Low Light Image Enhancement Based on Two-Step Noise Suppression

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Low Light Image Enhancement (LLIE)

- **Low light condition**: Low SNR, much noise, low contrast, weak color;
- **LLIE**: Over-enhancement, noise amplification in HVS after CE;
- **Our approach:**

1) Two-step noise suppression;
2) Adopt NLF and JND for perceptual CE;

Proposed Method

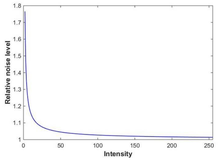
Noise Aware CE

- Noise aware histogram: Adjusting histogram by **high contrast pixels** from NLF (not corrupted by noise) [1][2];

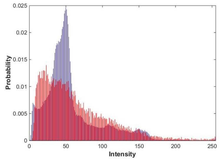
$$p(I)=\frac{\sum_{(x,y)\in B_I} l(x,y)}{\sum_{(x,y)\in S} l(x,y)}$$

where $S=\{(x,y): c(x,y)>n(x,y)\}$

$$B_I=\{(x,y)\in S: I=0,1,...,255\}$$



Noise level function (NLF)



Noise aware histogram
(Blue: original, Red: noise aware)

- Global CE by AGCWD [3]

JND-Based Noise Reduction

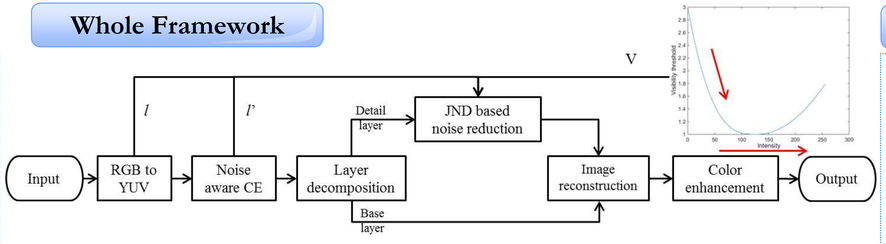
1) Noise becomes obvious after CE due to the decrease of JND thresholds (**luminance adaptation**);

2) Noise amplification is more severe in smooth regions than textural regions (**contrast masking**);

- We perform noise reduction in detail layer using JND model (**low contrast pixels**) as follows [4]:

$$d_{out}(x,y)=e\cdot\frac{V\left(l'_{(x,y)\in\bar{s}}(x,y)\right)}{V\left(l_{(x,y)\in\bar{s}}(x,y)\right)}d(x,y)$$

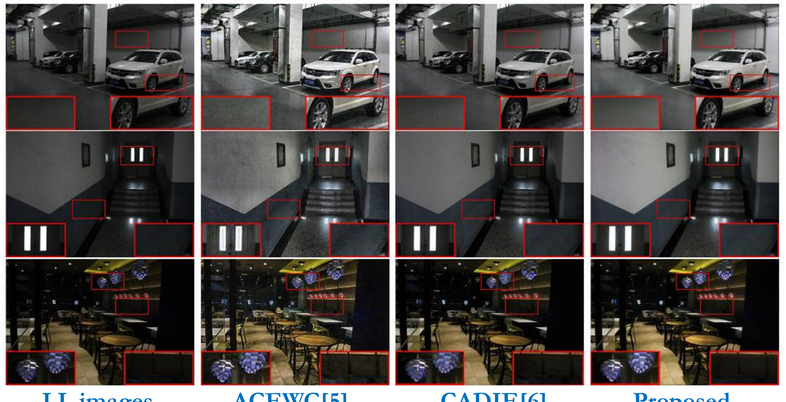
Whole Framework



Noise Aware CE JND-Based Noise Reduction

Experimental Results

Visual Comparison



LL images ACEWC[5] CADIE[6] Proposed

Objective Evaluation

Method	Luminance	Contrast	Structure
Proposed	**1.5873**	**1.4754**	**0.9833**
ACEWC [5]	1.7088	1.2886	0.9164
CADIE [6]	1.3170	1.1679	0.9875

Conclusions

- **LLIE based on two-step noise suppression;**
- **Noise aware CE** for high contrast pixels based on noise aware histogram;
- **JND-based noise reduction** for low contrast pixels using JND model (JND from luminance adaptation; Detail layer)
- Experiment results demonstrate that the proposed method **successfully enhances contrast** in low light images **while minimizing noise amplification**.

References

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[2] X. Liu, M. Tanaka, and M. Okutomi, "Practical signal dependent noise parameter estimation from a single noisy image," *IEEE Transactions on Image Processing*, vol. 23, no. 10, pp. 4361–4371, Oct. 2014.

[3] 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*, vol. 22, no. 3, pp. 1032–1041, Mar. 2013.

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[5] A. Loza, D. R. Bull, and P. R. Hill, "Automatic contrast enhancement of low-light images based on local statistics of wavelet coefficients," *Digital Signal Processing*, vol. 23, no. 6, pp. 1856–1866, Jun. 2013.

[6] A. R. Rivera, B. Ryu, and O. Chae, "Content-aware dark image enhancement through channel division," *IEEE Transactions on Image Processing*, vol. 21, no. 9, pp. 3967–3980, Sep. 2012

Acknowledgement

This work was supported by the National Natural Science Foundation of China (No. 61271298) and the International S&T Cooperation Program of China (No. 2014DFG12780).