Impact Analysis of Baseband Quantizer on Coding Efficiency for HDR Video

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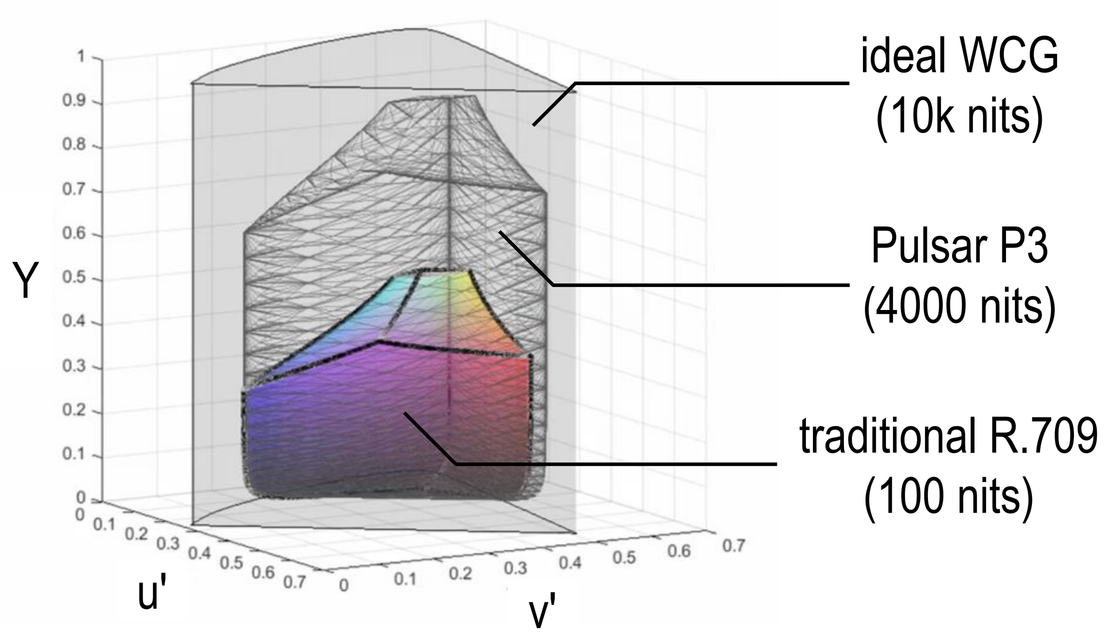
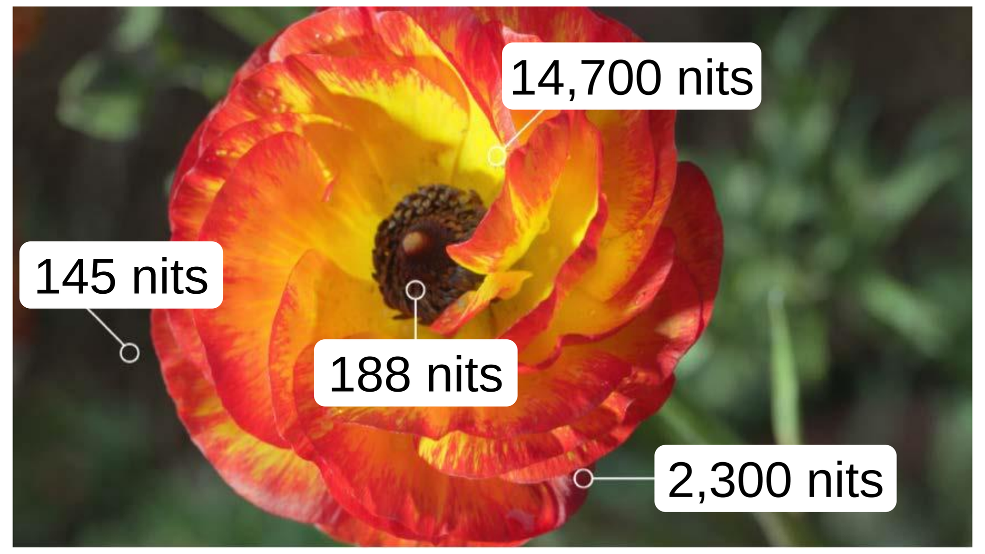
HDR Video: More and Better Pixels

- Major factors of more vivid videos: more pixels, and ***better*** pixels.
- "Better pixels": wide color gamut (WCG) + high dynamic range (HDR).

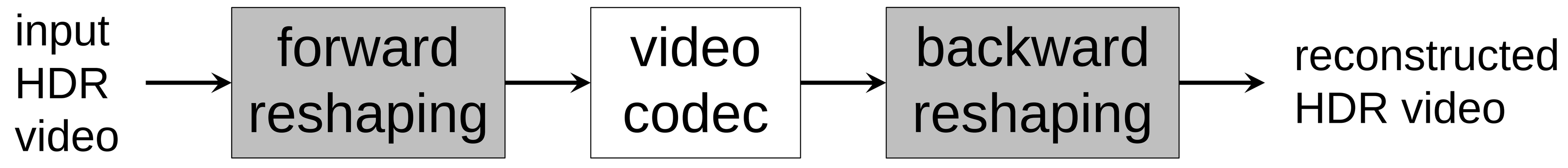


Motivation for Studying "Reshaping"

- State-of-the-art color coding standard (SMPTE ST. 2084): ***perceptual quantizer (PQ)***. 12 bits for luminance levels.
- Reuse legacy 8- or 10-bit video codecs by ***reshaping***, or baseband quantization.



Reproduced from Dolby Vision White Paper.
nit = cd/m^2 (candela per square meter)

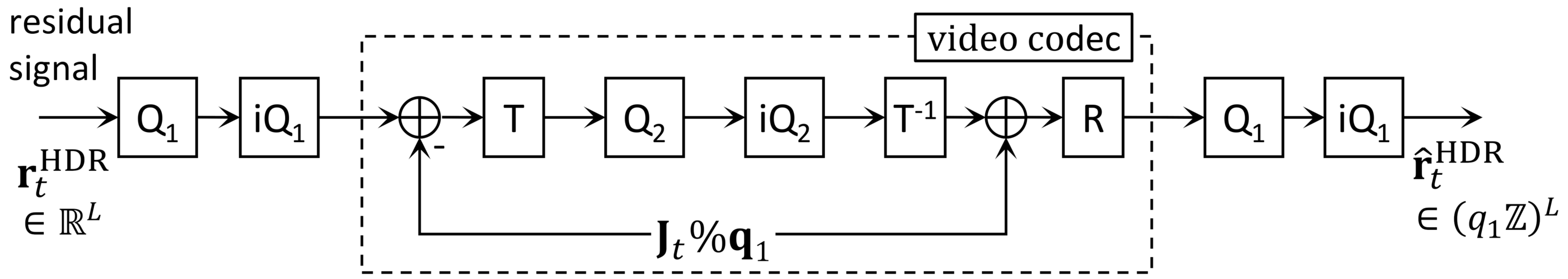


- Existing art lacks of the understandings of the quantitative balance between ***baseband quantizer*** and ***codec quantizer***. Solid analysis is needed to support practitioners' decisions.

Outline of Analysis

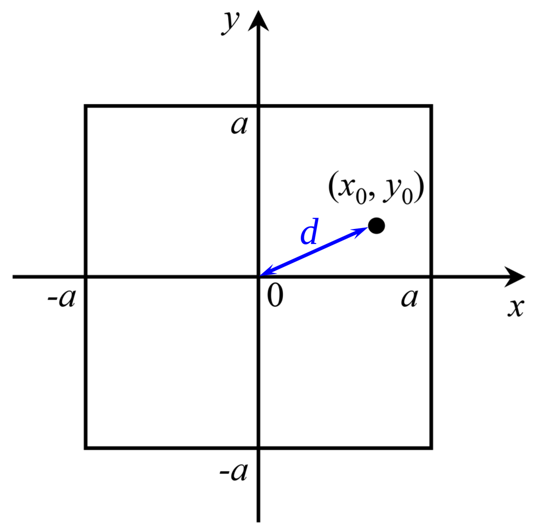
Establish relationship between ***strength of baseband quantizer*** and coding efficiency measured in peak signal-to-noise ratio (***PSNR***).

1. Problem simplification (Lemma 2): quantify the error in reconstructed ***residues*** instead of in reconstructed ***images***. Avoid the predictive coding loop in analysis.



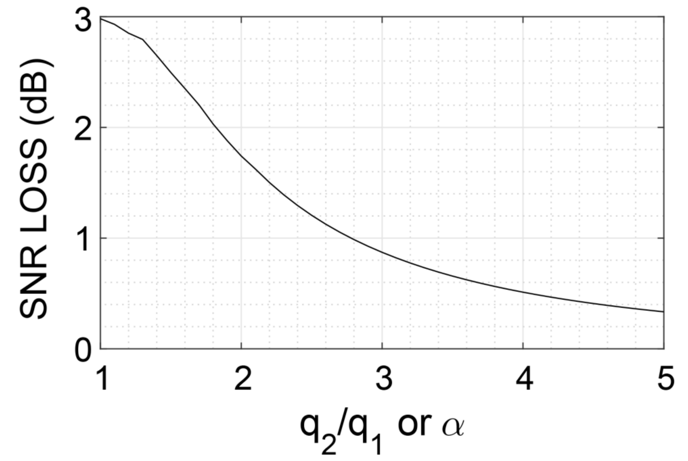
2. Error quantification for a single region (Lemma 1): use the error of the centroid as the reconstruction error of a region:

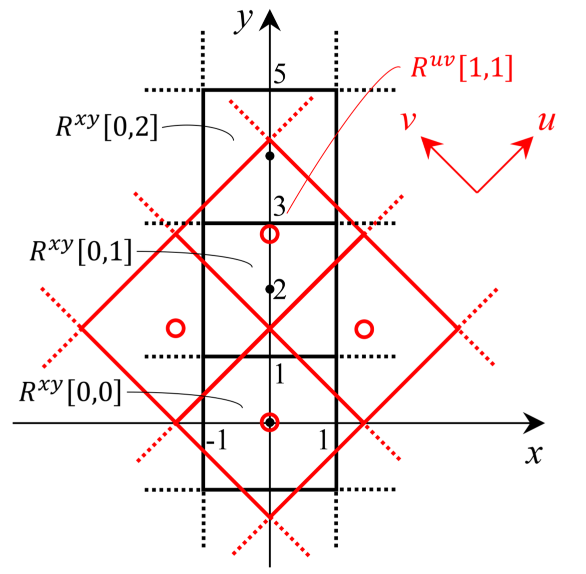
$$\mathrm{MSE}[\|(X,Y)-(x_0,y_0)\|^2] = d^2 + \frac{2}{3}a^2$$



3. Joint analysis: obtain overall distortion, $D(q_1,q_2) = \frac{N}{12}[q_2^2 + (1+\gamma_1)q_1^2 + 2\gamma_{12}q_2q_1]$, contributed jointly by baseband quantizer ($\mathcal{Q}_1$) and codec quantizer ($\mathcal{Q}_2$).

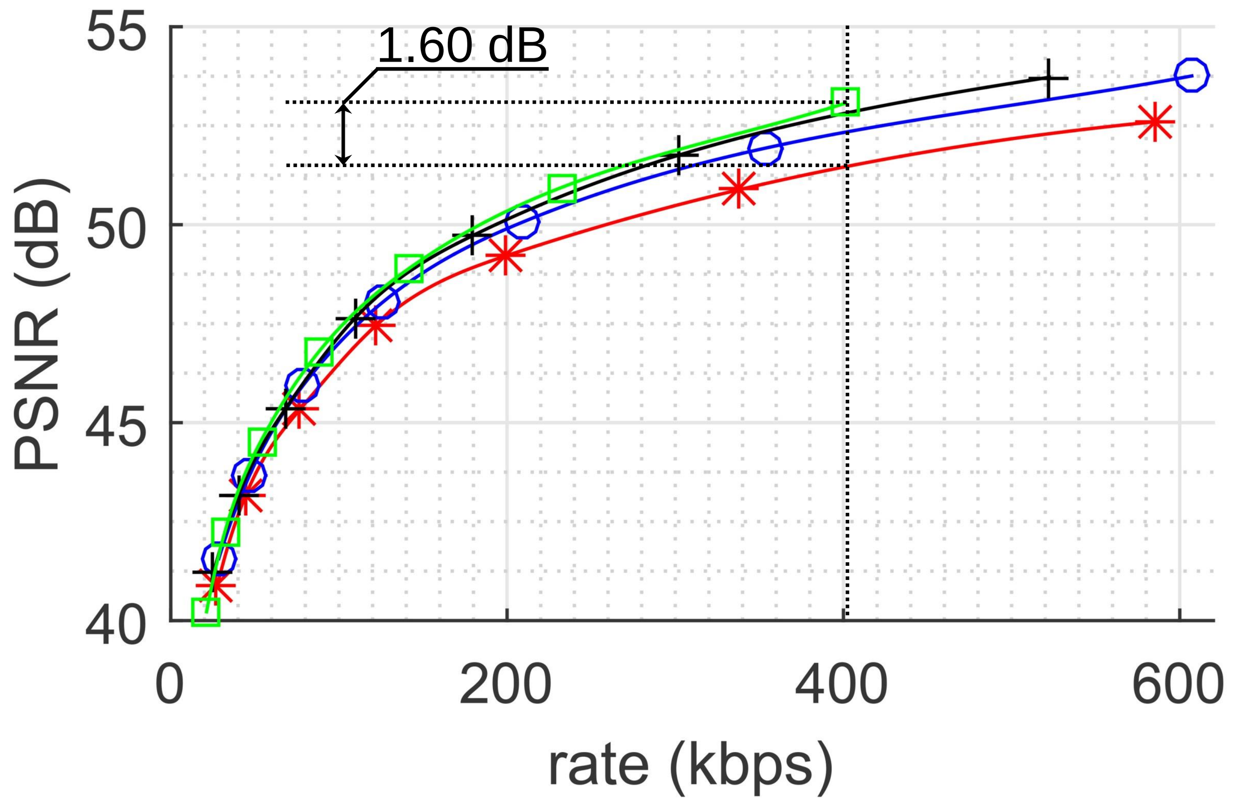
$$\text{SNR Loss} = 10\log_{10}\left[\frac{D(q_1,q_2)}{D(0,q_2)}\right]$$

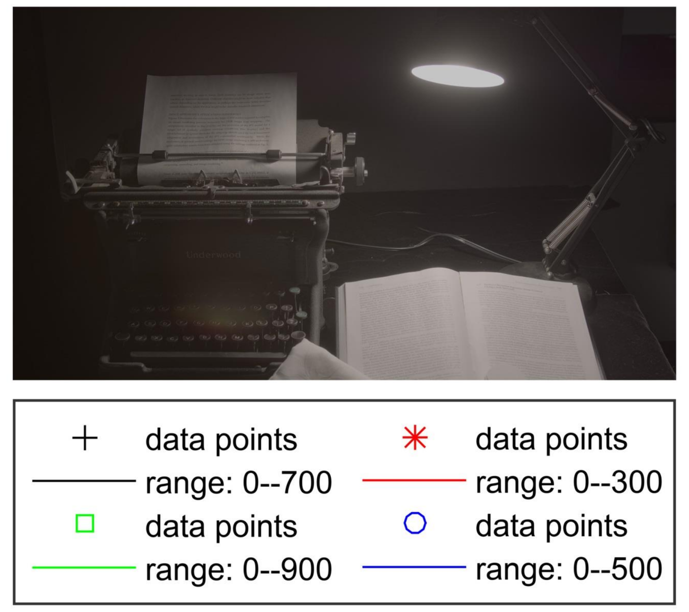




Experimental Results

- Conditions: HM14.0, Luma, BT.2020 color space, 12-bit PQ, 1920x1080. Sequence Typewriter. Intercoded.
- BD PSNR (29–401kbps): 1.12dB. PSNR gap at high bitrate: 1.6dB.





Conclusion

- Analyzed the video coding pipeline by explicitly considering the existence of the baseband quantizer.
- The baseband quantizer lowers the coding efficiency, whereas the codec quantizer does not.
- Hence, video information reduction should be incurred in the video codec instead of on the baseband signal.

Chau-Wai Wong, Guan-Ming Su, and Min Wu, "Impact analysis of baseband quantizer on coding efficiency for HDR video," *IEEE Signal Processing Letters (SPL)*, vol.23, no.10, pp.1354–1358, Oct. 2016. (Source code is available on the authors' webpages.)