JCTVC-L0059: CHROMA ENHANCEMENT FOR ILR PICTURE

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Introduction

- This contribution is proposed for Ref_Idx framework.

- Observation of chroma planes

  - Pixel values have small dynamic range

  - Severely blurred at medium to high QPs

- Motivation: improve the chroma quality of the ILR picture, and thus the efficiency of EL chroma coding

- Methodology: Enhance the chroma planes of the ILR picture using the corresponding information from the luma plane.

- Performance (BL+EL): Average BD-rate compared with SMuC v0.1.1 Ref_Idx framework

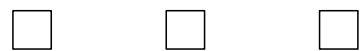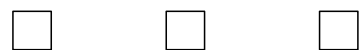|	AI 2x	AI 1.5x	RA 2x	RA 1.5x	RA SNR	LP 2x	LP 1.5x	LP SNR
Y	-0.8%	-0.8%	-0.4%	-0.3%	-0.3%	-0.2%	-0.2%	-0.2%
U	-7.3%	-9.3%	-9.8%	-12.0%	-10.5%	-6.2%	-7.8%	-7.1%
V	-8.6%	-11.8%	-9.6%	-14.2%	-9.6%	-5.7%	-10.2%	-6.7%

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Chroma Enhancement for ILR Picture

- Each chroma pixel is added by an offset

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

- Offset is output of applying a high-pass filter f_{Cb} to the surrounding 3 4 luma pixels

$$o(x, y) = \sum_{j=-2}^{1} \sum_{i=-1}^{1} f_{Cb}(i, j) Y(2x - i, 2y - j)$$

🔴 Chroma pixel (Cb or Cr)

⬜ Luma pixel (Y)

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High-Pass Filter Design

- Use Least Minimum MSE (LMMSE) estimator to minimize the MSE between chroma planes in enhanced ILR picture and original EL picture

$$h_{Cb,opt} = \arg\min_{h_{Cb}} E\left[\left(\sum_{j=-2}^{1}\sum_{i=-1}^{1} h_{Cb}(i,j)Y(2x-i,2y-j) + Cb(x,y) - S_{Cb}(x,y)\right)^2\right]$$

Y: Luma plane of ILR picture

Cb: Cb plane of ILR picture

S_{Cb}:   Cb plane in original EL picture

$h_{Cb,Opt}$:   Optimal high-pass filter for Cb plane

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Quantizing and Signaling High-Pass Filter

- 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 (65 bits for each chroma plane)
    - 1-bit flag: indicating On/Off for certain chroma plane
    - 3 4 filter coefficients: 4 bits each
    - 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

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Process of Chroma Enhancement

- Filter the surrounding 3 4 luma pixels to get the real-valued and scaled offset $z(x,y)$

$$z(x, y) = \sum_{j=-2}^{1} \sum_{i=-1}^{1} f_{Cb}(i, j) Y(2x - i, 2y - j)$$

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

  - If $z(x, y) \times Q_{Cb} > 0$, $o(x, y) = (z(x, y) \times Q_{Cb} + 2^{N_{Cb}-1}) >> N_{Cb}$.

  - Otherwise, $o(x, y) = -(-z(x, y) \times Q_{Cb} + 2^{N_{Cb}-1}) >> N_{Cb}$.

- Add offset $o(x,y)$

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

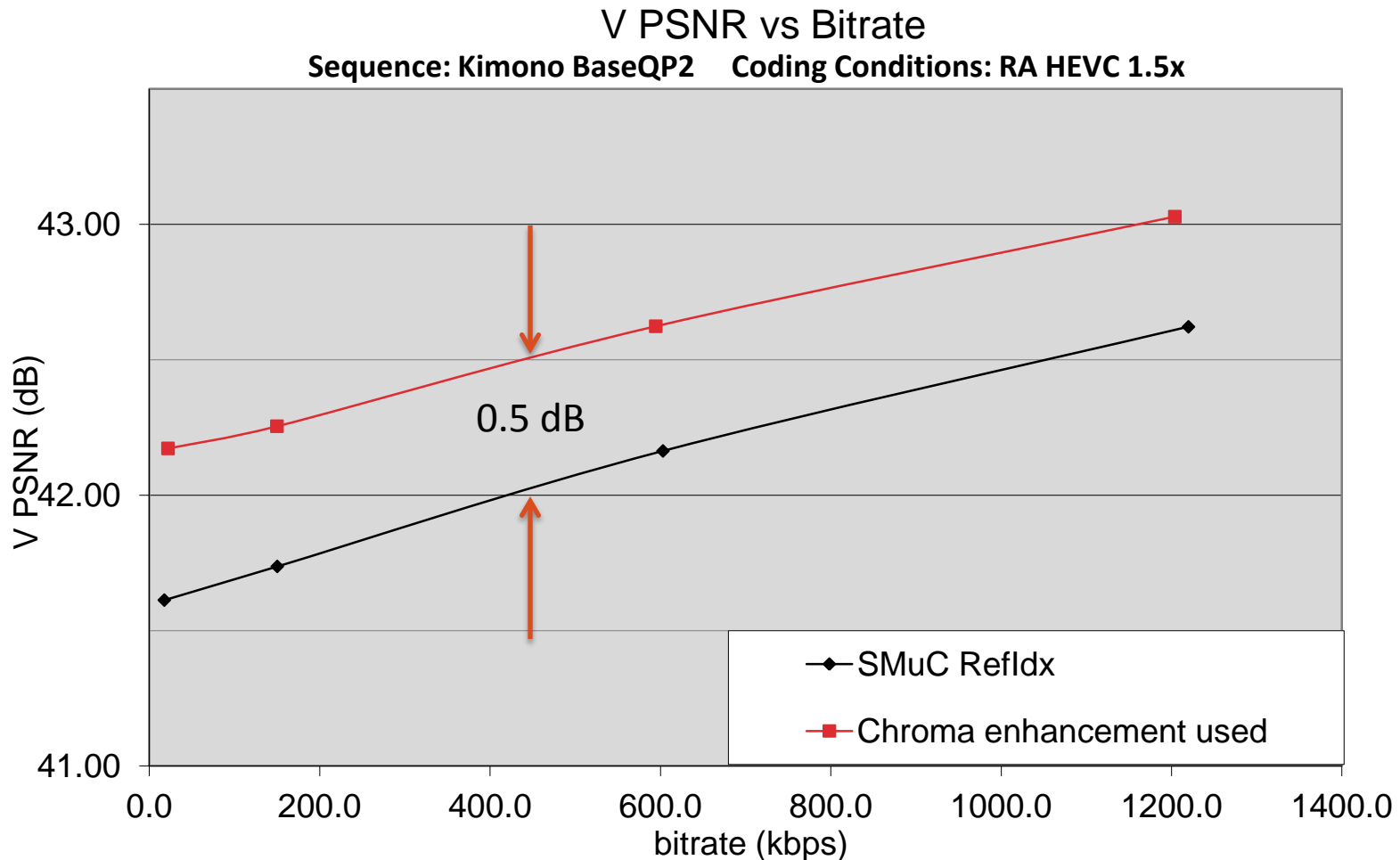INTERDIGITAL.

BD-Rate Compared with SMuC v0.1.1 Ref_Idx

	AI HEVC 2x			AI HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-0.9%	-8.3%	-6.9%			
Class B	-0.8%	-7.0%	-9.3%	-0.8%	-9.3%	-11.8%
Overall (EL+BL)	-0.8%	-7.3%	-8.6%	-0.8%	-9.3%	-11.8%
Overall (EL)	-1.6%	-14.0%	-15.7%	-2.1%	-27.1%	-31.9%
Enc Time[%]	102.5%			102.7%		
Dec Time[%]	105.5%			107.8%		

	RA HEVC 2x			RA HEVC 1.5x			RA HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	-0.5%	-13.1%	-7.8%				-0.4%	-12.4%	-6.9%
Class B	-0.3%	-8.5%	-10.4%	-0.3%	-12.0%	-14.2%	-0.3%	-9.8%	-10.7%
Overall (EL+BL)	-0.4%	-9.8%	-9.6%	-0.3%	-12.0%	-14.2%	-0.3%	-10.5%	-9.6%
Overall (EL)	-0.6%	-16.9%	-15.8%	-0.6%	-27.4%	-29.9%	-0.5%	-19.6%	-17.6%
Enc Time[%]	108.1%			103.9%			94.8%		
Dec Time[%]	115.5%			109.5%			104.2%		

	LD-P HEVC 2x			LD-P HEVC 1.5x			LD-P HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	-0.2%	-9.8%	-4.9%				-0.2%	-9.3%	-5.3%
Class B	-0.2%	-4.8%	-6.0%	-0.2%	-7.8%	-10.2%	-0.2%	-6.3%	-7.3%
Overall (EL+BL)	-0.2%	-6.2%	-5.7%	-0.2%	-7.8%	-10.2%	-0.2%	-7.1%	-6.7%
Overall (EL)	-0.4%	-10.9%	-9.6%	-0.4%	-18.7%	-21.1%	-0.3%	-12.6%	-11.6%
Enc Time[%]	104.5%			108.8%			101.2%		
Dec Time[%]	113.5%			116.7%			109.5%		

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An Example of R-D Curve (EL only)

- Cr R-D curve of *Kimono* (BaseQP=30, RA 1.5x)

V PSNR vs Bitrate

Sequence: Kimono BaseQP2   Coding Conditions: RA HEVC 1.5x

0.5 dB

- SMuC RefIdx
- Chroma enhancement used

V PSNR (dB) vs bitrate (kbps)

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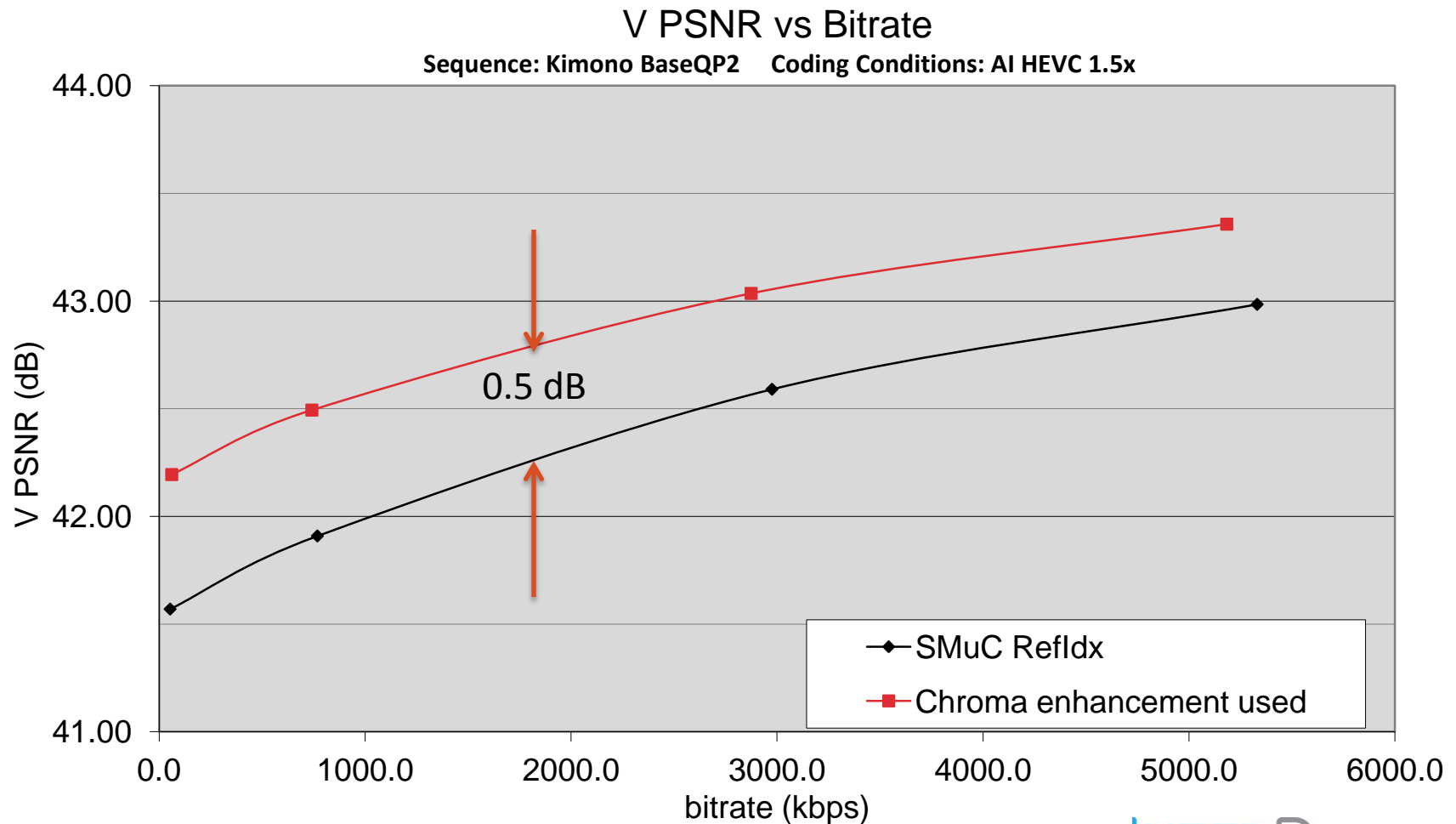
Conclusion

- Enhance the chroma planes of the ILR picture using the corresponding information from the luma plane
- Average BD-rate compared with SMuC v0.1.1 Ref_Idx framework

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- Visual example of IRL improvement available in document
- We suggest adopting it into test model for further investigation.

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