

Supplementary Material: A Holistic Approach to Cross-Channel Image Noise Modeling and its Application to Image Denoising

Seonghyeon Nam*
Yonsei University

Youngbae Hwang*
KETI

Yasuyuki Matsushita
Osaka University

Seon Joo Kim
Yonsei University

1. Dataset

As mentioned in the main paper, we captured 500 JPEG images of 11 static scenes to compute both the mean and the covariance for each pixel. We also generated a mask to exclude unreliable regions due to small movements. Figure 1 shows the scenes in our dataset and Table 1 shows the camera settings used to capture the data. We divided our dataset into the training set and the test set as shown on the right side of Table 1.

2. Image Denoising Results

Figure 2 to Figure 14 show all the qualitative results of Table 2 in the main paper. We compare our noise model to BM3D [1], original BNLM [2], and BNLM with NLF noise model [3]. It is recommended to zoom in the figures in the digital copy for better evaluation.

* Authors contributed equally to this work.



(a) From left to right, 1, 2, 3, 4, and 5



(b) From left to right, 1, 2, and 3

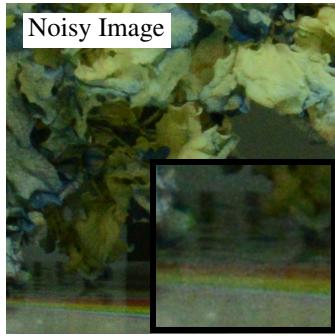


(c) From left to right, 1, 2, and 3

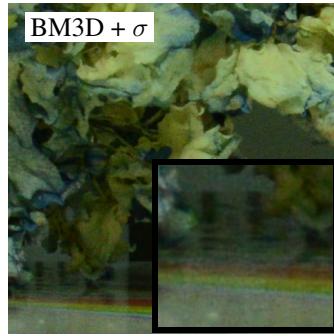
Figure 1. Our dataset.

Dataset #	Camera Settings				Training Set #	Test Set #
	Camera	ISO	JPEG	Image Size		
(b)	Nikon D800	1600	Normal	7360×4912	1-2	3
(a)	Nikon D800	3200	Normal	7360×4912	1-2	3-5
(b)	Nikon D800	6400	Normal	7360×4912	1-2	3
(c)	Nikon D600	3200	Normal	6016×4016	1-2	3
(c)	Canon EOS 5D Mark III	3200	Fine	5760×3840	1-2	3

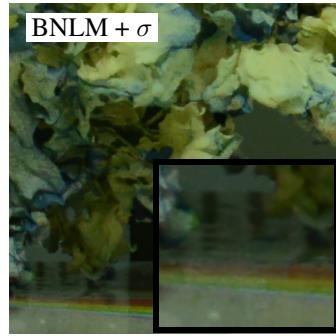
Table 1. Camera settings used to capture our dataset shown in Fig. 1. We captured Fig. 1 (b) using different ISOs and Fig. 1 (c) using different cameras.



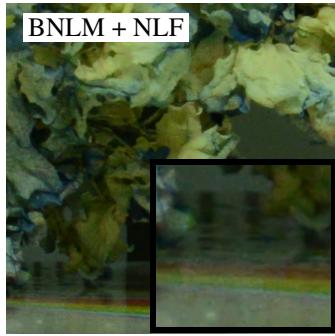
(a) PSNR: 35.47, SSIM: 0.957



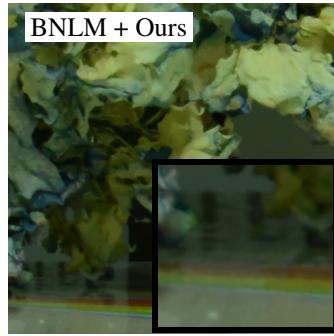
(b) PSNR: 36.15, SSIM: 0.964



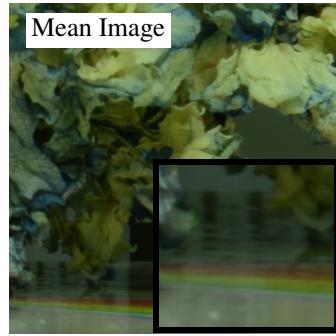
(c) PSNR: 37.59, SSIM: 0.980



(d) PSNR: 36.61, SSIM: 0.972

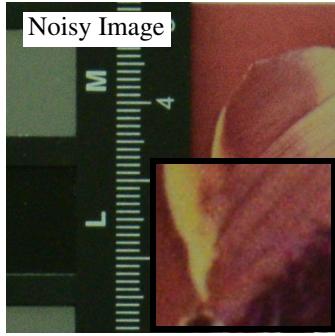


(e) PSNR: **37.99**, SSIM: **0.982**

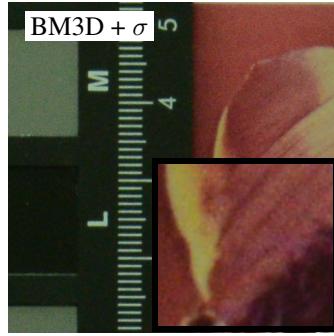


(f) Mean Image

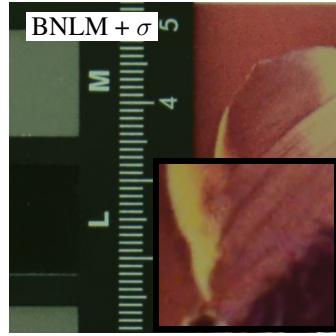
Figure 2. Denoised images of Image 1.



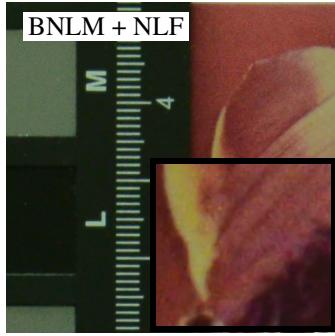
(a) PSNR: 35.71, SSIM: 0.954



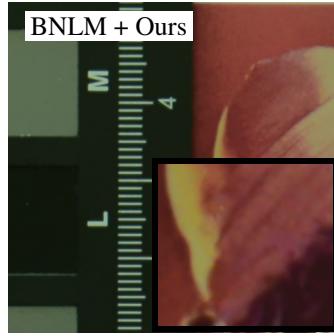
(b) PSNR: 36.57, SSIM: 0.964



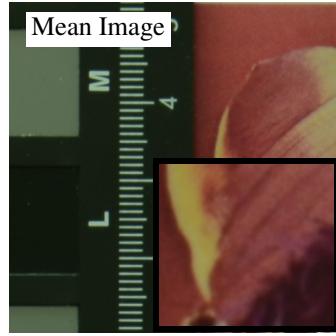
(c) PSNR: 39.42, SSIM: 0.990



(d) PSNR: 37.61, SSIM: 0.981

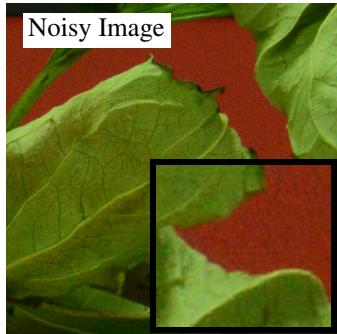


(e) PSNR: **40.36**, SSIM: **0.992**

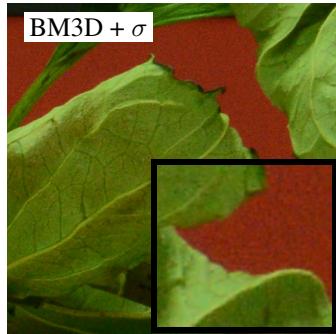


(f) Mean Image

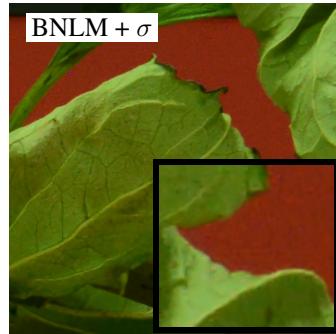
Figure 3. Denoised images of Image 2.



(a) PSNR: 34.81, SSIM: 0.989



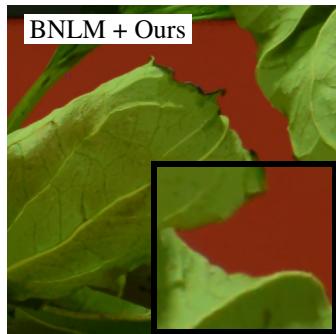
(b) PSNR: 35.47, SSIM: 0.991



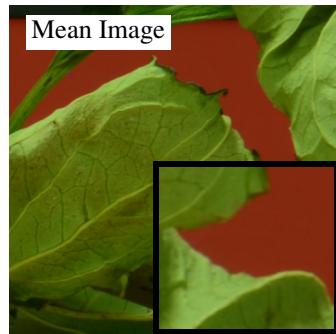
(c) PSNR: 37.40, SSIM: 0.995



(d) PSNR: 35.91, SSIM: 0.993



(e) PSNR: **38.30**, SSIM: **0.996**

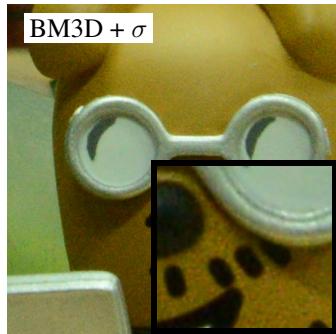


(f) Mean Image

Figure 4. Denoised images of Image 3.



(a) PSNR: 33.26, SSIM: 0.978



(b) PSNR: 34.00, SSIM: 0.982



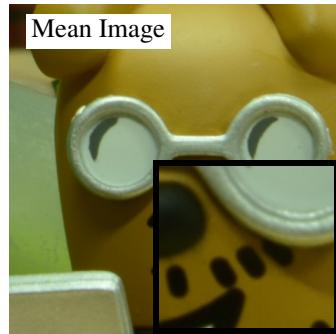
(c) PSNR: 38.10, SSIM: 0.992



(d) PSNR: 35.99, SSIM: 0.988



(e) PSNR: **39.01**, SSIM: **0.993**



(f) Mean Image

Figure 5. Denoised images of Image 4.

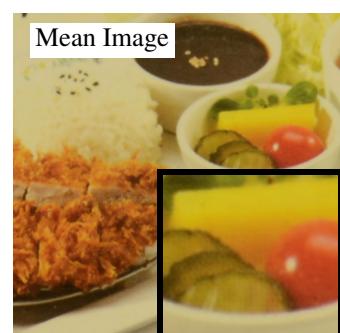
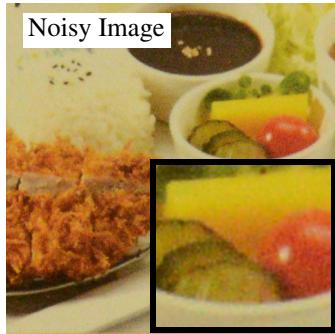


Figure 6. Denoised images of Image 5.

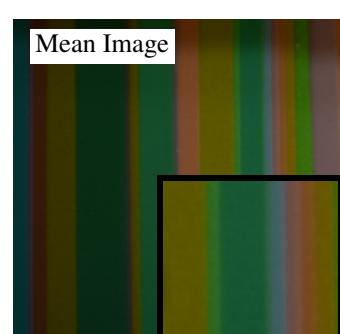
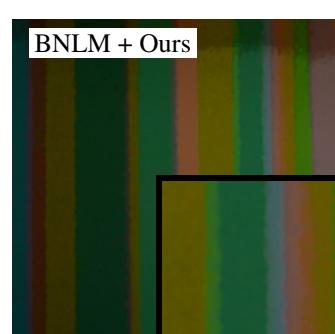
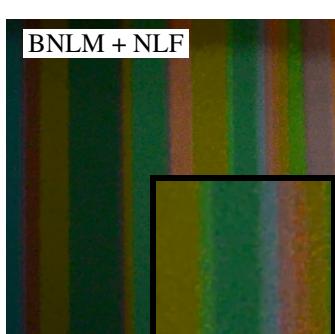
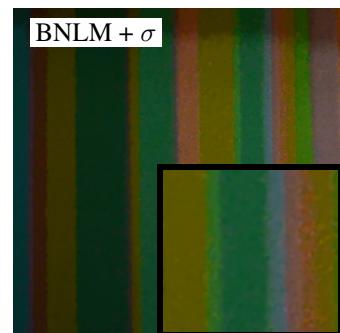
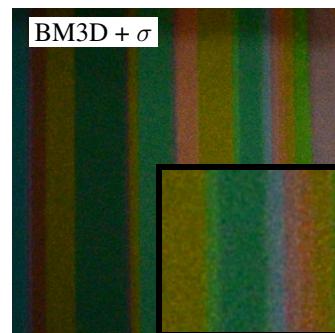
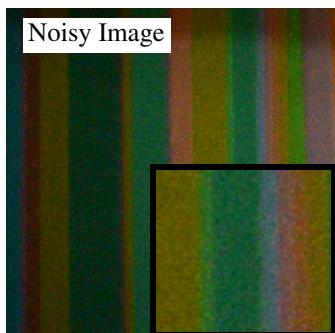


Figure 7. Denoised images of Image 6.

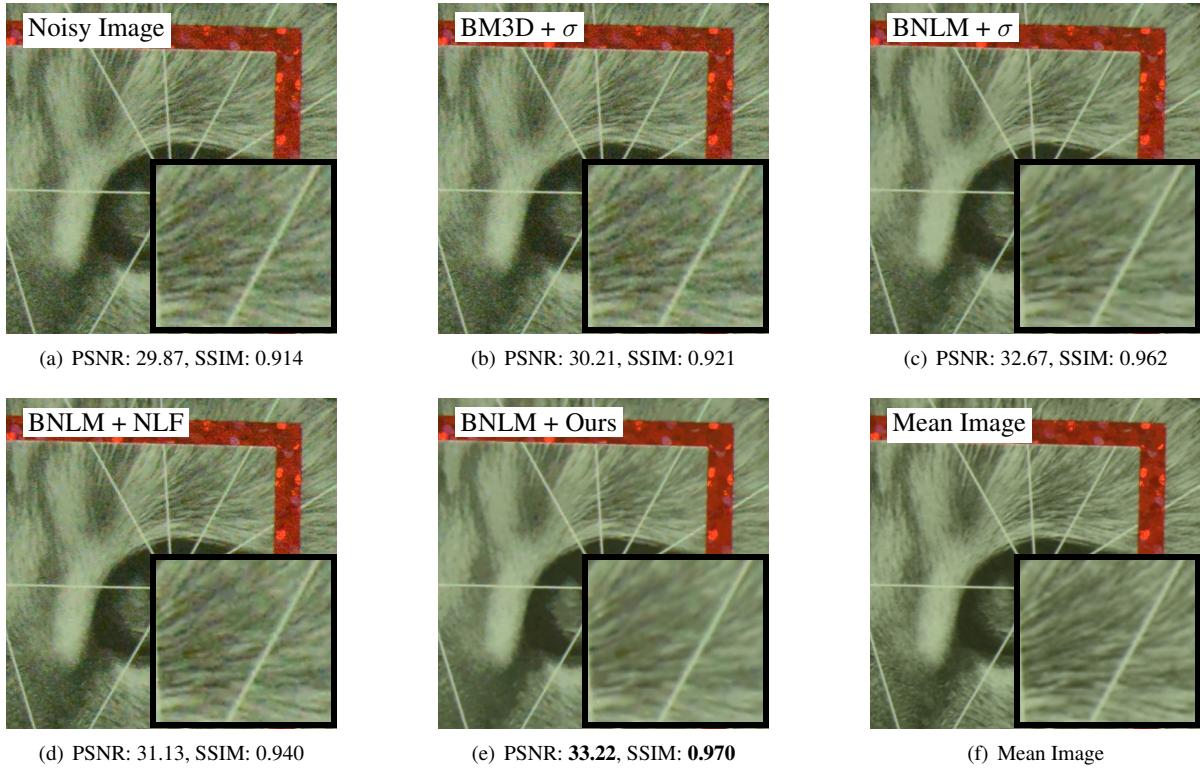


Figure 8. Denoised images of Image 9.

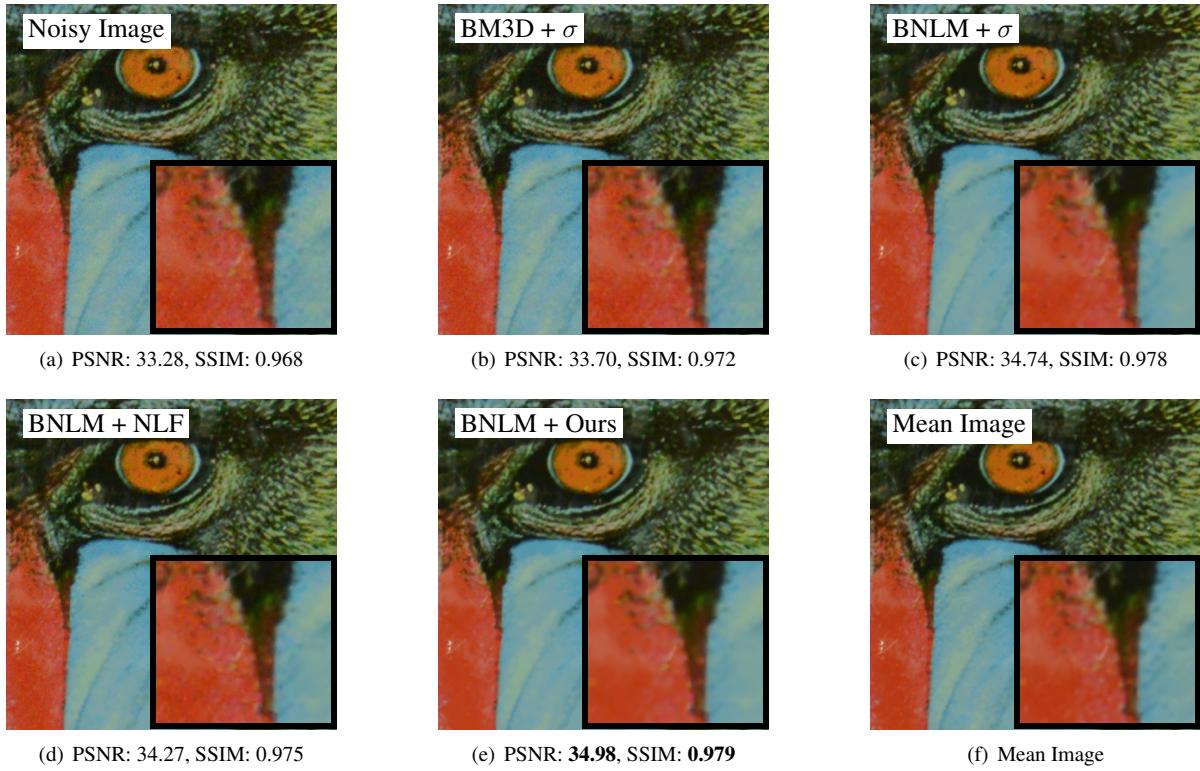


Figure 9. Denoised images of Image 10.

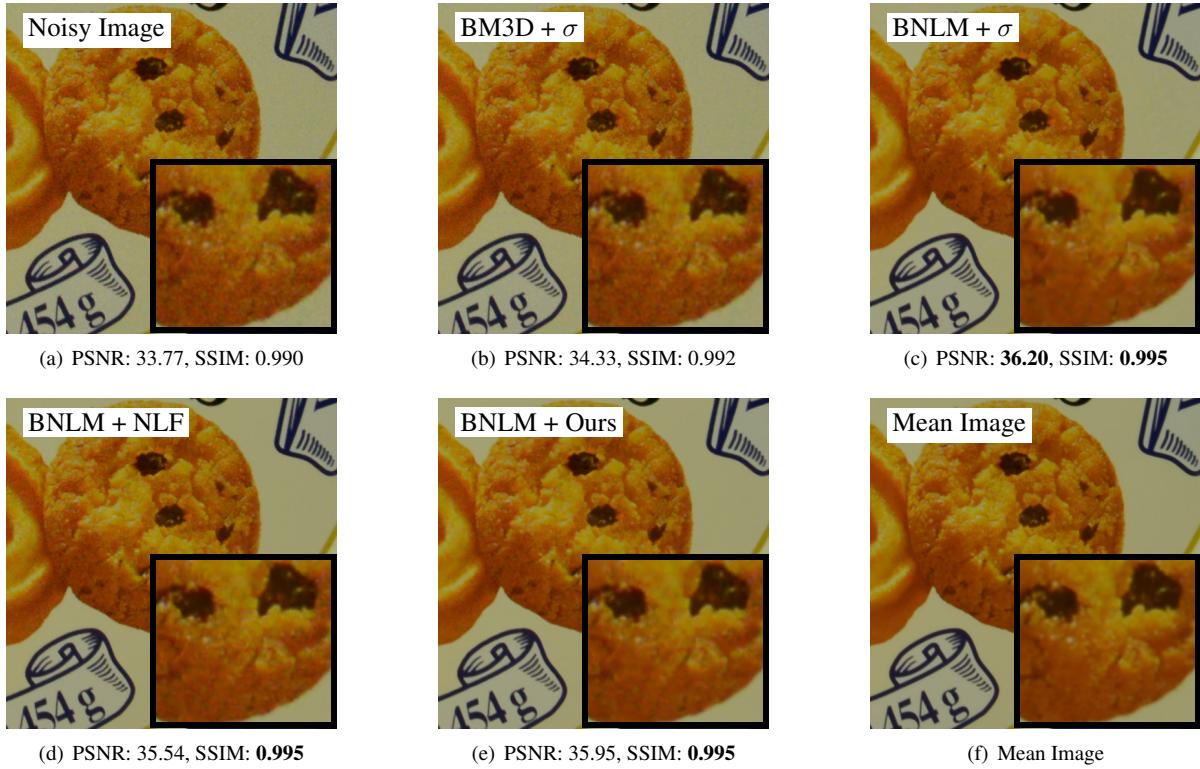


Figure 10. Denoised images of Image 11.

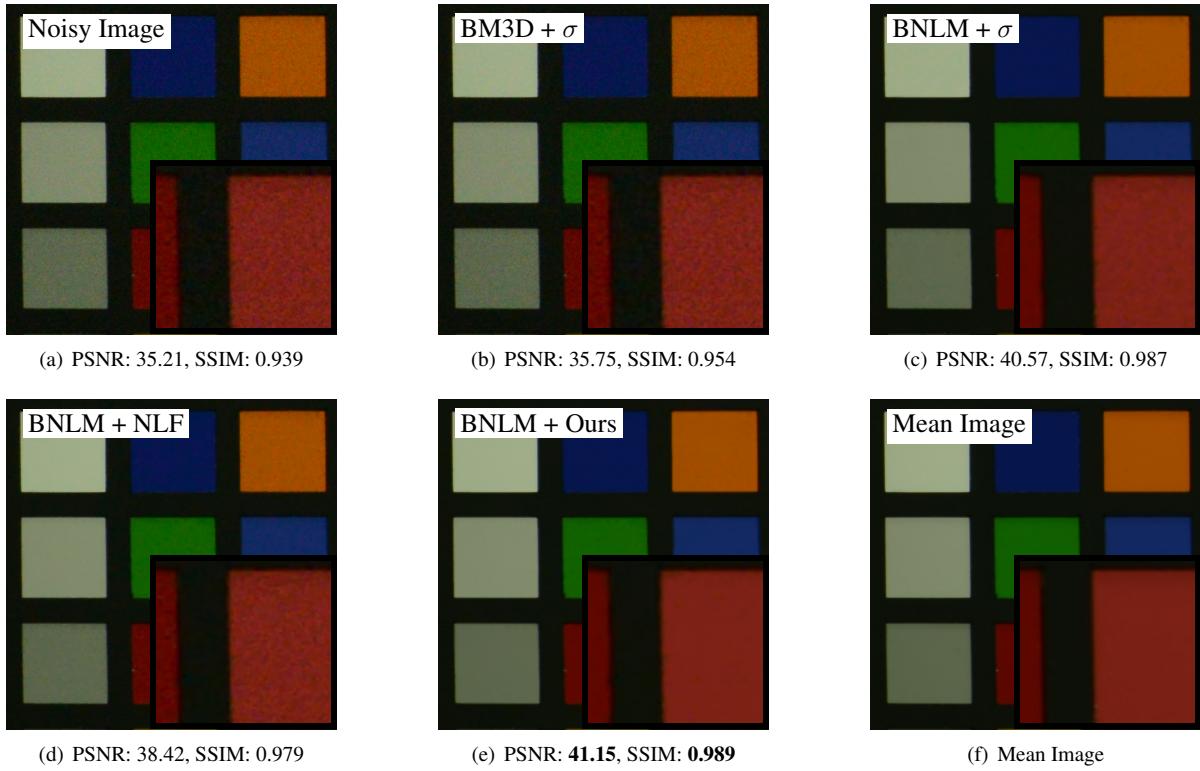


Figure 11. Denoised images of Image 12.



(a) PSNR: 37.00, SSIM: 0.976



(b) PSNR: 37.79, SSIM: 0.984



(c) PSNR: **38.44**, SSIM: 0.986



(d) PSNR: 37.97, SSIM: 0.987

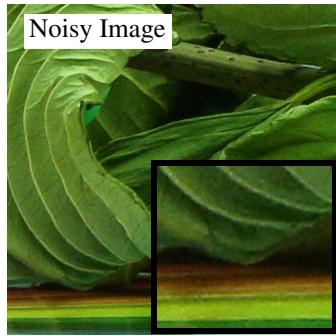


(e) PSNR: 38.37, SSIM: **0.988**

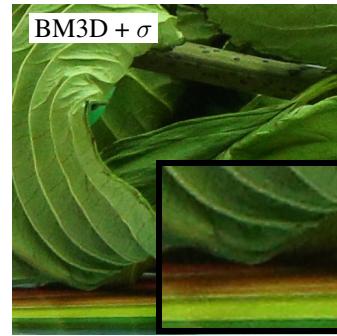


(f) Mean Image

Figure 12. Denoised images of Image 13.



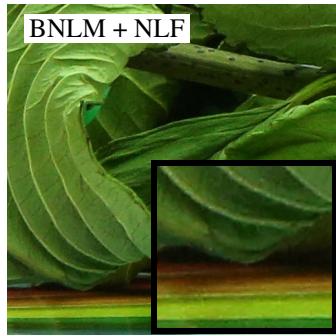
(a) PSNR: 33.88, SSIM: 0.983



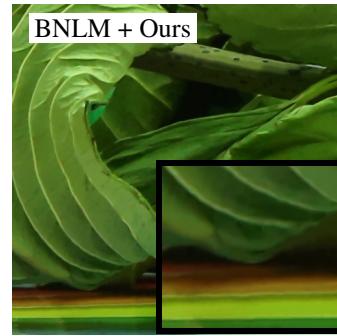
(b) PSNR: 34.34, SSIM: 0.986



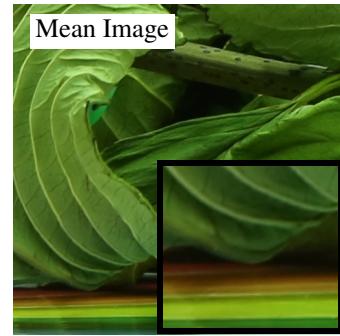
(c) PSNR: 35.27, SSIM: 0.988



(d) PSNR: 34.39, SSIM: 0.986



(e) PSNR: **35.37**, SSIM: **0.990**



(f) Mean Image

Figure 13. Denoised images of Image 14.

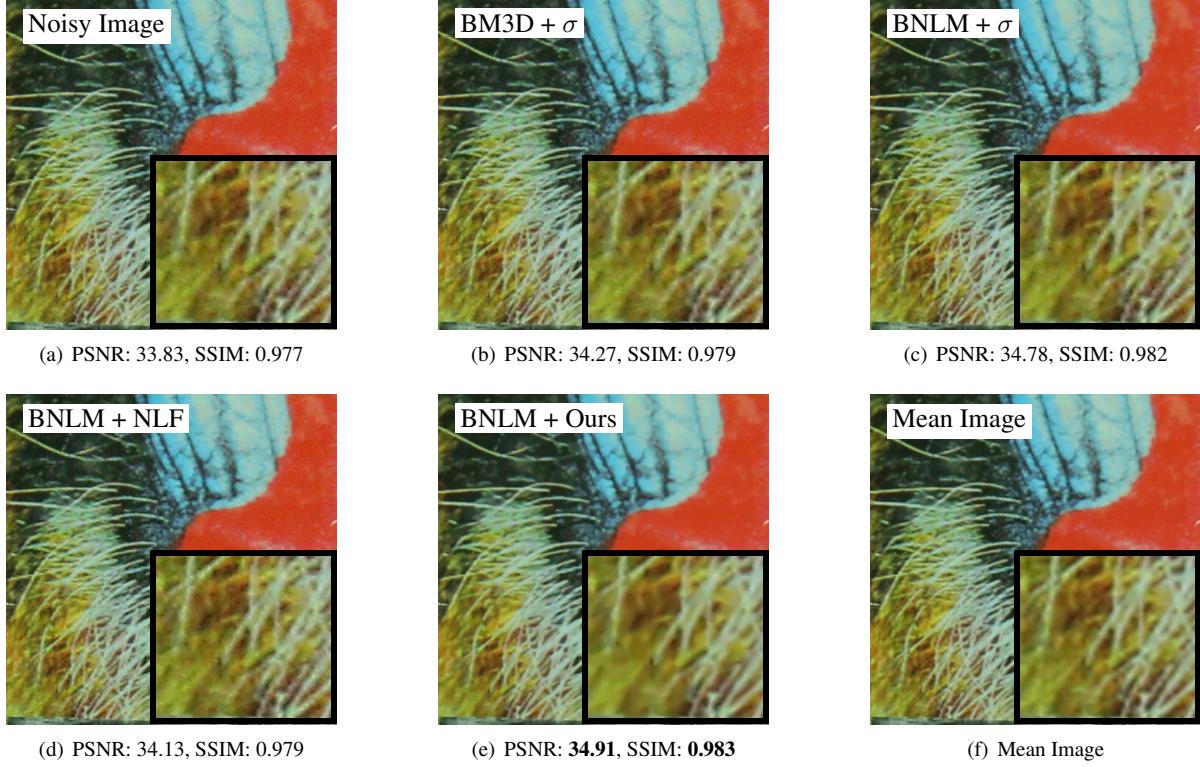


Figure 14. Denoised images of Image 15.

References

- [1] K. Dabov, A. Foi, V. Katkovnik, and K. Egiazarian. Image denoising by sparse 3-d transform-domain collaborative filtering. *IEEE Trans. Image Process.*, 16(8):2080–2095, Aug 2007.
- [2] C. Kerfrann, J. Boulanger, and P. Coup. Bayesian non-local means filter, image redundancy and adaptive dictionaries for noise removal. In *Proc. Conf. Scale-Space and Variational Meth.*, 2007.
- [3] C. Liu, R. Szeliski, S. B. Kang, C. L. Zitnick, and W. T. Freeman. Automatic estimation and removal of noise from a single image. *IEEE Trans. Pattern Anal. Mach. Intell.*, 30(2):299–314, 2008.