MBLLEN: Low-Light Image/Video Enhancement Using CNNs Supplementary Material

BMVC 2018 Submission # 700

1 Additional Quantitative Comparisons

	PSNR	SSIM [⬚]	VIF [⬚]	LOE	TMQI [⬚]	AB [⬚]
Input	12.80	0.43	0.38	606.85	0.79	-54.62
AMSR [⬚]	8.82	0.17	0.10	4377.32	0.42	-80.38
CVC [⬚]	11.13	0.29	0.27	912.45	0.75	-65.18
LDR [⬚]	12.92	0.41	0.36	703.75	0.79	-53.86
SRIE [⬚]	15.84	0.59	0.43	788.53	0.82	-37.02
BPDHE [⬚]	15.01	0.59	0.39	607.43	0.81	-37.38
HE	15.00	0.65	0.42	753.66	0.88	34.60
MSRCR [⬚]	13.30	0.64	0.44	1235.92	0.83	47.08
LIME [⬚]	15.16	0.60	0.44	1215.58	0.82	10.90
MF [⬚]	18.48	0.67	0.45	882.24	0.84	-23.24
Dong [⬚]	17.80	0.64	0.37	1398.35	0.82	-16.43
NPE [⬚]	17.65	0.68	0.43	1051.15	0.84	-25.28
DHECI [⬚]	18.18	0.68	0.43	606.98	0.87	-1.21
WAHE [⬚]	17.64	0.67	0.48	648.29	0.84	-30.28
Ying [⬚]	19.66	0.73	0.47	892.56	0.86	2.57
BIMEF [⬚]	19.80	0.74	0.48	675.15	0.85	-20.22
Ours	26.56	0.89	0.55	478.02	0.91	-0.96

Table 1: Comparison of low-light image enhancement without additional noise.

	PSNR	SSIM [⬚]	VIF [⬚]	LOE	TMQI [⬚]	AB [⬚]
Input	13.63/13.59	0.42/0.42	0.34/0.34	739.63/ 739.59	0.79/0.79	-47.96/-49.00
AMSR [⬚]	9.57/ 9.91	0.18/0.18	0.09/0.09	4357.38/4357.40	0.43/0.45	-74.49/-68.47
CVC [⬚]	11.83/11.80	0.28/0.29	0.25/0.25	1006.25/1006.33	0.75/0.75	-58.80/-59.34
LDR [⬚]	13.64/13.61	0.40/0.41	0.32/0.32	817.24/ 817.28	0.79/0.78	-47.26/-48.56
SRIE [⬚]	16.84/17.07	0.58/0.58	0.37/0.37	828.63/ 828.28	0.83/0.82	-27.09/-29.84
BPDHE [⬚]	15.90/15.80	0.60/0.59	0.33/0.32	688.33/ 688.44	0.81/0.81	-31.47/-33.99
HE	14.50/16.49	0.58/0.60	0.36/0.36	853.38/ 853.36	0.87/0.86	38.93/ 19.42
MSRCR [⬚]	12.64/13.37	0.62/0.63	0.36/0.36	1249.31/1249.17	0.83/0.84	53.07/ 47.91
LIME [⬚]	14.36/15.26	0.59/0.60	0.37/0.37	1250.82/1250.75	0.81/0.82	19.23/ 14.84
MF [⬚]	19.37/19.66	0.67/0.67	0.39/0.38	896.67/ 896.46	0.84/0.84	-13.77/-16.88
Dong [⬚]	17.80/18.42	0.63/0.64	0.32/0.31	1390.64/1390.82	0.82/0.82	-6.43/ -9.69
NPE [⬚]	18.55/18.55	0.67/0.68	0.36/0.36	1070.94/1070.64	0.84/0.84	-17.88/-20.85
DHECI [⬚]	18.03/18.71	0.67/0.68	0.36/0.36	687.60/ 687.61	0.86/0.86	3.75/ 0.16
WAHE [⬚]	17.91/17.37	0.62/0.59	0.40/0.40	771.34/ 771.33	0.83/0.82	-26.41/-30.04
Ying [⬚]	18.61/19.69	0.70/0.71	0.40/0.39	928.13/ 927.83	0.86/0.86	10.99/ 6.99
BIMEF [⬚]	20.27/17.56	0.73/0.70	0.41/0.39	725.72/ 725.61	0.85/0.83	-11.58/-31.13
Ours	25.97/26.39	0.87/0.87	0.49/0.49	573.14/ 573.14	0.98/0.89	1.45/ -1.57

Table 2: Comparison of low-light image enhancement with additional Poisson noise. As described in the paper, the numbers on the right indicate the brightness-scaled results by using ground truth for reference.

2 More Image Enhancement Results

1. Figure 1 - Figure 15: comparison on images without additional noise

2. Figure 16 - Figure 25: comparison on images with additional Poisson noise

3. Figure 26 - Figure 30: comparison on natural low-light images

4. Figure 31: more results on on natural low-light images

In order to see the visual difference more clearly, it is recommended to first check the same dark regions in the input images and zoom in on the images if necessary.

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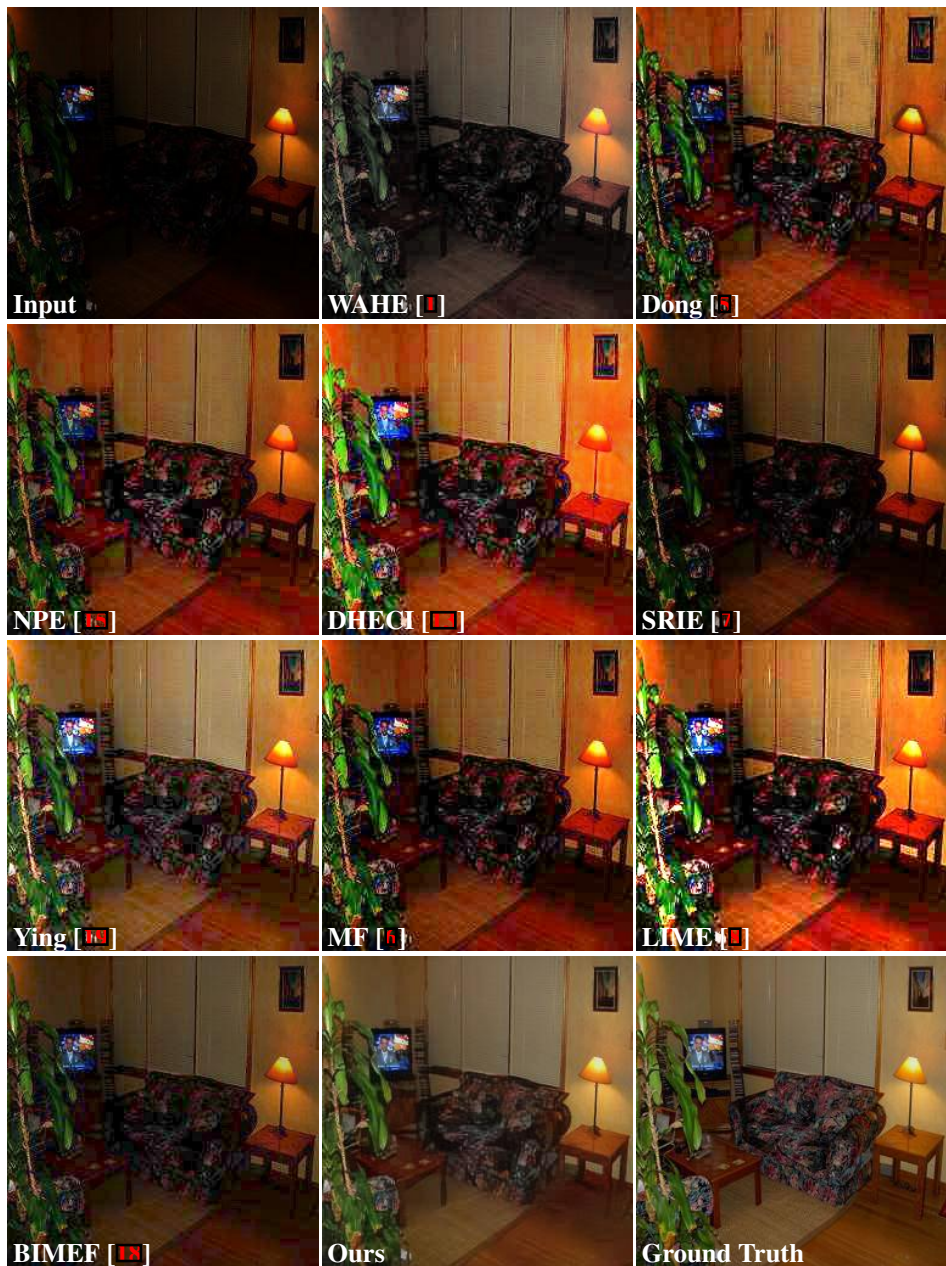
Figure 1: Low-light image enhancement without additional noise.
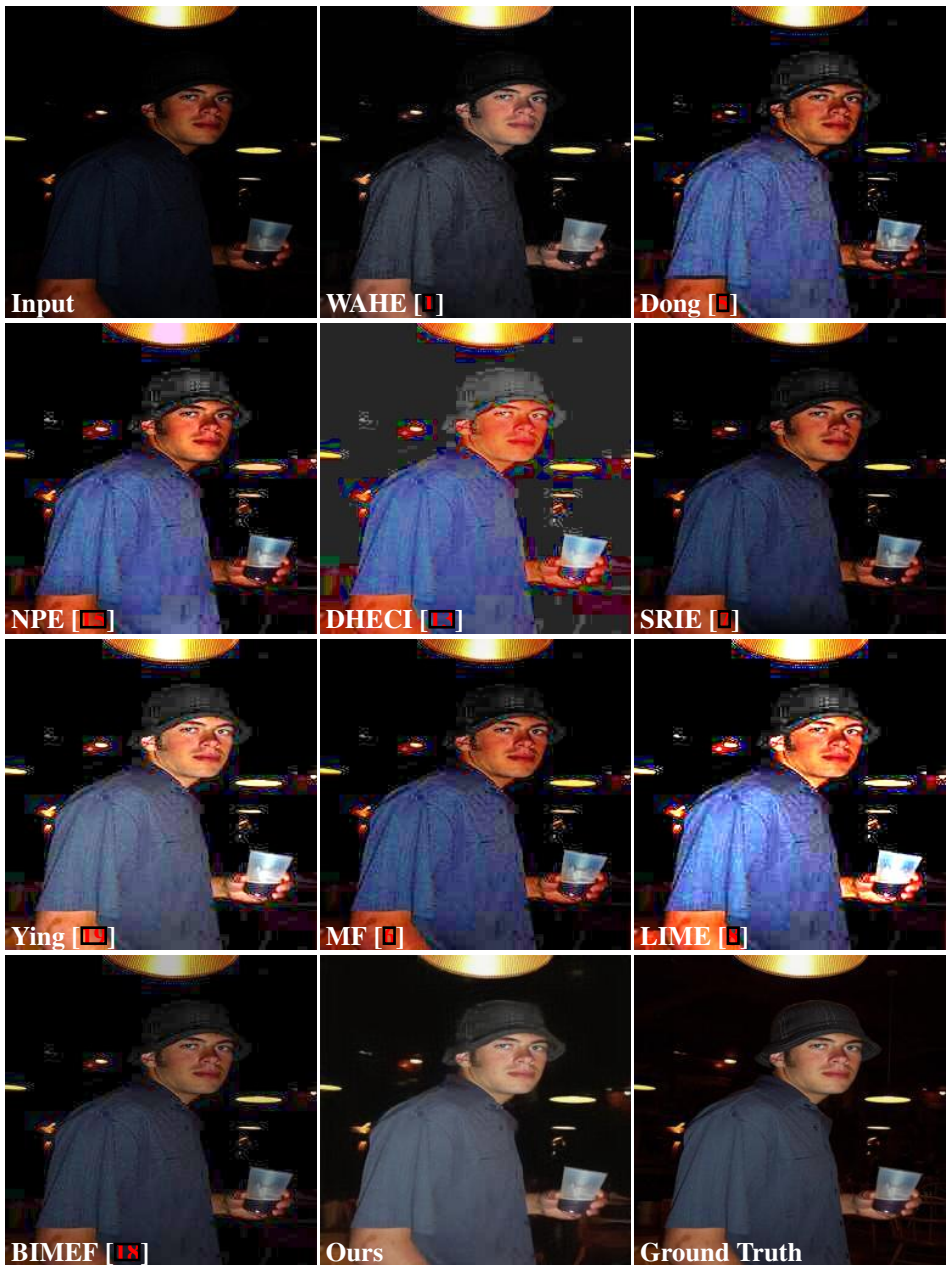
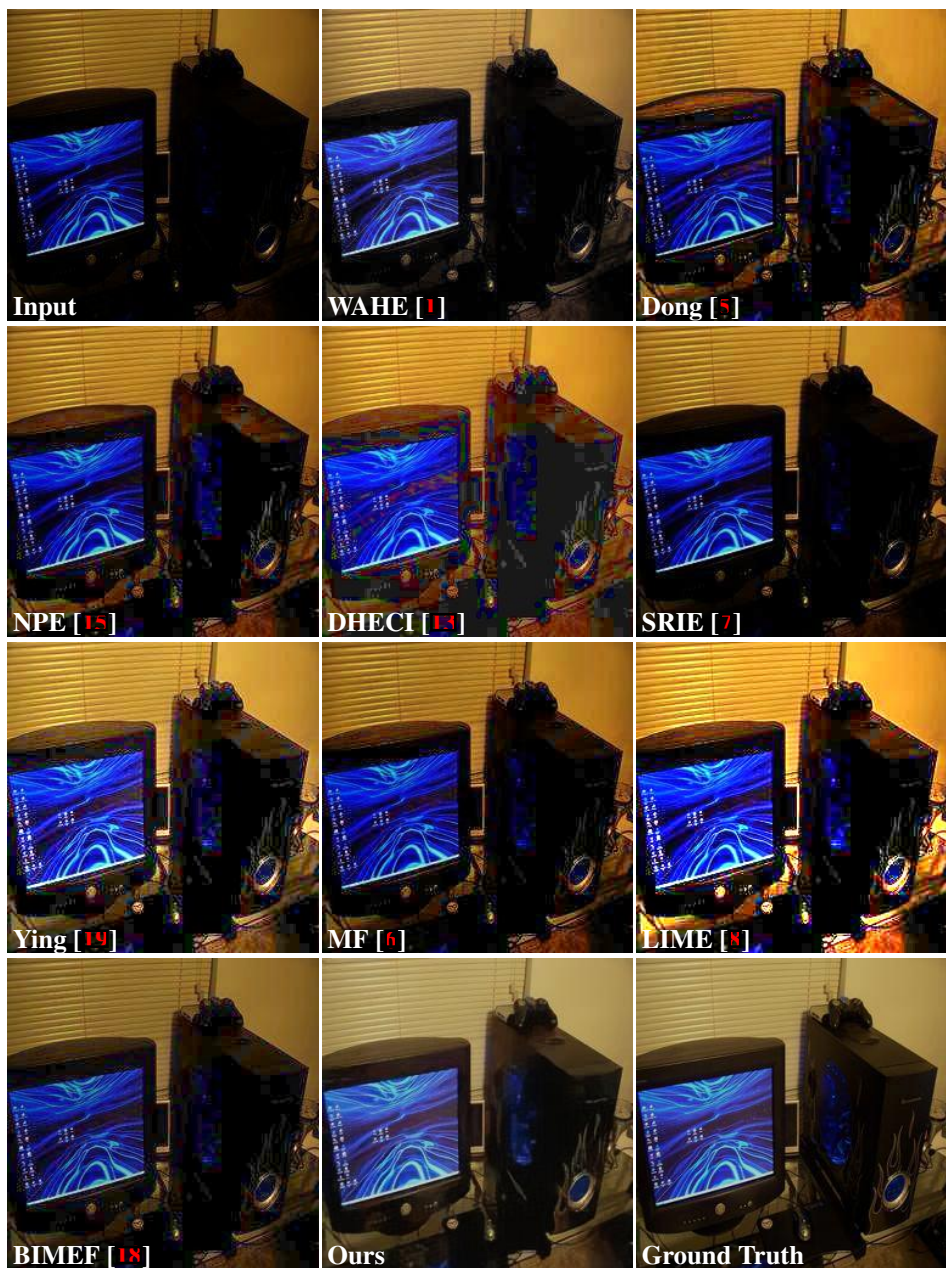Figure 2: Low-light image enhancement without additional noise.

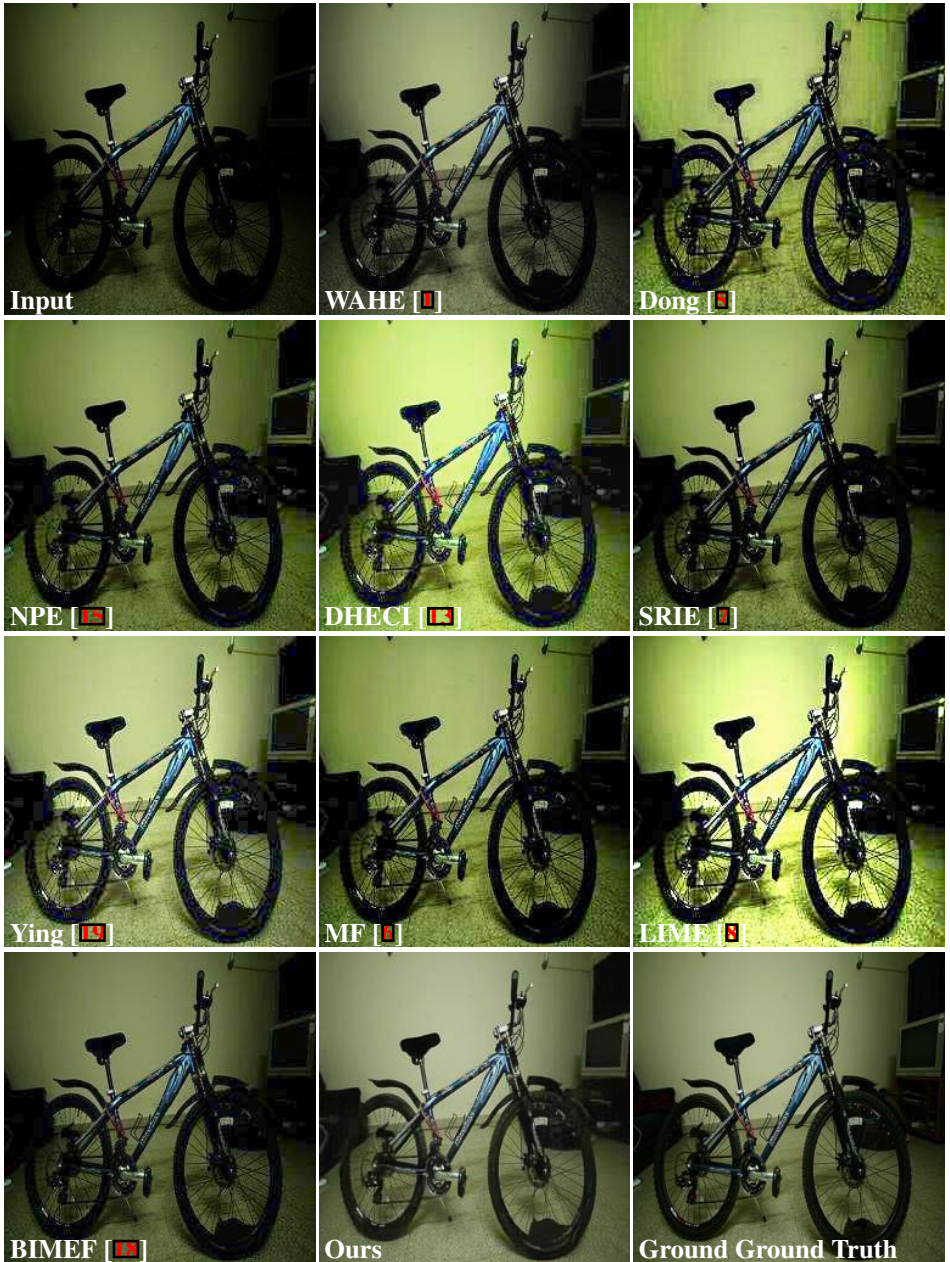Figure 3: Low-light image enhancement without additional noise.

Figure 4: Low-light image enhancement without additional noise.
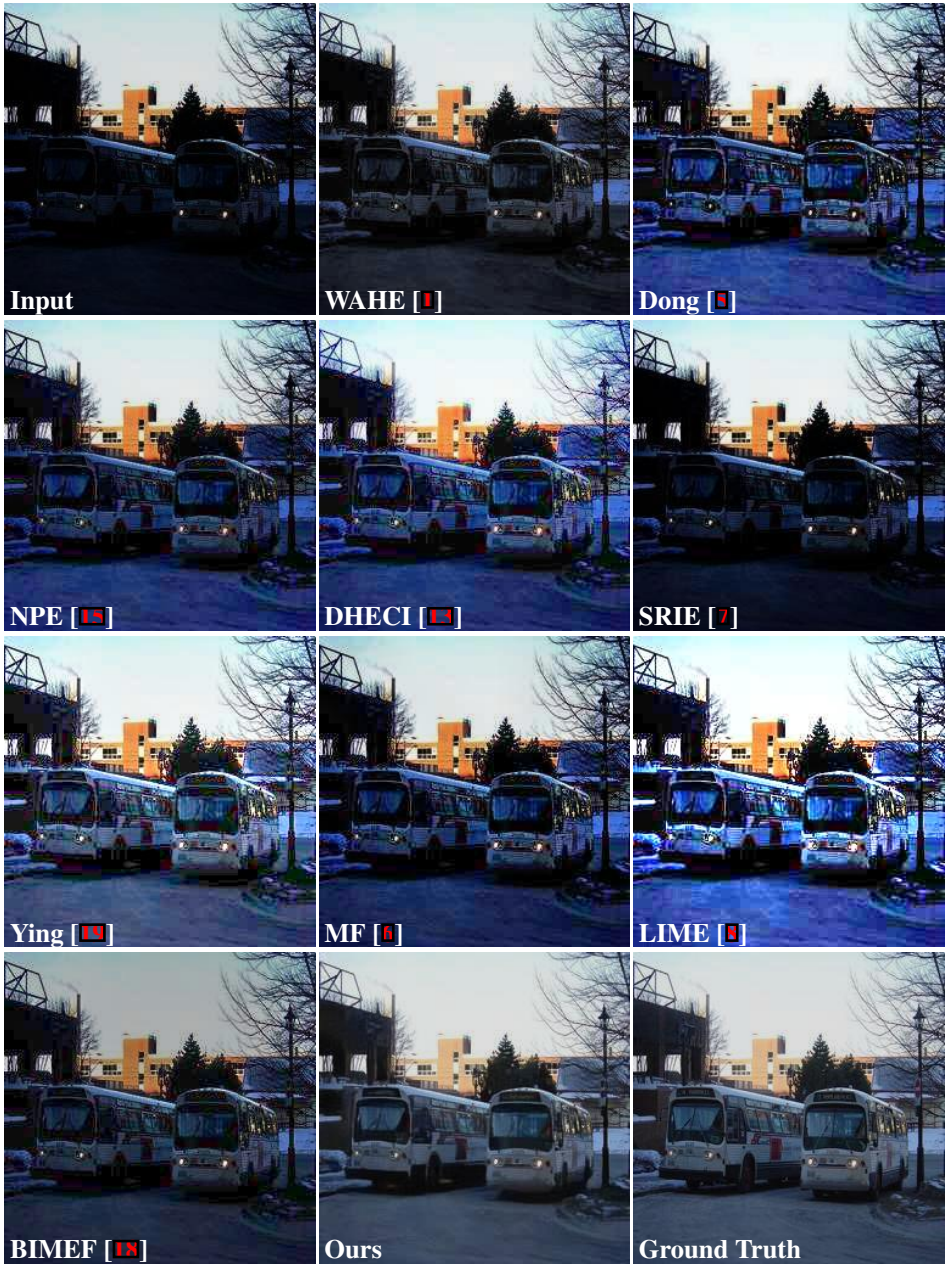
Figure 5: Low-light image enhancement without additional noise.
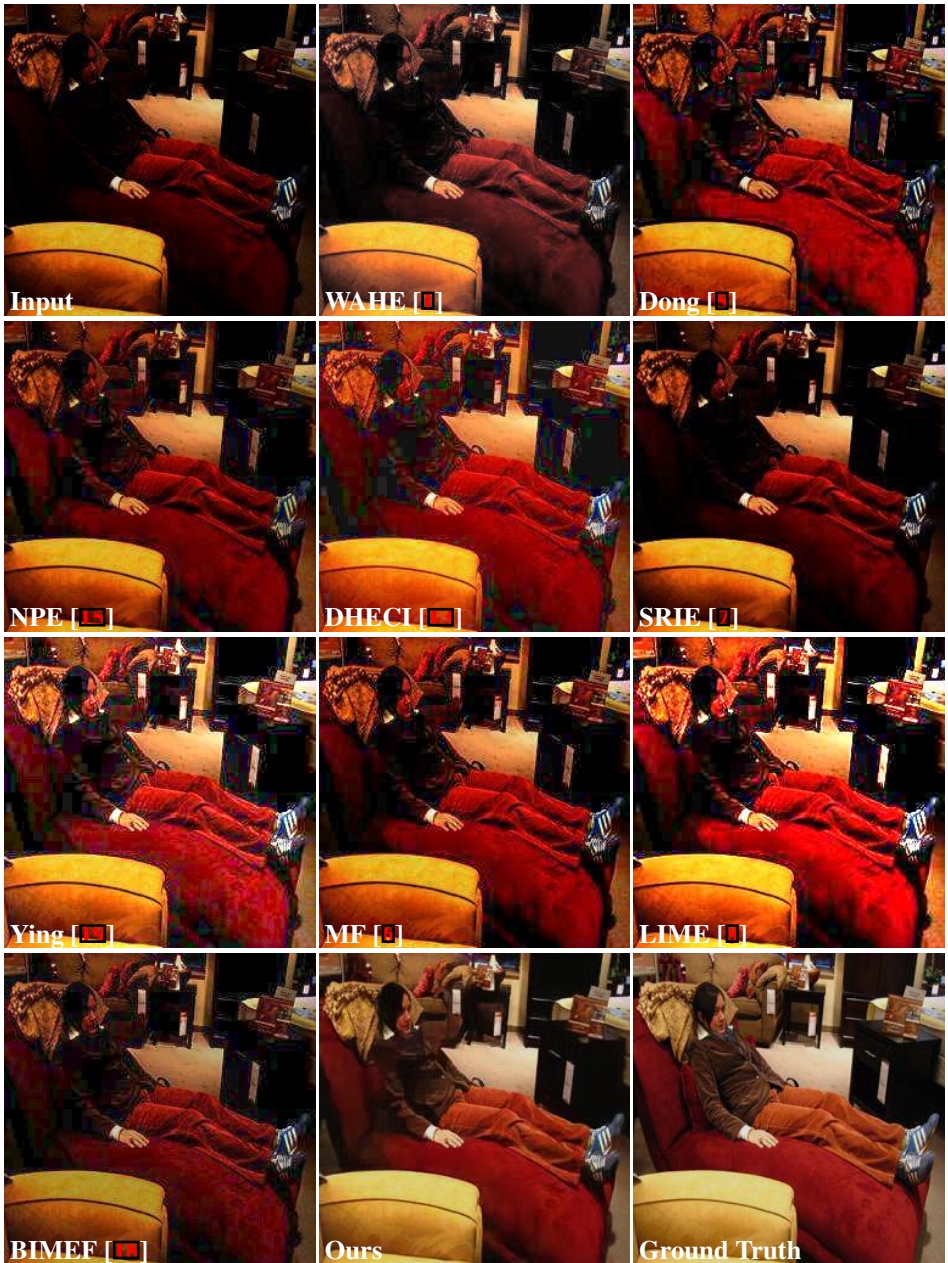
Figure 6: Low-light image enhancement without additional noise.
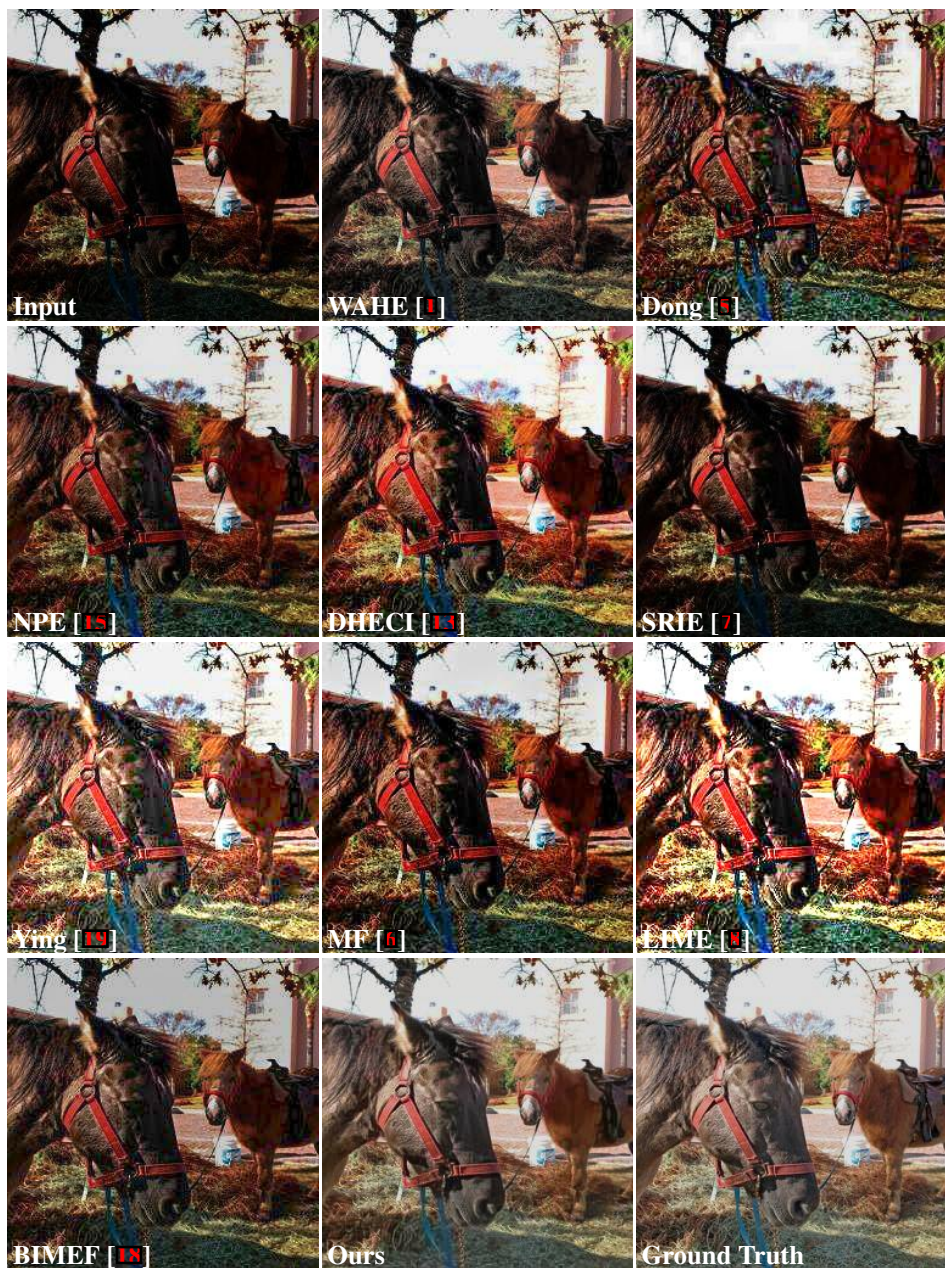
Figure 7: Low-light image enhancement without additional noise.

Figure 8: Low-light image enhancement without additional noise.

Figure 9: Low-light image enhancement without additional noise.
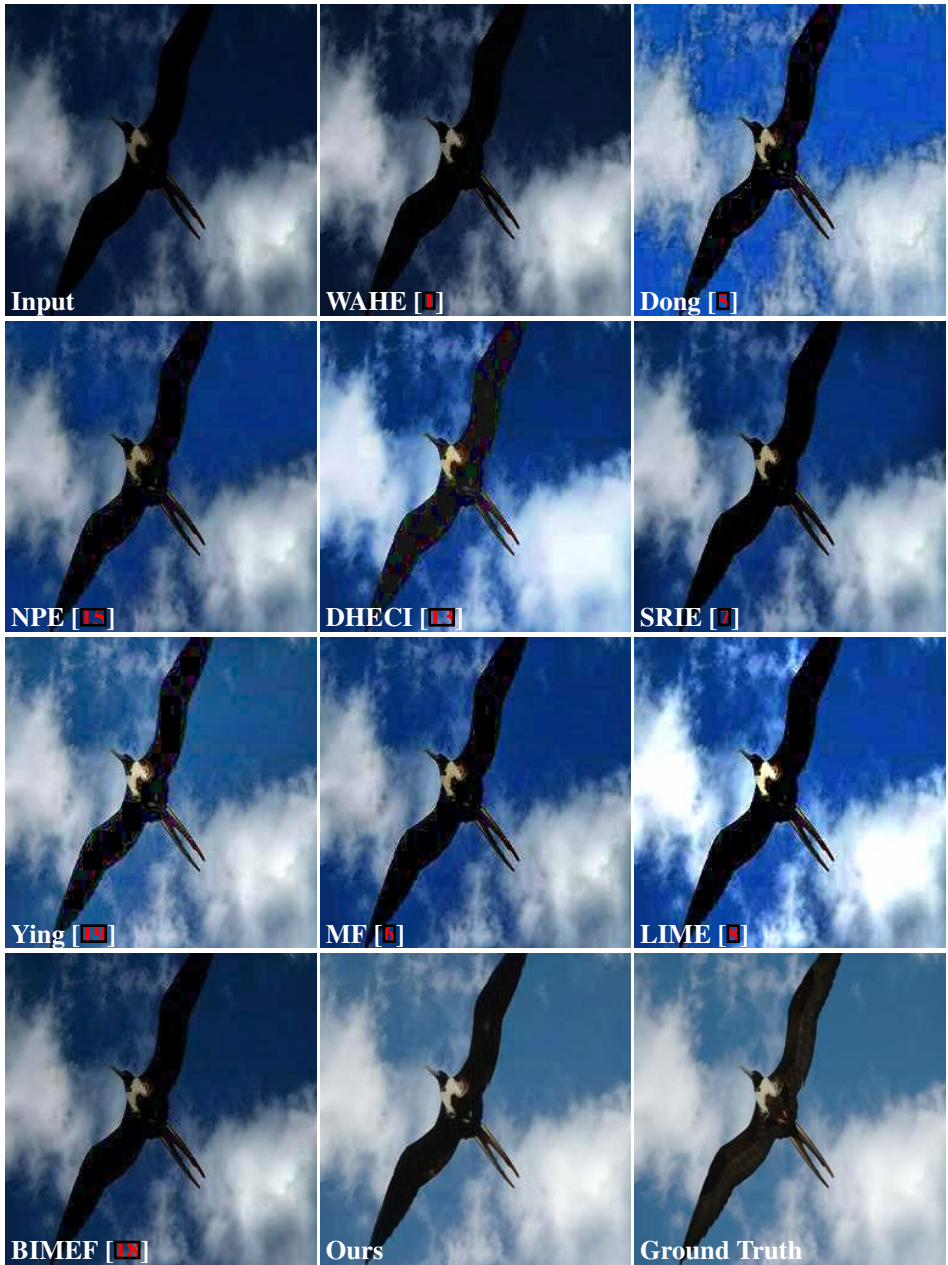
Figure 10: Low-light image enhancement without additional noise.

Figure 11: Low-light image enhancement without additional noise.
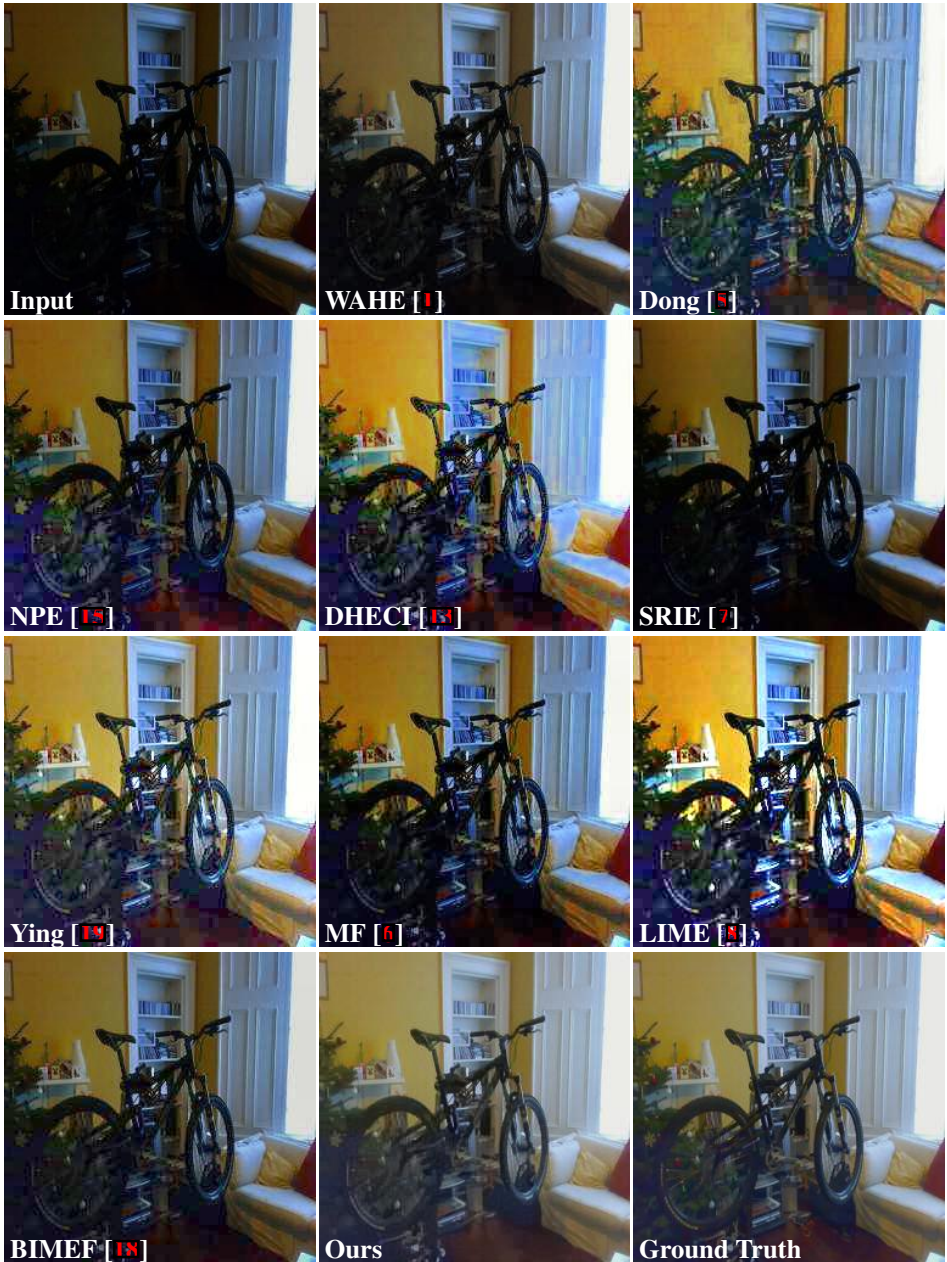
Figure 12: Low-light image enhancement without additional noise.

Figure 13: Low-light image enhancement without additional noise.
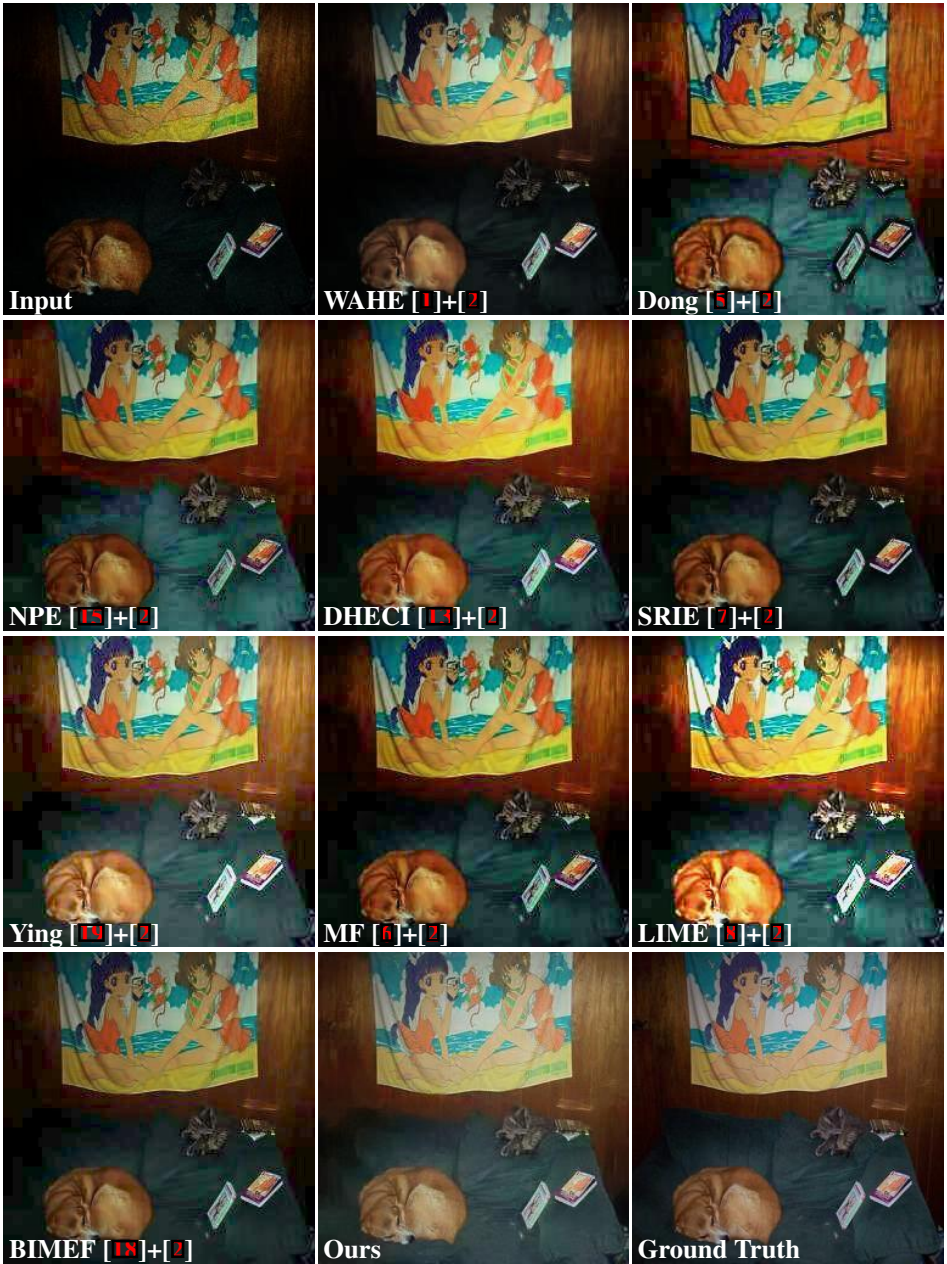
Figure 14: Low-light image enhancement without additional noise.

Figure 15: Low-light image enhancement without additional noise.
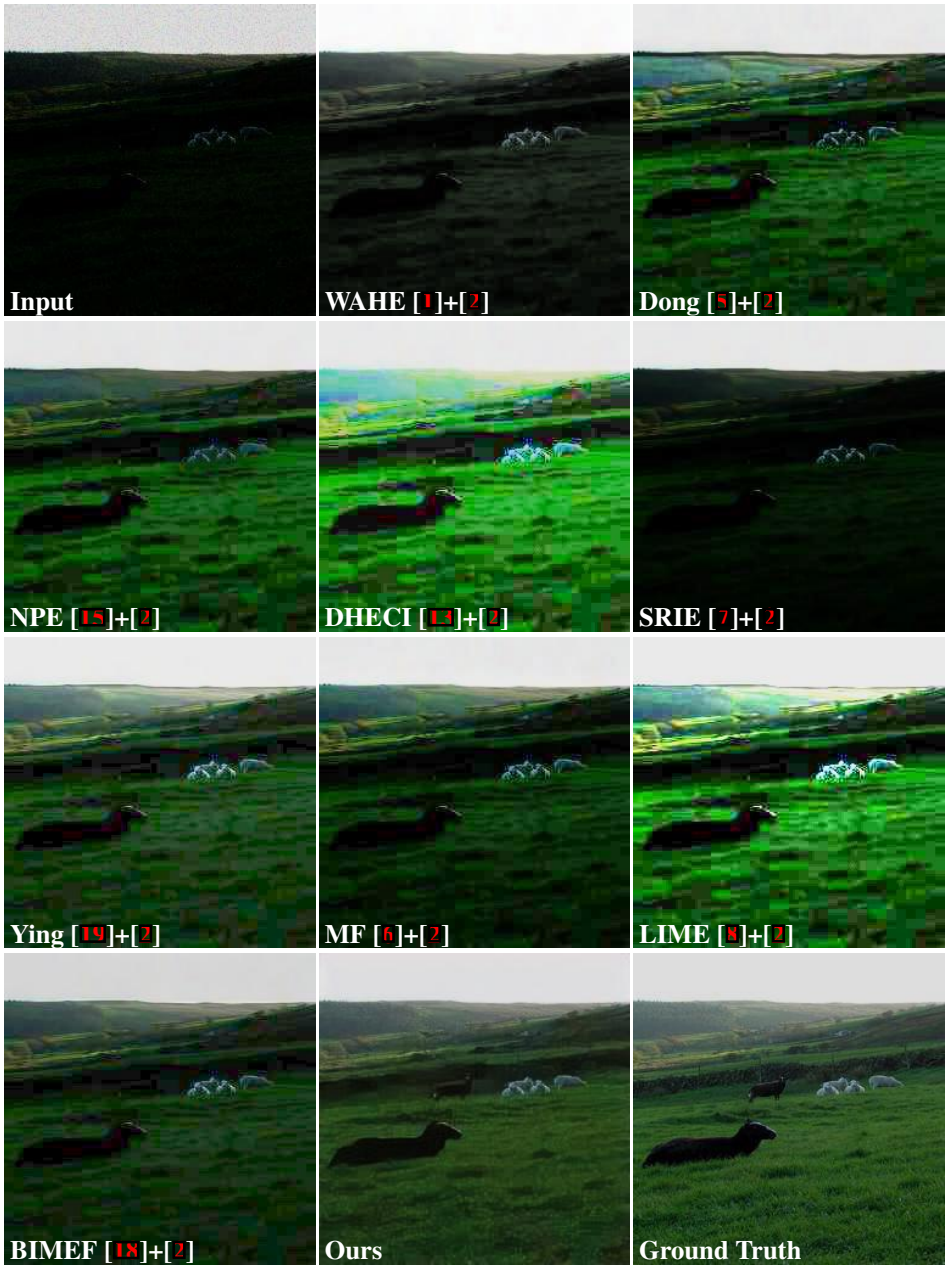
Figure 16: Low-light image enhancement with additional Poisson noise.

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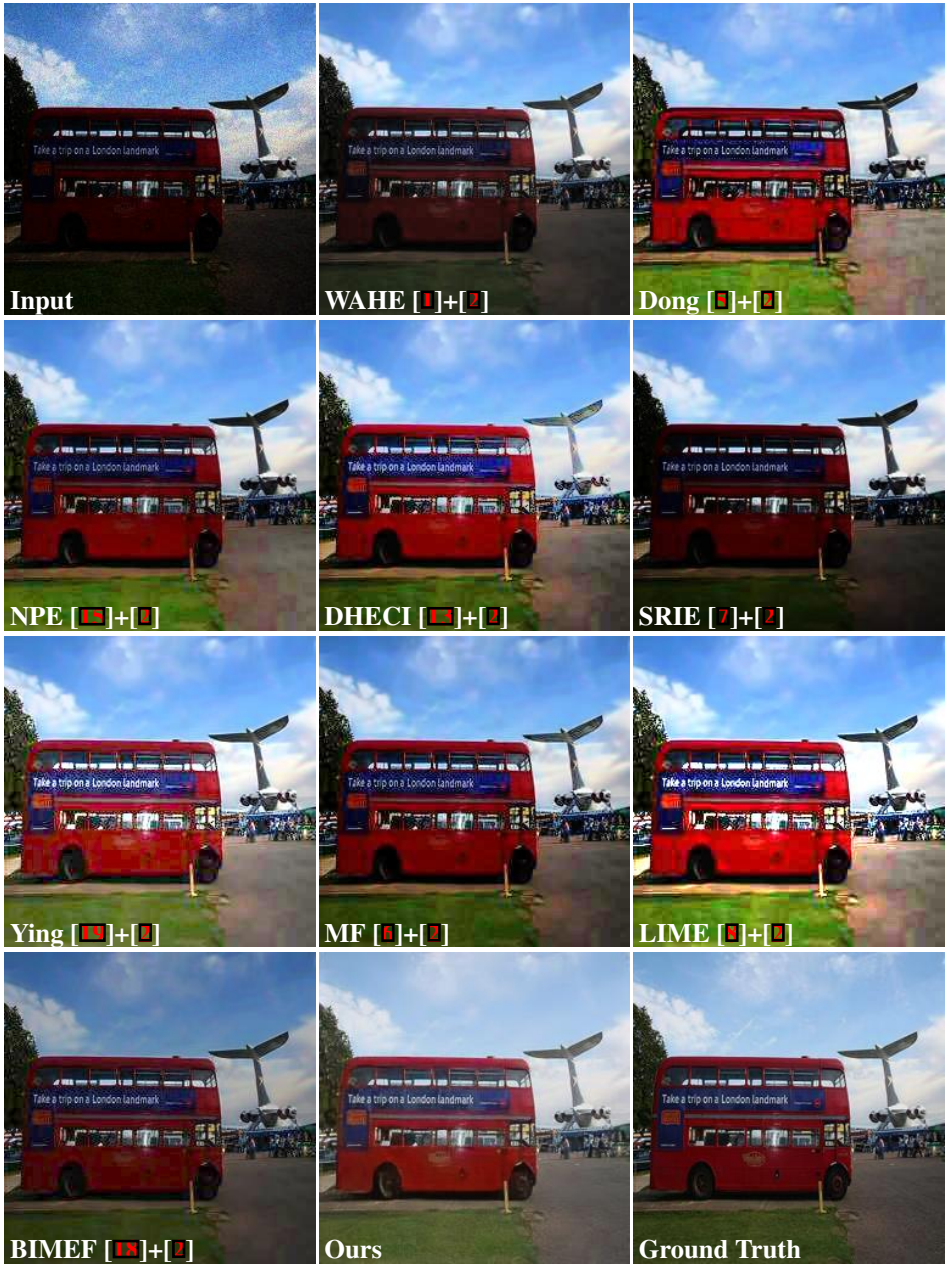
Figure 17: Low-light image enhancement with additional Poisson noise.
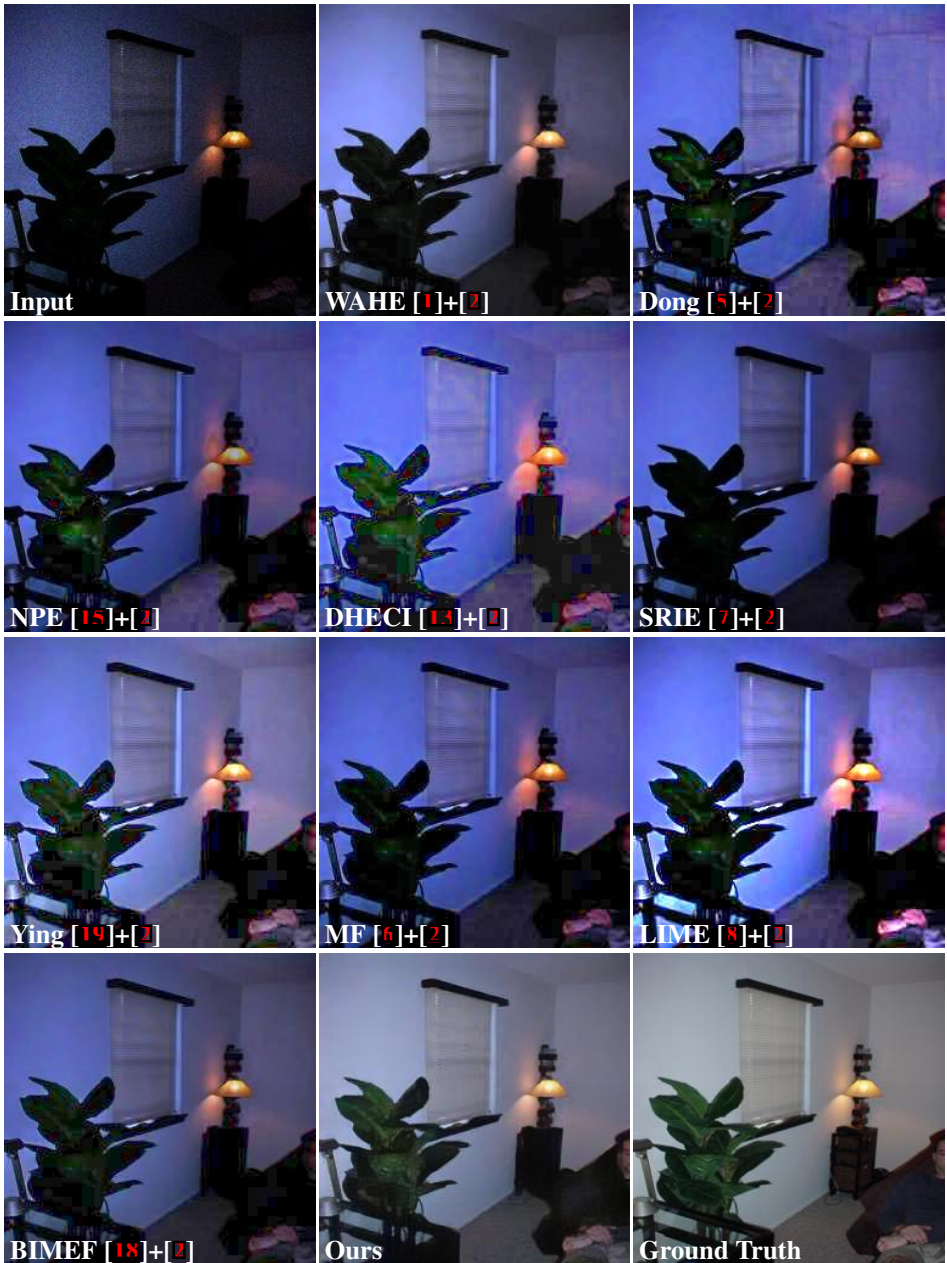
Figure 18: Low-light image enhancement with additional Poisson noise.

Figure 19: Low-light image enhancement with additional Poisson noise.
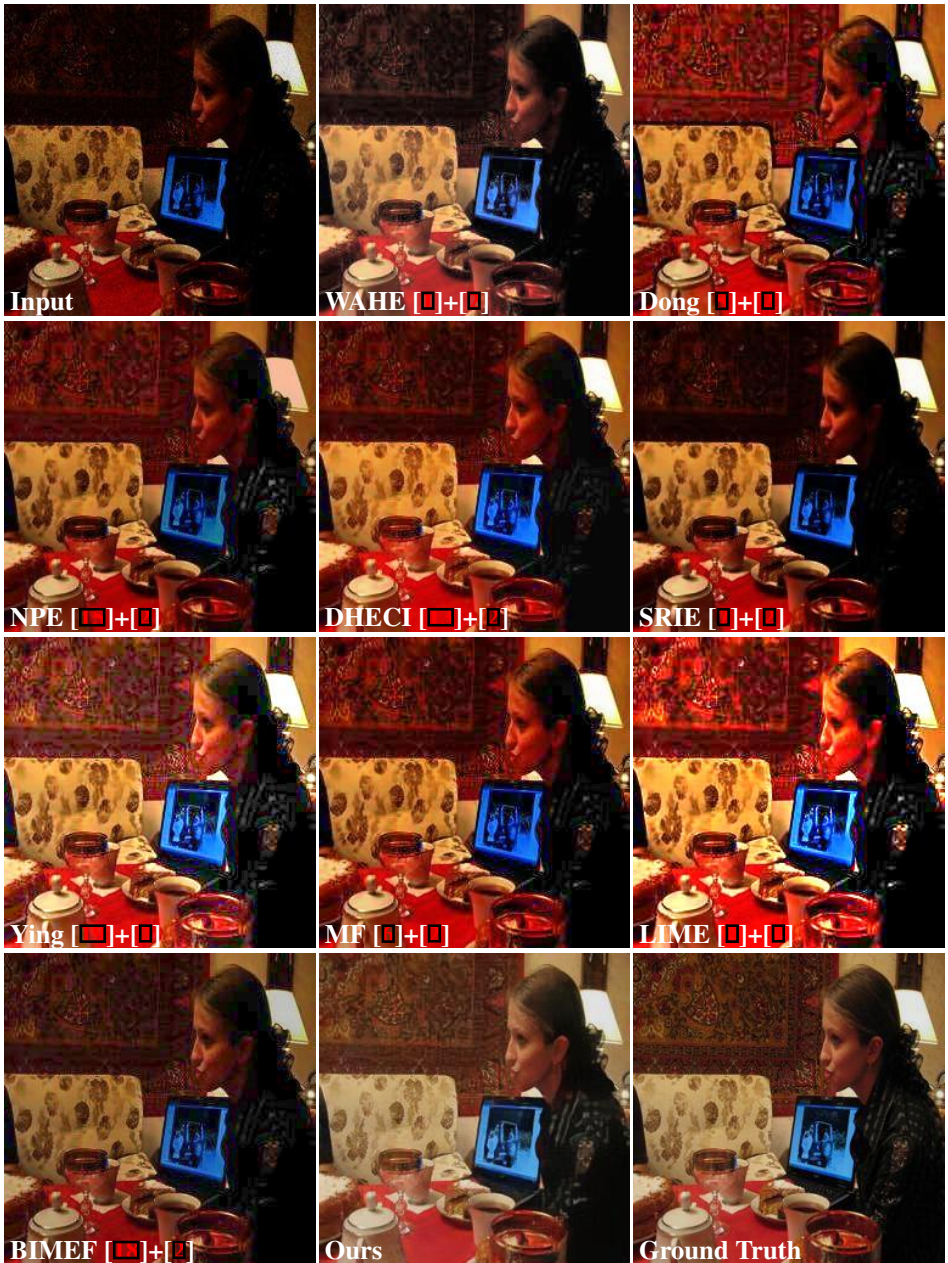
Figure 20: Low-light image enhancement with additional Poisson noise.

Figure 21: Low-light image enhancement with additional Poisson noise.
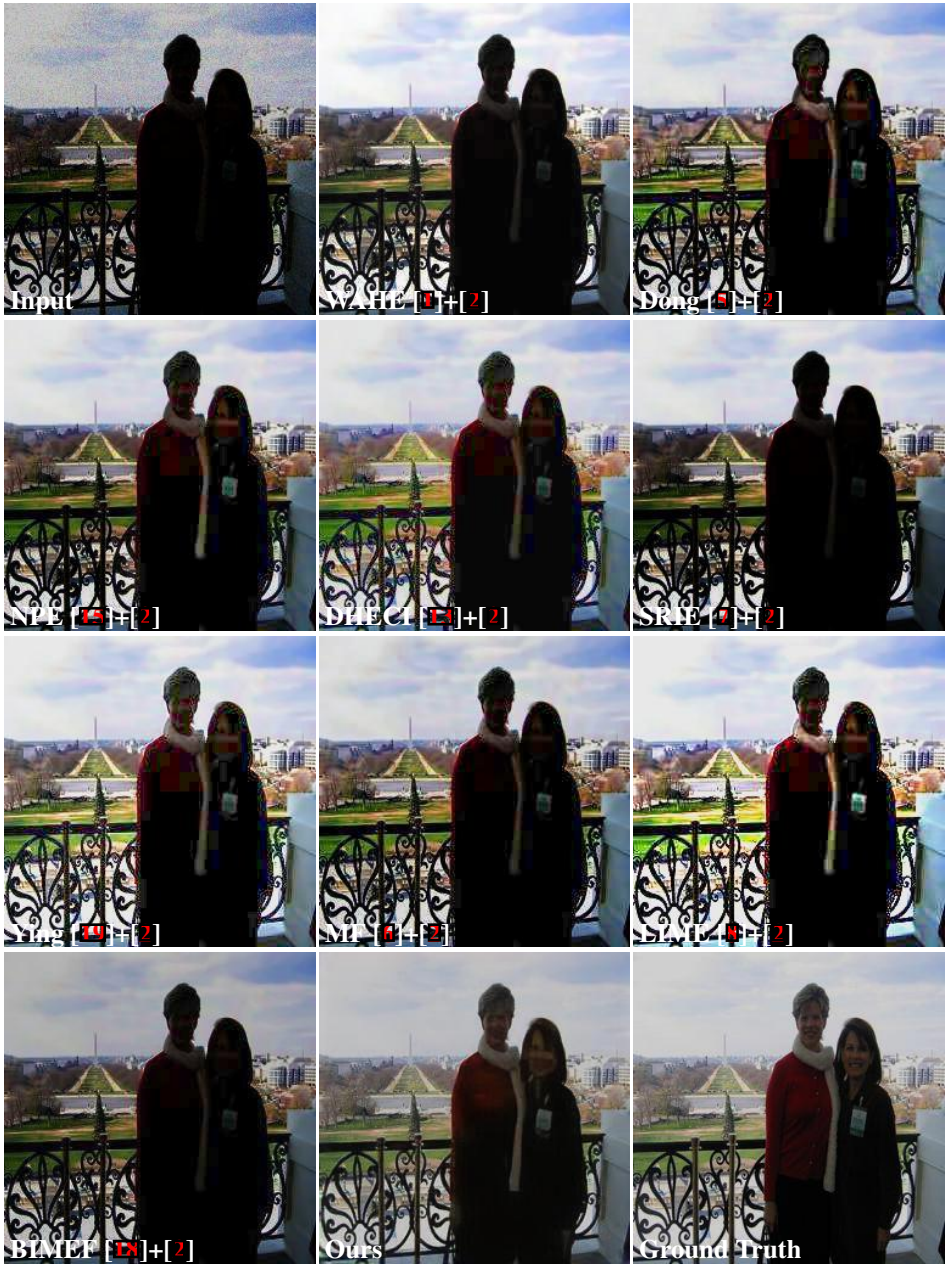
Figure 22: Low-light image enhancement with additional Poisson noise.

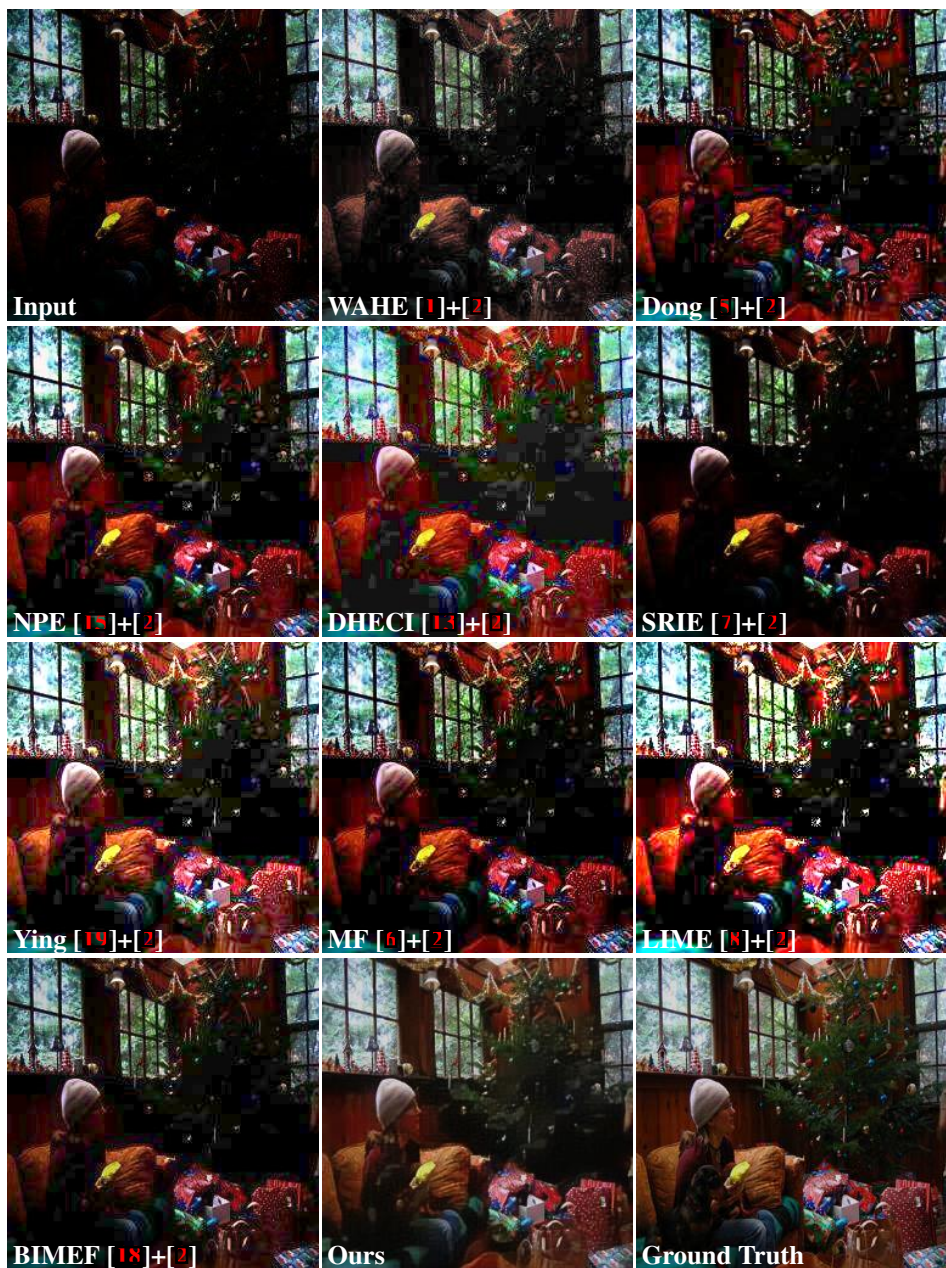Figure 23: Low-light image enhancement with additional Poisson noise.
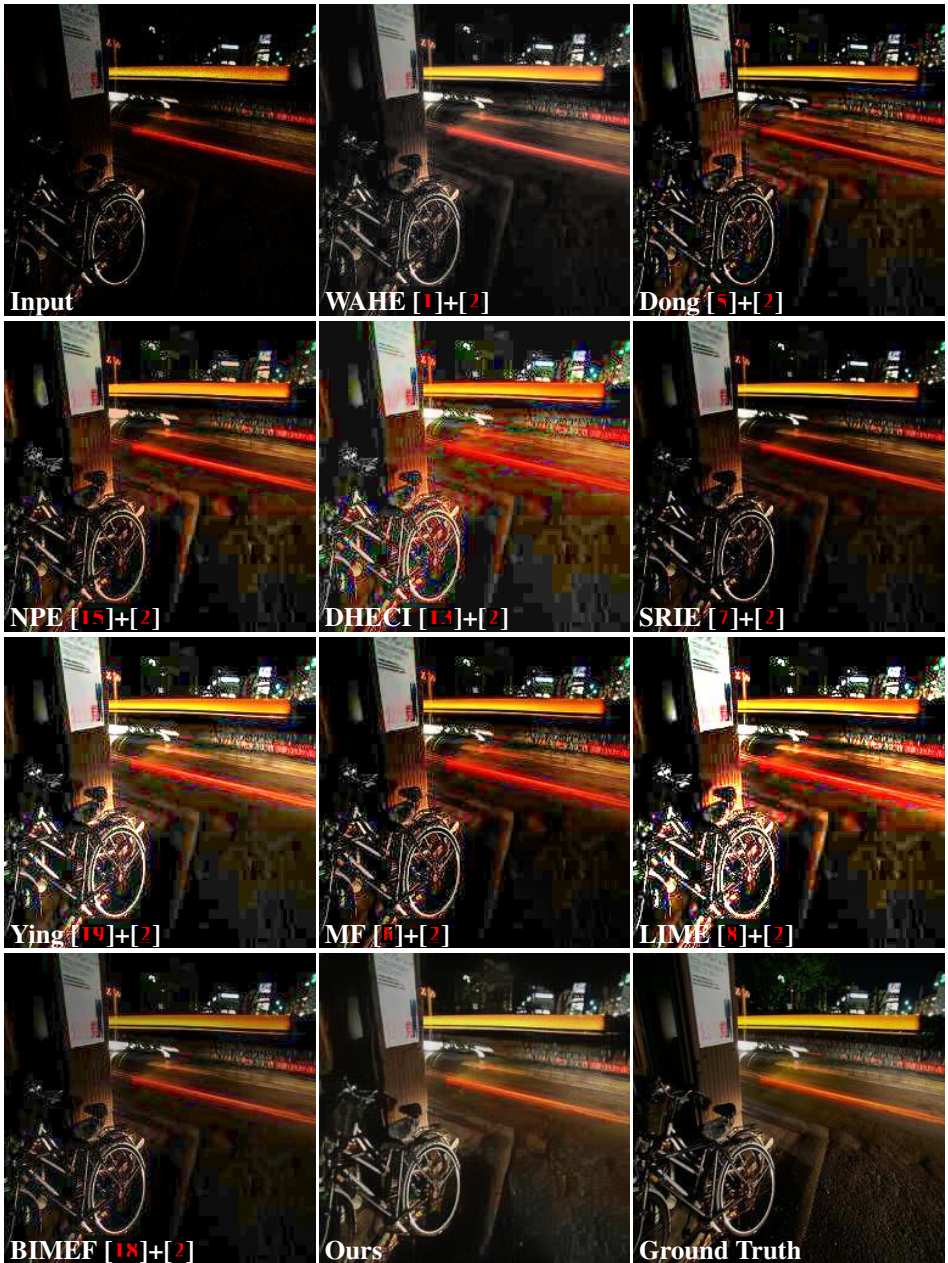
Figure 24: Low-light image enhancement with additional Poisson noise.

Figure 25: Low-light image enhancement with additional Poisson noise.
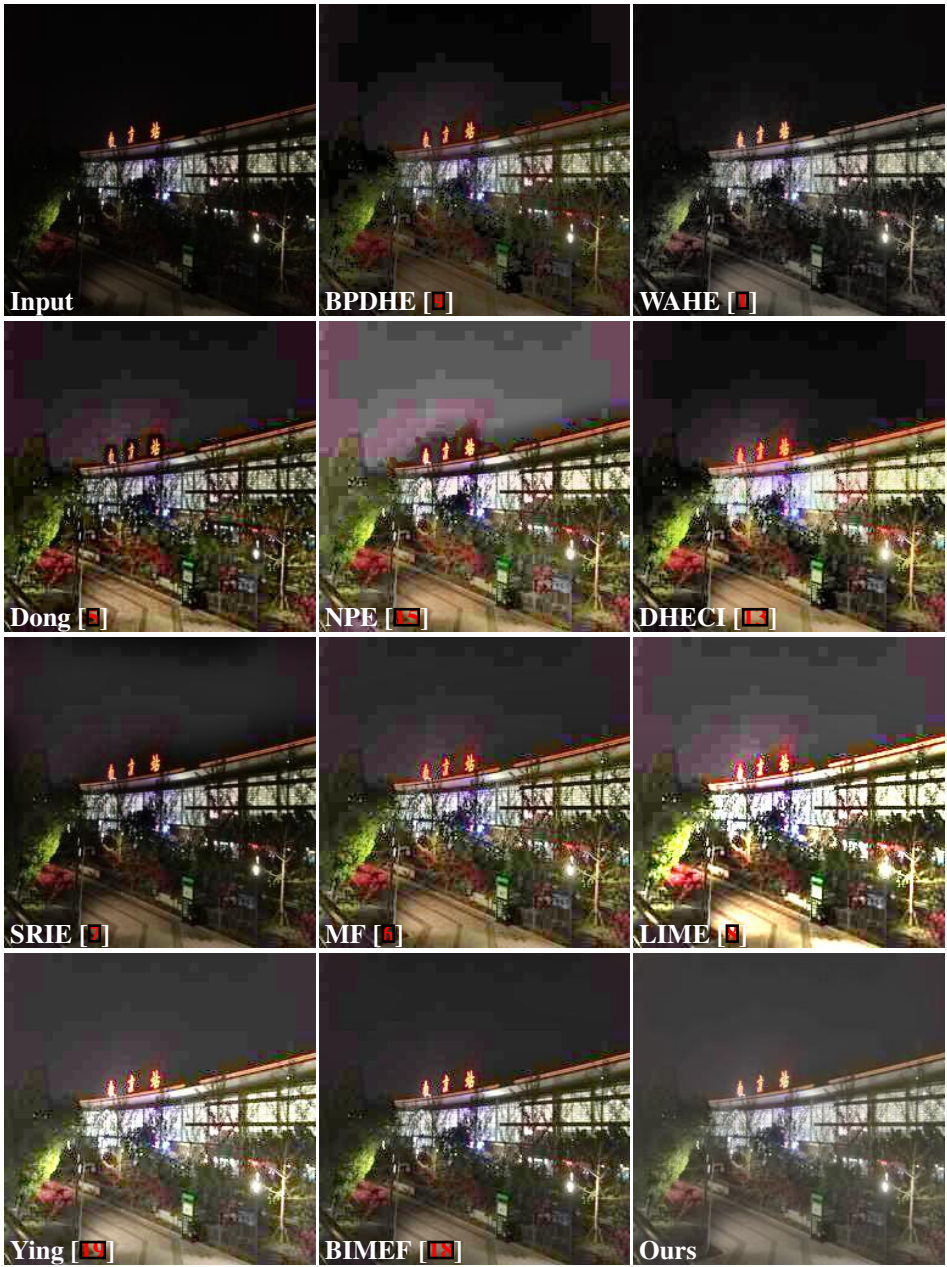
Figure 26: Comparison on natural low-light image enhancement.

Figure 27: Comparison on natural low-light image enhancement.
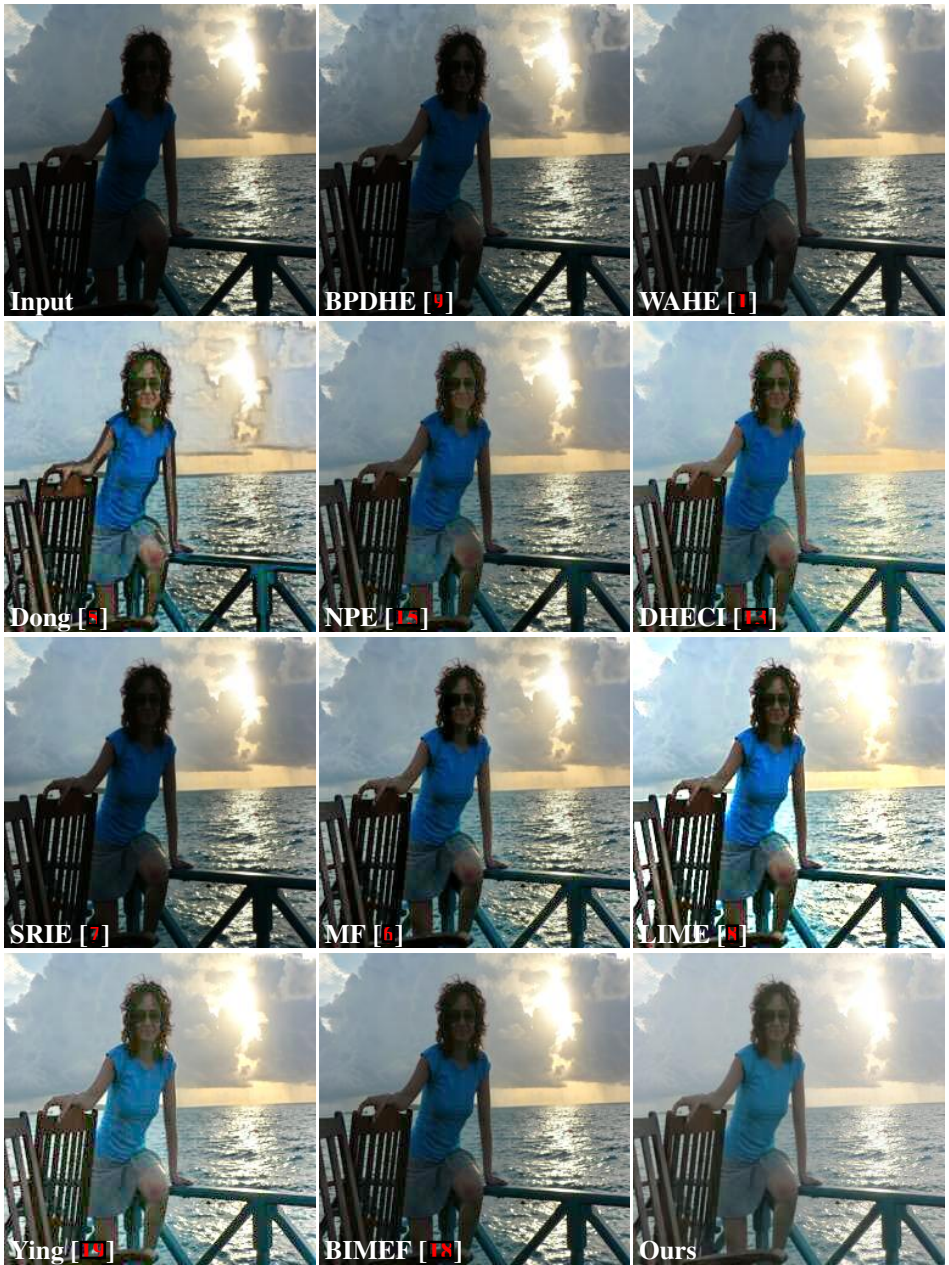
Figure 28: Comparison on natural low-light image enhancement.

Figure 29: Comparison on natural low-light image enhancement.

Figure 30: Comparison on natural low-light image enhancement.

Figure 31: Additional results on natural low-light image enhancement.

References

[1] Tarik Arici, Salih Dikbas, and Yucel Altunbasak. A histogram modification framework and its application for image contrast enhancement. *IEEE Transactions on image processing*, 18(9):1921–1935, 2009.

[2] Lucio Azzari and Alessandro Foi. Variance stabilization for noisy+ estimate combination in iterative poisson denoising. *IEEE signal processing letters*, 23(8):1086–1090, 2016.
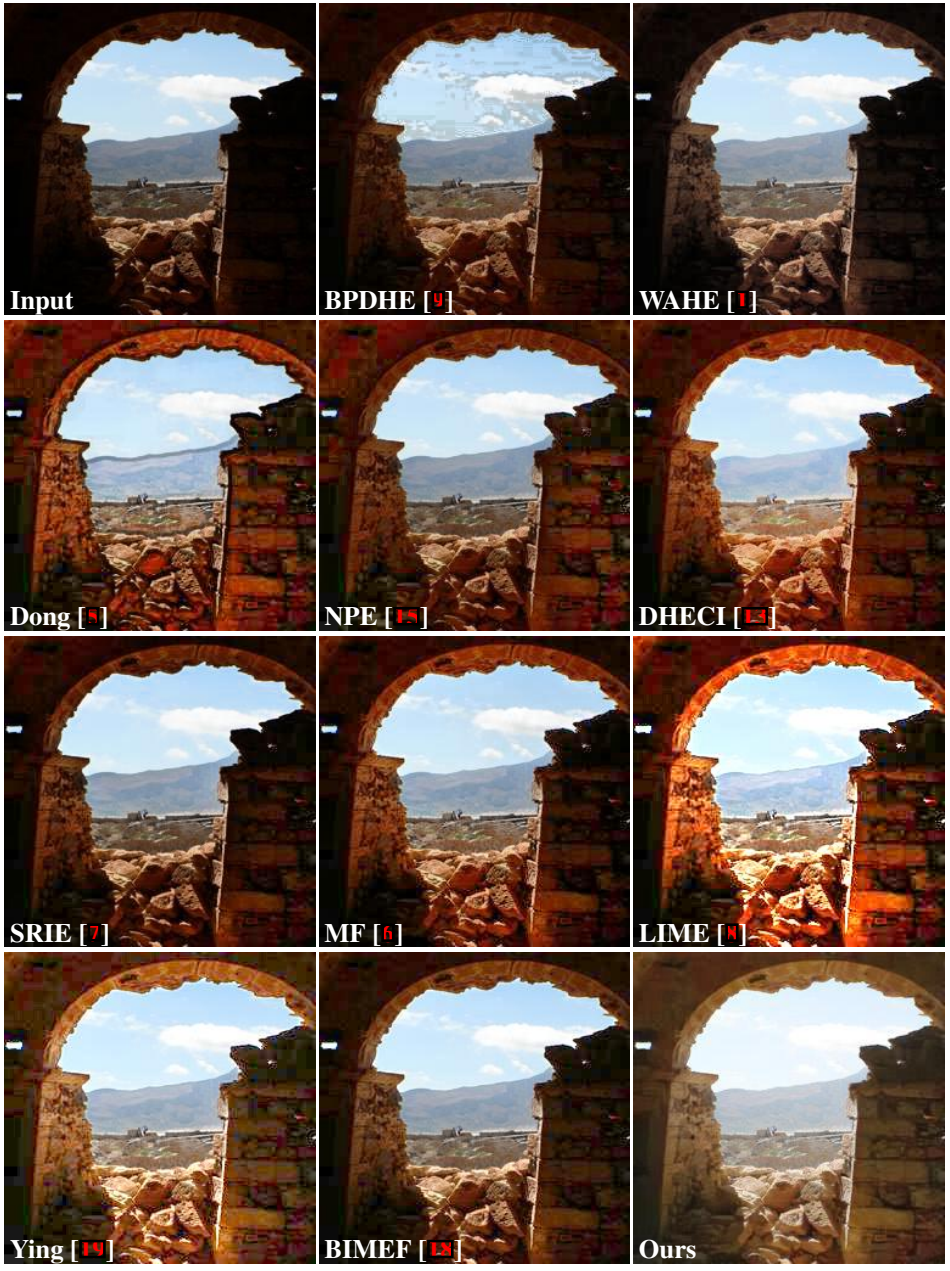
[3] Turgay Celik and Tardi Tjahjadi. Contextual and variational contrast enhancement. *IEEE Transactions on Image Processing*, 20(12):3431–3441, 2011.

[4] ZhiYu Chen, Besma R Abidi, David L Page, and Mongi A Abidi. Gray-level grouping (glg): an automatic method for optimized image contrast enhancement-part i: the basic method. *IEEE transactions on image processing*, 15(8):2290–2302, 2006.

[5] Xuan Dong, Guan Wang, Yi Pang, Weixin Li, Jiangtao Wen, Wei Meng, and Yao Lu. Fast efficient algorithm for enhancement of low lighting video. In *Multimedia and Expo (ICME), 2011 IEEE International Conference on*, pages 1–6. IEEE, 2011.

[6] Xueyang Fu, Delu Zeng, Yue Huang, Yinghao Liao, Xinghao Ding, and John Paisley. A fusion-based enhancing method for weakly illuminated images. *Signal Processing*, 129:82–96, 2016.

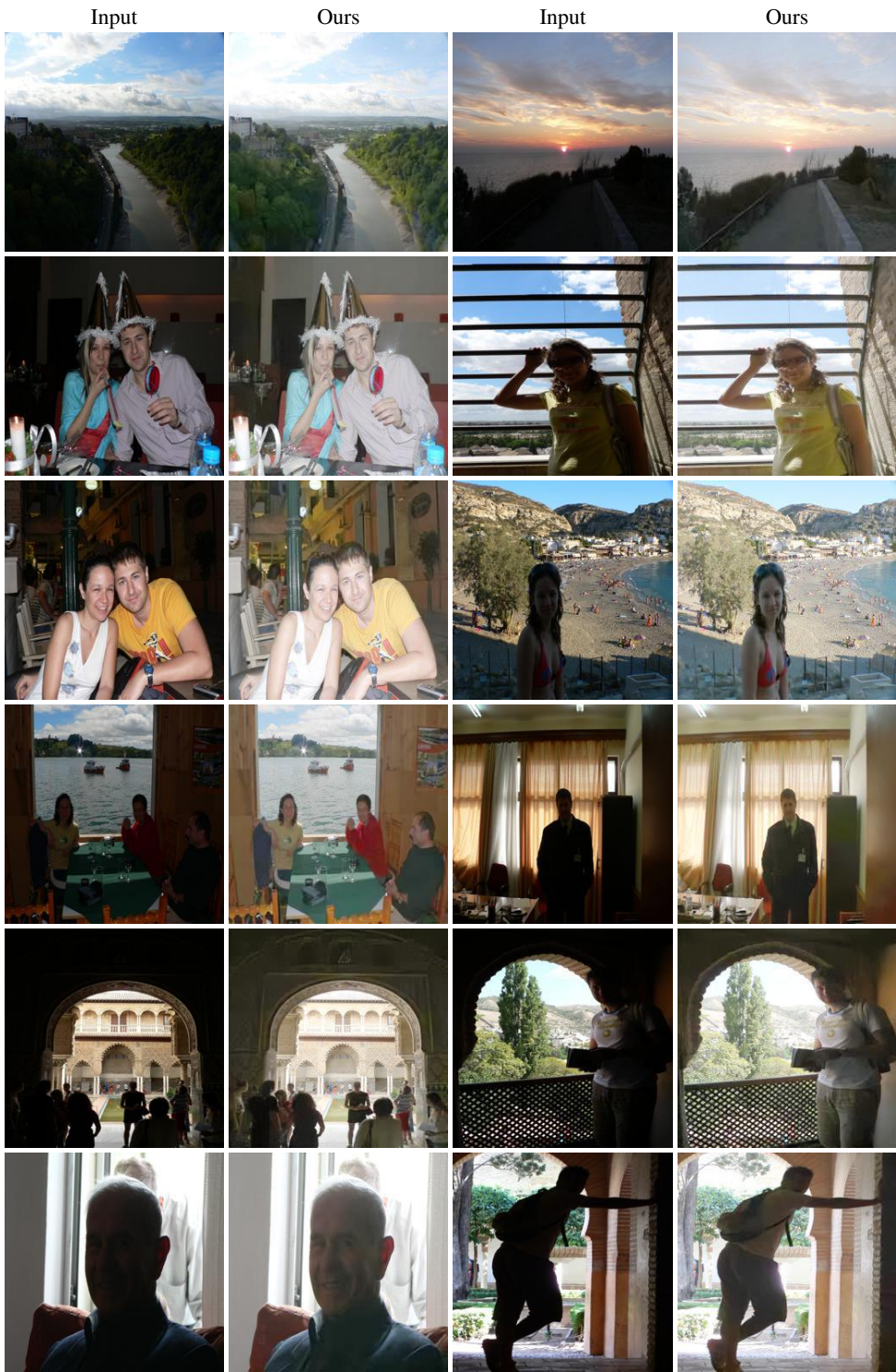[7] Xueyang Fu, Delu Zeng, Yue Huang, Xiao-Ping Zhang, and Xinghao Ding. A weighted variational model for simultaneous reflectance and illumination estimation. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pages 2782–2790, 2016.

[8] Xiaojie Guo, Yu Li, and Haibin Ling. Lime: Low-light image enhancement via illumination map estimation. *IEEE Transactions on Image Processing*, 26(2):982–993, 2017.

[9] Haidi Ibrahim and Nicholas Sia Pik Kong. Brightness preserving dynamic histogram equalization for image contrast enhancement. *IEEE Transactions on Consumer Electronics*, 53(4):1752–1758, 2007.

[10] Daniel J Jobson, Zia-ur Rahman, and Glenn A Woodell. A multiscale retinex for bridging the gap between color images and the human observation of scenes. *IEEE Transactions on Image processing*, 6(7):965–976, 1997.

[11] Chang-Hsing Lee, Jau-Ling Shih, Cheng-Chang Lien, and Chin-Chuan Han. Adaptive multiscale retinex for image contrast enhancement. In *Signal-Image Technology & Internet-Based Systems (SITIS), 2013 International Conference on*, pages 43–50. IEEE, 2013.

[12] Chulwoo Lee, Chul Lee, and Chang-Su Kim. Contrast enhancement based on layered difference representation of 2d histograms. *IEEE transactions on image processing*, 22 (12):5372–5384, 2013.

[13] Keita Nakai, Yoshikatsu Hoshi, and Akira Taguchi. Color image contrast enhacement method based on differential intensity/saturation gray-levels histograms. In *Intelligent Signal Processing and Communications Systems (ISPACS), 2013 International Symposium on*, pages 445–449. IEEE, 2013.

[14] Hamid R Sheikh and Alan C Bovik. Image information and visual quality. *IEEE Transactions on image processing*, 15(2):430–444, 2006.

[15] Shuhang Wang, Jin Zheng, Hai-Miao Hu, and Bo Li. Naturalness preserved enhancement algorithm for non-uniform illumination images. *IEEE Transactions on Image Processing*, 22(9):3538–3548, 2013.

[16] Zhou Wang, Alan C Bovik, Hamid R Sheikh, and Eero P Simoncelli. Image quality assessment: from error visibility to structural similarity. *IEEE transactions on image processing*, 13(4):600–612, 2004.

[17] Hojatollah Yeganeh and Zhou Wang. Objective quality assessment of tone-mapped images. *IEEE Transactions on Image Processing*, 22(2):657–667, 2013.

[18] Zhenqiang Ying, Ge Li, and Wen Gao. A bio-inspired multi-exposure fusion framework for low-light image enhancement. *arXiv preprint arXiv:1711.00591*, 2017.

[19] Zhenqiang Ying, Ge Li, Yurui Ren, Ronggang Wang, and Wenmin Wang. A new low-light image enhancement algorithm using camera response model. *manuscript submitted for publication*, 2017.