# Supplementary Material: Learning to dehaze with polarization

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## 7 Additional synthetic results

In this section, we provide additional comparisons on synthetic data among our method, a representative polarization-based dehazing algorithm SPCVE [4] which also takes three polarized images as the input, and five state-of-the-art learning-based dehazing methods including GDN [3], BPP [6], FFA [5], HardGAN [1], and MSBDN [2] which take a single hazy image as the input, as shown in Figure 7, Figure 8, and Figure 9, corresponding to Footnote 9 in Section 5.1 of the paper.

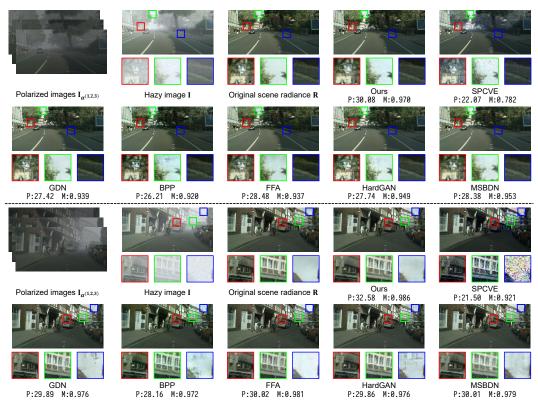


Figure 7: Additional comparisons on synthetic data (part 1). Quantitative results evaluated using PSNR (P) and MS-SSIM (M) are displayed below each image.

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Polarized images $I_{\alpha^{(1,2,3)}}$	Hazy image I	Original scene radiance R	Ours P:33.17 M:0.984	SPCVE P:17.34 M:0.793
GDN P:29.80 M:0.968	BPP P:29.50 M:0.966	FFA P:30.69 M:0.974	HardGAN P:28.62 M:0.964	MSBDN P:30.38 M:0.970
Polarized images $I_{\alpha^{(1,2,3)}}$	Hazy image I	Original scene radiance <b>R</b>	Ours P:32.46 M:0.976	SPCVE P:18.98 M:0.687
GDN	BPP	FFA	HardGAN	MSBDN
P:28.86 M:0.952	P:28.11 M:0.950	P:26.44 M:0.930	P:27.11 M:0.937	P:30.06 M:0.958
1				
Polarized images $I_{\alpha^{(1,2,3)}}$	Hazy image I	Original scene radiance <b>R</b>	Ours P:30.06 M:0.970	SPCVE P:18.55 M:0.672
GDN	BPP	FFA	HardGAN	MSBDN
P:27.98 M:0.934	P:26.77 M:0.932	P:28.40 M:0.946	P:25.32 M:0.926	P:27.34 M:0.934
Polarized images I <sub>a</sub> (12.3)	Hazy image I	Original scene radiance R	Ours	SPCVE
Folanzed images $I_{\alpha^{(1,2,3)}}$			P:30.56 M:0.978	P:22.11 M:0.900
GDN P:28.51 M:0.966	BPP P:28.15 M:0.965	FFA P:28.73 M:0.968	HardGAN P:27.86 M:0.967	MSBDN P:29.04 M:0.973

Figure 8: Additional comparisons on synthetic data (part 2). Quantitative results evaluated using PSNR (P) and MS-SSIM (M) are displayed below each image.

Polarized images $I_{\alpha^{(1,2,3)}}$	Hazy image I	Original scene radiance R	Ours P:30.27 M:0.979	SPCVE P:16.83 M:0.750
GDN	BPP	FFA	HardGAN	MSBDN
P:28.00 M:0.944	P:27.35 M:0.939	P:28.68 M:0.944	P:27.49 M:0.951	P:27.98 M:0.954
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Polarized images $I_{\alpha^{(1,2,3)}}$	Hazy image I	Original scene radiance <b>R</b>	Ours P:30.94 M:0.958	SPCVE P:16.88 M:0.601
GDN P:27.51 M:0.915	BPP P:25.69 M:0.933	FFA P:27.86 M:0.939	HardGAN P:28.58 M:0.942	MSBDN P:28.76 M:0.936
P:27.51 M:0.915	P:25.69 M:0.933	P:27.86 M:0.939	P:28.58 M:0.942	P:28.76 M:0.936
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Polarized images $I_{\alpha^{(1,2,3)}}$	Hazy image I	Original scene radiance R	Ours P:32.70 M:0.981	SPCVE P:14.62 M:0.601
GDN P:28.87 M:0.954	BPP P:26.43 M:0.953	FFA P:31.25 M:0.973	HardGAN P:29.02 M:0.964	MSBDN P:29.89 M:0.968
Polarized images $I_{a^{(1,2,3)}}$	Hazy image I	Original scene radiance R	Ours P:31.79 M:0.976	SPCVE P:23.19 M:0.813
GDN B 00 500		FFA P:27.69 M:0.950	HardGAN	
P:28.70 M:0.950	P:27.91 M:0.950	P:27.69 M:0.950	P:29.22 M:0.957	P:29.60 M:0.954

Figure 9: Additional comparisons on synthetic data (part 3). Quantitative results evaluated using PSNR (P) and MS-SSIM (M) are displayed below each image.

### 8 Additional real results

In this section, we provide additional qualitative comparisons on real data among our method, a representative polarization-based dehazing algorithm SPCVE [4] which also takes three polarized images as the input, and five state-of-the-art learning-based dehazing methods including GDN [3], BPP [6], FFA [5], HardGAN [1], and MSBDN [2] which take a single hazy image as the input, as shown in Figure 10, corresponding to Footnote 10 in Section 5.2 of the paper.

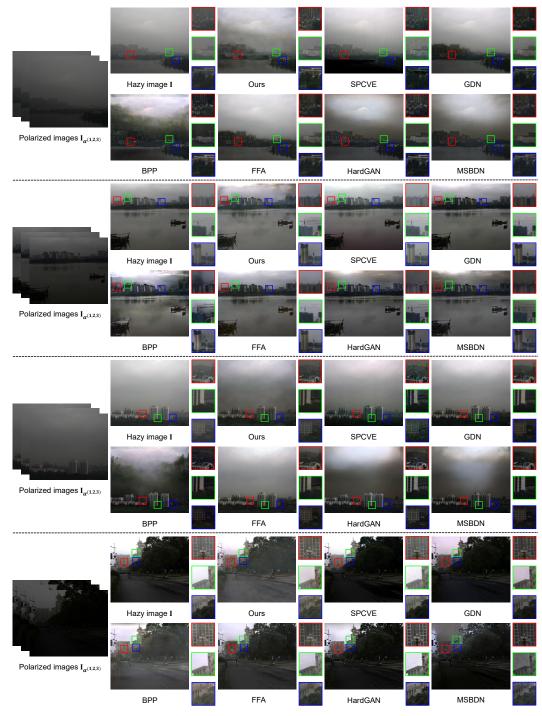


Figure 10: Additional qualitative comparisons on real data. All dehazing results are white-balanced to the similar color appearance and multiplied by a factor of 1.25 for better visualization.

### 9 Synthetic results without refinement

In this section, we provide qualitative comparisons on synthetic data without refinement (including the transmitted light  $\mathbf{T}$  and the original scene radiance  $\mathbf{R}$ ), as shown in Figure 11, corresponding to Footnote 11 in Section 5.3 of the paper.



Figure 11: Qualitative comparisons on synthetic data without refinement (including the transmitted light  $\mathbf{T}$  and the original scene radiance  $\mathbf{R}$ ). Quantitative results evaluated using PSNR (P) and MS-SSIM (M) are displayed below each image.

#### References

- Qili Deng, Ziling Huang, Chung-Chi Tsai, and Chia-Wen Lin. HardGAN: A haze-aware representation distillation GAN for single image dehazing. In Proc. of European Conference on Computer Vision, pages 722–738, 2020.
- [2] Hang Dong, Jinshan Pan, Lei Xiang, Zhe Hu, Xinyi Zhang, Fei Wang, and Ming-Hsuan Yang. Multi-scale boosted dehazing network with dense feature fusion. In *Proc. of Computer Vision and Pattern Recognition*, pages 2157–2167, 2020.
- [3] Xiaohong Liu, Yongrui Ma, Zhihao Shi, and Jun Chen. GridDehazeNet: Attention-based multi-scale network for image dehazing. In *Proc. of International Conference on Computer Vision*, pages 7314–7323, 2019.
- [4] Einav Namer, Sarit Shwartz, and Yoav Y Schechner. Skyless polarimetric calibration and visibility enhancement. *Optics Express*, 17(2):472–493, 2009.
- [5] Xu Qin, Zhilin Wang, Yuanchao Bai, Xiaodong Xie, and Huizhu Jia. FFA-Net: Feature fusion attention network for single image dehazing. In *Proc. of the AAAI Conference on Artificial Intelligence*, pages 11908–11915, 2020.
- [6] Ayush Singh, Ajay Bhave, and Dilip K Prasad. Single image dehazing for a variety of haze scenarios using back projected pyramid network. In *Proc. of European Conference on Computer Vision Workshops*, pages 166–181, 2020.