Naturalness-Preserved Tone Mapping in Images Based on Perceptual Quantization

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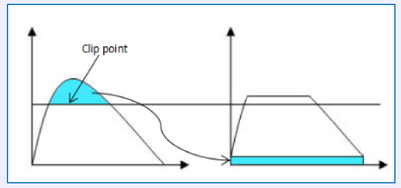
CLAHE

- Contrast limited adaptive histogram equalization (CLAHE) : Histogram redistribution based on a clip point
- Still causing over-enhancement in smooth regions without considering human visual perception in the clip point



Histogram redistribution

Over-enhancement

References

[1] G. W. Larson, H. Rushmeier, and C. Piatko, “Avisibility matching tone reproduction operator for high dynamic range scenes,” *IEEE Transactions on Visualization and Computer Graphics*, 3(4): 291–306, 1997.

[2] S. Miller, M. Nezamabadi, and S. Daly, “Perceptual signal coding for more efficient usage of bit codes,” *SMPTE Motion Imaging Journal*, 122(4): 52–59, 2013.

[3] T. Celik and T. Tjahjadi, “Contextual and variational contrast enhancement,” *IEEE Transactions on Image Processing*, 20(12): 3431–3441, 2011.

[4] Q. Wang and R. K. Ward, “Fast image/video contrast enhancement based on weighted thresholded histogram equalization,” *IEEE Transactions on Consumer Electronics*, 53(2): 757–764, 2007.

[5] A. R. Rivera, B. Ryu, and O. Chae, “Content-aware dark image enhancement through channel division,” *IEEE Transactions on Image Processing*, 21(9): 3967–3980, 2012.

[6] S.-C. Huang, F.-C. Cheng, and Y.-S. Chiu, “Efficient contrast enhancement using adaptive gamma correction with weighting distribution,” *IEEE Transactions on Image Processing*, 22(3): 1032–1041, 2013.

Proposed Method

- Histogram adjustment based on human contrast sensitivity (Population of local adaptation luminance in a scene)
- Contrast visibility thresholds:

$$\frac{dL_d}{dL_w} \le \frac{\Delta L(L_d)}{\Delta L(L_w)}$$

L_d: Display luminance
L_w: Scene luminance
$\Delta L(L_d)$: Just noticeable difference (JND)

- Constraint curve for histogram adjustment [1]:

$$f(b_i) \le \frac{T}{N} \cdot \frac{log(L_{wmax}) - log(L_{wmin})}{log(L_{dmax}) - log(L_{wdmin})} \cdot \frac{\Delta L(L_{di})/L_{di}}{\Delta L(L_{wi})/L_{wi}}$$

$f(b_i)$: Frequency count for histogram bin b_i T: Sum of pixels

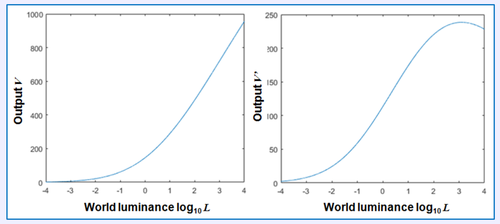
- Perceptual quantization (PQ) transfer function for 10bit videos [2]:

$$V(L) = v_{max} \cdot \left(\frac{c_1 + c_2(L_1^{10}/10000)^{m_1}}{1 + c_3(L_1^{10}/10000)^{m_1}}\right)^{m_2}$$

L_1: Log10 luminance
m_1, m_2, c_1, c_2, c_3: Constants

- Derivative of PQ transfer function:

$$V'(L_1) = log(10) \cdot L/\Delta L$$



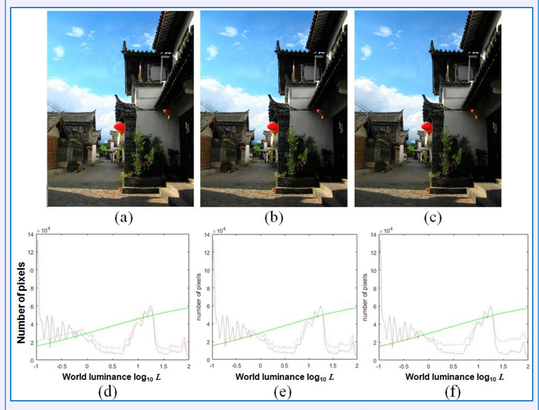
PQ transfer function and its derivative

- New constraint curve using relationship between the slopes of tone mapping and HVS model curves:

$$\frac{f(b_i)}{T} \le k \cdot \frac{V'(L_{1i})}{\sum_{i=1}^{n} V'(L_{1i})}$$

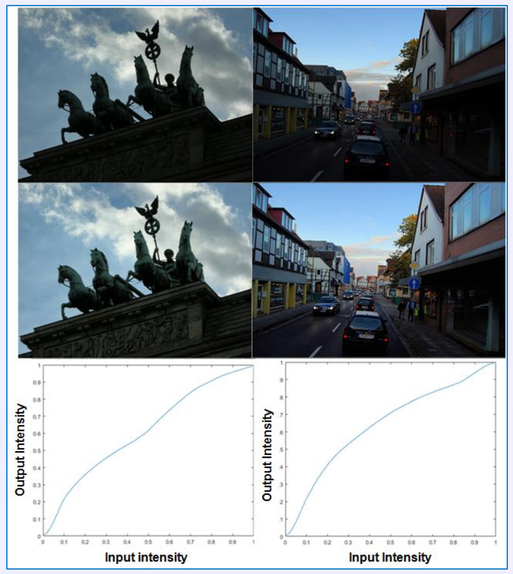
k: Constant to adjust tone mapping results

- Histogram redistribution based on the new constraint curve



Contrast enhancement results and their histograms
(a) CLAHE. (b) [12]. (c) Proposed method. (d), (e), and (f) Processed histograms and their limit curves of (a), (b), and (c).
Black: Untreated histogram.
Green: Constraint curve.
Red: Histogram after processing.

Experimental Results



Top: Original images of *DSCN* and *Town*.
Middle: Results by the proposed method.
Bottom: Mapping curves.

Input image (*DSCN*), CVC [3], WTHE [4], ChDiv [5], AGCWD [6], and proposed method.

TABLE I
OBJECTIVE EVALUATION RESULTS OF DE, FSIM

Method	Input	CVC	WTHE	ChDiv	AGCWD	Proposed
DE	6.9825	7.0162	7.0064	7.1996	7.270	7.2981
FSIM	1	0.8956	0.8611	0.8882	0.9325	0.9375

Discrete entropy (DE): Degree of details
Feature similarity (FSIM): Overall feature preservation

Conclusions

- We have proposed naturalness-preserved tone mapping based on PQ.
- We have generated a new constraint curve based on HVS model (PQ) to adjust the contrast enhancement degree.
- We have redistributed the histogram of images using the constraint curve.
- Experimental results demonstrate that the proposed method achieves a good performance in contrast enhancement and produces natural-looking results.