:4:4 | -0.3% | -4.3% | -6.8% | -0.3% | -2.6% | -4.9% | | | |
| YUV 4:4:4 | 0.3% | -3.0% | -6.8% | 0.1% | -2.1% | -6.4% | | | |
| YUV 4:2:2 | 0.1% | -7.3% | -7.4% | 0.0% | -3.8% | -5.0% | | | |
| | LD-B Main-tier | | | LD-B High-tier | | | | | |
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) | | | |
| RGB 4:4:4 | -1.1% | -3.5% | -6.0% | -0.7% | -2.0% | -3.9% | | | |
| YUV 4:4:4 | 0.4% | -1.8% | -4.8% | 0.0% | -1.2% | -4.4% | | | |
| YUV 4:2:2 | 0.1% | -3.6% | -3.3% | 0.0% | -2.3% | -2.4% | | | |

Conclusion

- Enhance the chroma planes of the reconstructed picture using the corresponding information from the luma plane
- Average BD-rate compared with HEVC RExt. (filter size 5 5, use RA as an example)

| | RA Main-tier | | | RA High-tier | | |
|-----------|--------------|----------|----------|--------------|----------|----------|
| | Y (or G) | U (or B) | V (or R) | Y (or G) | U (or B) | V (or R) |
| RGB 4:4:4 | -0.2% | -4.4% | -7.6% | -0.2% | -2.6% | -5.3% |
| YUV 4:4:4 | 0.6% | -4.3% | -8.4% | 0.2% | -3.3% | -8.3% |
| YUV 4:2:2 | 0.2% | -9.2% | -9.3% | 0.0% | -4.9% | -6.8% |

- We suggest further studying this proposal in a core experiment.