HVS-BASED PERCEPTUAL COLOR COMPRESSION OF IMAGE DATA

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Outline

- RGB Still Image Coding in HEVC HM RExt
- Motivation for the Proposed PCC Technique
- Coding Block (CB)-Level Quantization
- Spectral Sensitivity and JNCD Modeling
- Perceptual Quantization Operations
- Experimental Setup and Evaluation Results
- Subjective Evaluations, Metrics and Scores
- Subjective Evaluation Results
- Discussion, Conclusions and Future Work
- References

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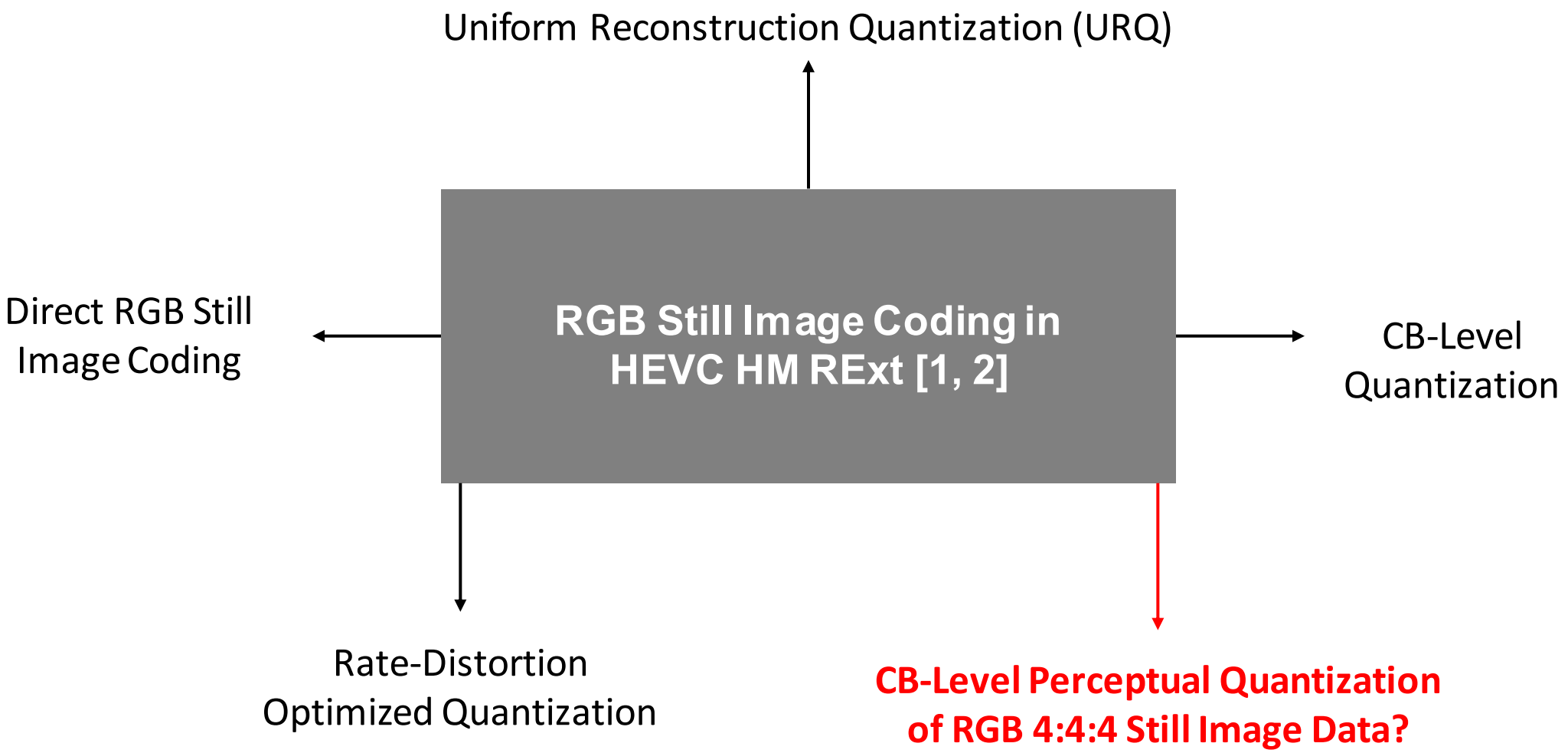
RGB Still Image Coding in HEVC HM RExt



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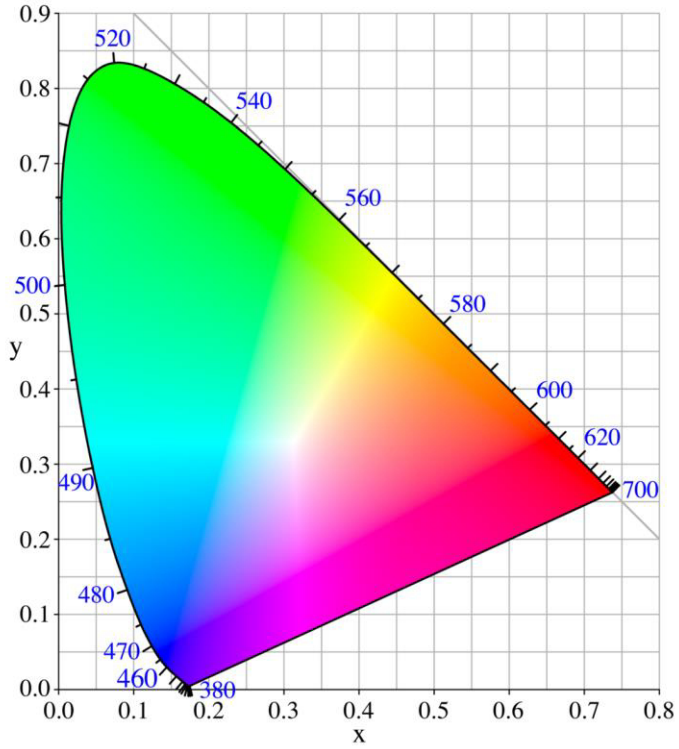
Motivation for the Proposed PCC Technique

- The perceptual optimization for RGB still image coding is not exploited in HEVC HM RExt.
- RGB 4:4:4 still image data potentially contains vast amounts of perceptual redundancy [3].
  - The visually lossless coding of RGB data can give rise to considerable file size reductions, as quantified by Bits Per Pixel Per Channel (BPP).
- Perceptual Quantization (PQ) in the PCC Method
  - Coding Block (CB)-Level PQ
    - PQ performed on G, B and R CBs.
    - PQ is based on spectral sensitivity and JNCD modeling.
    - PCC achieves visually lossless coding.



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Coding Block (CB)-Level Quantization

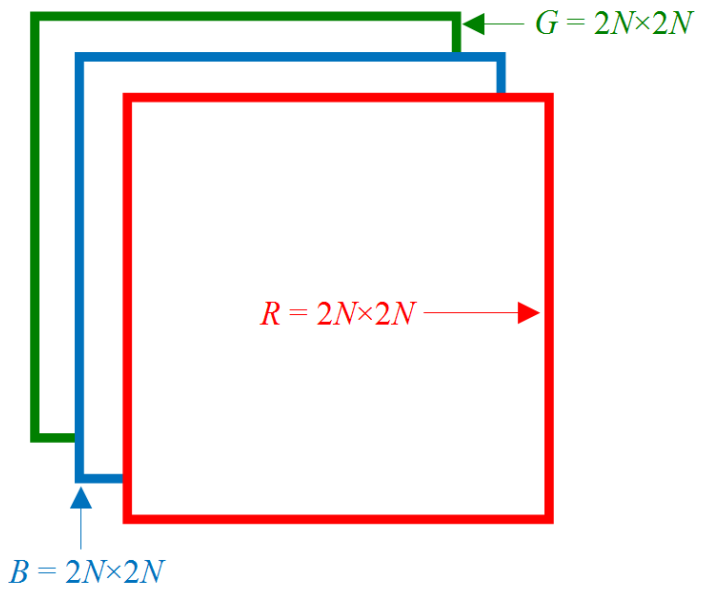

Figure 1: Illustration of R, G and B CBs in the HEVC standard.

- HEVC RExt enables the Quantization Step Size (QStep) to be modified at the RGB CB level [2, 3].
  - JCT-VC provides the flexibility for data in $2N \times 2N$ G, B and R CBs to be separately quantized [2] (see Figure 1).
  - Perceptual redundancy in RGB 4:4:4 still image data is often very high.

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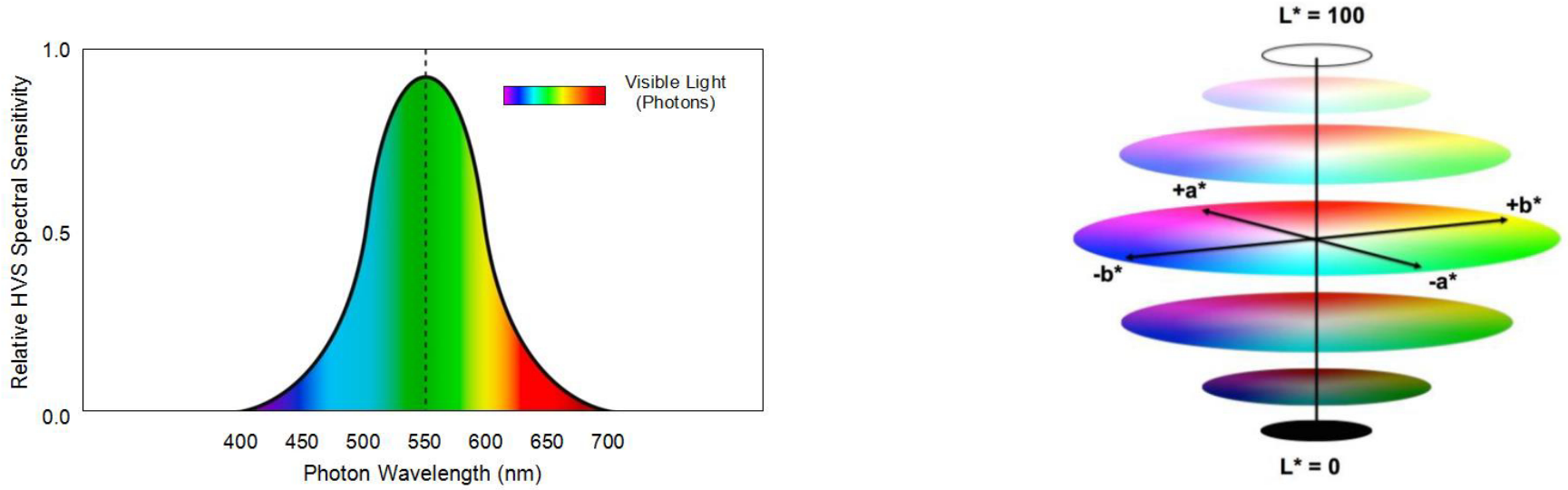
Spectral Sensitivity and JNCD Modeling



(a) **(b)**

Figure 2: (a) Relative HVS spectral sensitivity of visible light photons. (b) Conceptual diagram of CIELAB.

- The HVS is much more sensitive to the brightness of photons that are perceived as green [4, 5]; see Figure 2 (a). As such, PCC employs spectral sensitivity modelling during CB-level quantization.
- We utilize the CIELAB color difference formula, ΔE_{ab} [6]. Note that ΔE_{ab} is a quasi-Euclidean distance metric. JNCD is computed as $\Delta E_{ab} \approx 2.3$; see Figure 2 (b) for a illustration of CIELAB.

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Perceptual Quantization Operations

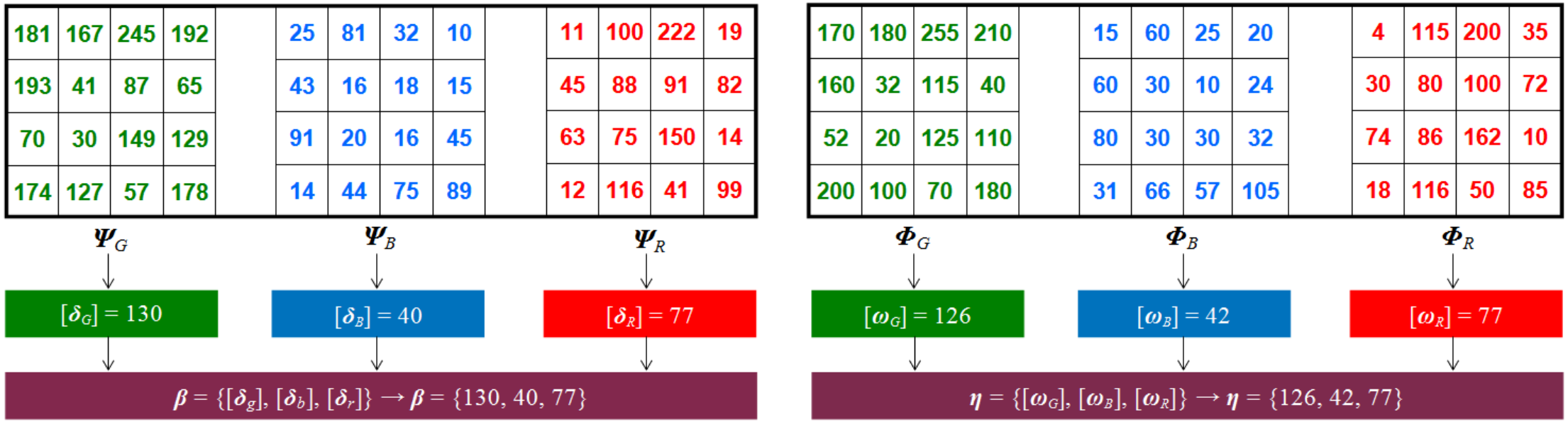

Figure 3: Illustration of spectral sensitivity-based CU-level perceptual quantization in PCC.

- As shown in Figure 3, for brevity the perceptual quantization process is shown using toy 4×4 raw G, B and R CBs (Ψ_G, Ψ_B and Ψ_R) and toy 4×4 reconstructed G, B and R CBs (Φ_G, Φ_B and Φ_R) within raw and reconstructed CUs, respectively. This figure is shown to illustrate the computation of the JNCD threshold (i.e., CIELAB $\Delta E_{ab} \approx 2.3$), which is integral to PCC.

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Experimental Setup and Evaluation Results

Table 1: Tabulated BPP, SSIM, MS-SSIM and MOS results for PCC versus four anchor methods.

Bits Per Pixel (BPP), SSIM and MS-SSIM Scores and MOS for Proposed PCC Method versus Reference Techniques																				
	Bits Per Pixel (BPP)					SSIM					MS-SSIM					MOS (Rounded)				
RGB Data	PCC	SPAQ	FDPQ	VVC	HEVC	PCC	SPAQ	FDPQ	VVC	HEVC	PCC	SPAQ	FDPQ	VVC	HEVC	PCC	SPAQ	FDPQ	VVC	HEVC
BirdsInCage	0.40	0.60	1.00	1.05	1.10	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5
Bubbles	0.51	0.82	1.17	1.04	1.11	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5
CrowdRun	2.16	3.92	5.03	5.57	5.85	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5
CT	0.32	0.36	0.59	0.44	0.47	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5
DucksAndLegs	2.21	3.79	4.69	5.38	5.55	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5
Kimono	0.50	1.01	1.87	1.82	1.90	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	4
OldTownCross	1.30	3.33	4.57	5.26	5.49	0.99	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.99	0.99	5	5	5	5	5
ParkScene	1.10	2.35	3.33	3.58	3.78	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	4	5	5	5	5
Seeking	1.71	3.74	4.81	5.53	5.80	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	4	5	5	5	5
Traffic	1.14	1.35	1.95	1.83	2.03	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5
VenueVu	0.64	0.73	1.07	0.92	1.01	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	4	4	4	4	4
WSI (4K)	0.53	0.52	0.78	0.63	0.66	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	5	5	5	5	5

- Experimental Setup: PCC versus four anchors (SPAQ, FDPQ, VVC VTM 10.0 and HEVC HM RExt 16.20); All Intra coding and 12 RGB 4:4:4 raw images (11 HD 1080p and One 4K).
- Quantification: BPP reductions, subjective evaluation (MOS) and perceptual quality metrics (SSIM and MS-SSIM).
- Best Result: Kimono — 72.5% BPP reduction (versus VVC) in addition to MOS = 5, SSIM ≥ 0.99, and also MS-SSIM ≥ 0.99 in all tests conducted (see Table 1).

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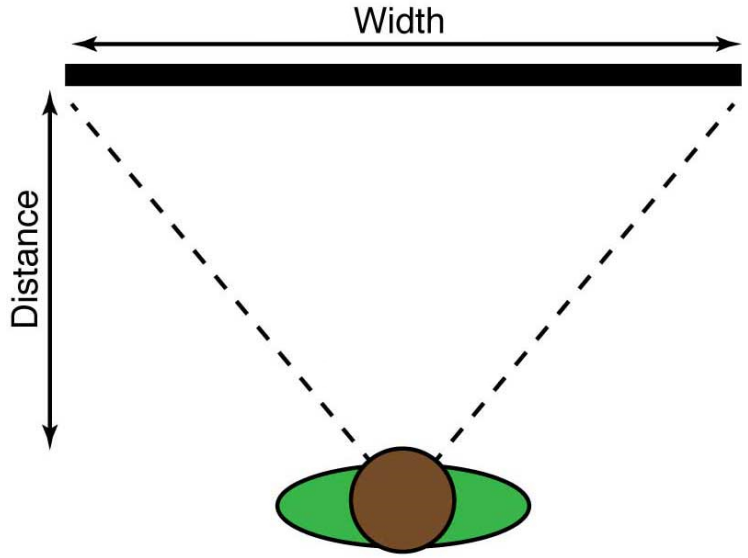
Subjective Evaluation, Metrics and Scores

- ITU.T P.910 Subjective Evaluation [7]
  - 10 Participants
  - Viewing Distance = Various (Inch)
  - TV/VDU Screen Size = Various (Inch)
  - Mean Opinion Score (MOS)
  - Spatiotemporal Analysis of Artifacts
  - 600 Visual Comparisons
- Subjective Metrics
  - MOS [7]
  - SSIM [8]
  - MS-SSIM [9]

In the subjective evaluation, MOS = 5 equates to visually lossless quality in. Furthermore, the following perceptual quality metrics: SSIM ≥ 0.99 and also MS-SSIM ≥ 0.99 equate to visually lossless quality.



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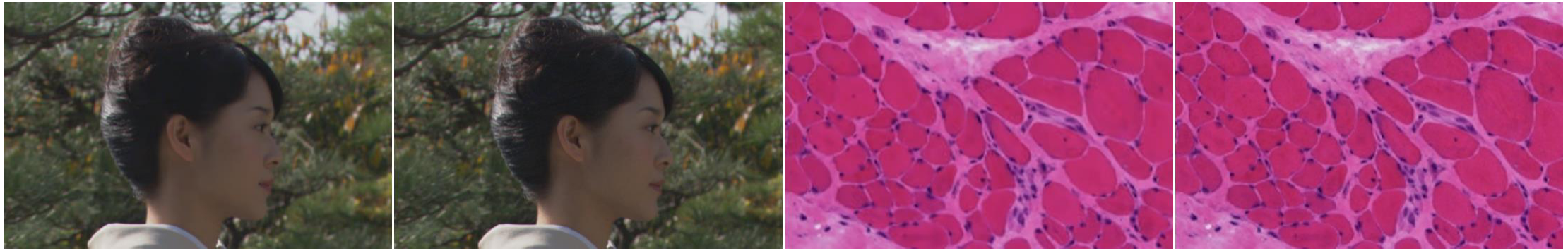
Subjective Evaluation Results



(a) (b) (c) (d)

Figure 4: (a) PCC-coded Kimono RGB image (HD 1080p) versus (b) Kimono raw RGB image. PCC attains an overall MOS = 5, SSIM ≥ 0.99 in addition to MS-SSIM ≥ 0.99 in the Kimono evaluations. (c) PCC coded Whole Slide Image (WSI) 4K RGB image versus (d) WSI raw RGB image (4K). PCC also achieves an overall MOS = 5, SSIM ≥ 0.99 as well as MS-SSIM ≥ 0.99 in the WSI evaluations.

- As proved to be the case with the vast majority of the tests in the subjective evaluations, the PCC coded versions of Kimono and WSI are perceptually indistinguishable from the raw RGB data.
- Considerable BPP reductions, of up to 72.5% (compared with VVC), are attained by PCC on the Kimono RGB 4:4:4 still image while also achieving visually lossless quality (i.e., MOS = 5); see Figure 4 (a) and 4 (b) for a visual comparison.

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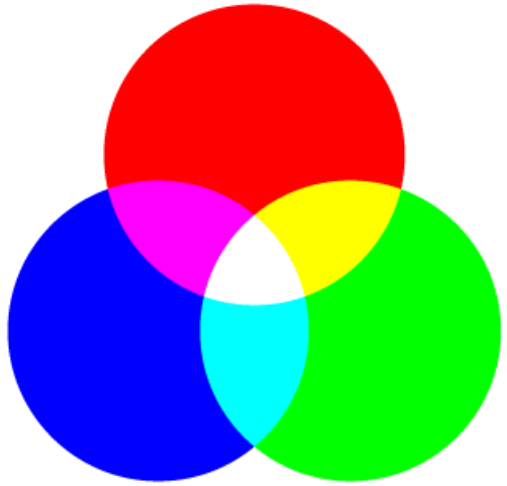
Discussion, Conclusions and Future Work

- Discussion and Conclusion
  - Spectral sensitivity and JNCD modelling is efficacious in the CB-level perceptual quantization of RGB 4:4:4 image data.
  - Spectral sensitivity-based and JNCD-based perceptual quantisation of RGB image data considerably decreases BPP.
  - The decrease in reconstruction quality is not perceptually discernible in spite of the vast BPP reductions achieved.
  - PCC successfully achieves both vast BPP reductions and visually lossless quality.
- Future Work
  - Extend the proposed PCC technique for spatiotemporal RGB (GBR) video data.
  - Potential additional applications for the proposed PCC technique include medical imaging and video coding.



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References

1. G. Sullivan, J-R. Ohm, W. Han and T. Wiegand, "Overview of the High Efficiency Video Coding (HEVC) Standard," *IEEE Trans. Circuits Syst. Video Techn.*, vol. 22, no. 12, pp. 1649-1668, 2012.
2. D. Flynn, D. Marpe, M. Naccari, T. Nguyen, C. Rosewarne, K. Sharman, J. Sole and J. Xu, "Overview of the Range Extensions for the HEVC Standard: Tools, Profiles, and Performance," *IEEE Trans. Circuits Syst. Video Techn.*, vol. 26, no. 1, pp. 4-19, 2016.
3. L. Prangnell, M. Hernández-Cabronero and V. Sanchez, "Coding Block-Level Perceptual Video Coding for 4:4:4 Data in HEVC," *IEEE Int. Conf. Image Processing*, Beijing, China, 2017, pp. 2488-2492.
4. K. R. Gegenfurtner, "Cortical Mechanisms of Colour Vision," *Nature Neuroscience*, vol. 4, pp. 563-572, 2003.
5. A. Chaparro, C. F. Stromeyer, E. P. Huang, R. E. Kronauer and R. T. Eskew, Jr., "Colour is what the eye sees best," *Nature*, vol. 361, pp. 348-350, 1993.
6. A. R. Robertson, "Historical development of CIE recommended color difference equations," *Color Research and Application*, vol. 15, no. 3, pp. 167-170, 1990.
7. ITU-R: Rec. P.910, "Subjective Video Quality Assessment Methods for Multimedia Applications," 2008.
8. Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, "Image Quality Assessment: From Error Visibility to Structural Similarity," *IEEE Trans. Image Processing*, vol. 13, no. 4, pp. 600-612, 2004.
9. Z. Wang, E. P. Simoncelli, A. C. Bovik, "Multiscale Structural Similarity for Image Quality Assessment," *IEEE Asilomar Conf. Signals, Systems and Computers*, Pacific Grove, CA, USA, 2003, pp. 1398-1402.

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