Physically Disentangled Intra- and Inter-domain Adaptation for Varicolored Haze Removal (Supplementary Materials)

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1. Introduction

For supplementary materials, we firstly provide more visualized varicolored haze removal results on real-world and synthetic images in Sec. 2. Then we present several analyses to further demonstrate the rationality of the proposed physically disentangled intra- and inter-domain adaptation (PDI2A) paradigm for varicolored haze removal in Sec. 3. Finally, we provide more implementation details in Sec. 4.

2. Additional Qualitative Comparisons

In this section, we provide more qualitative comparisons with existing state-of-the-art semi-supervised or unsupervised dehazing methods. Moreover, to better illustrate the generalization of the proposed method, we further compare the result of PDI2A with state-of-the-art fully-supervised method FFA-Net [5] on both synthetic and real-world data.

2.1. Comparisions on Synthetic Data

We compare more dehazing results of the proposed PDI2A with various state-of-the-art dehazing methods on synthetic varicolored haze images. All methods are further finetuned on our varicolored haze dataset for fair comparisons. Specifically, from Fig. 1 to 3 are the dehazing results on grayish, orange, bluish haze images. We can observe that FFA-Net [5] could achieve good results on synthetic data after finetuning, while other methods still could not get rid of the color cast effect.

2.2. Comparisions on Real Data

For further evaluating the generalization ability of the proposed method, we perform more visual comparisons on the collected real varicolored haze images, as shown in Fig. 4 to 13. Specifically, Fig. 4 to 6 show the comparison results under orange haze, while Fig. 7 to 9 and Fig. 10 to 13 represent the results under bluish and grayish haze respectively. We can observe that DCP [3], NLD [2], ZID [4] seriously darken the scene due to unsuitable prior for varicolored haze. DA-Dehazing [6] could generate results with higher contrast while still losing the original color of the scene. PSD [1] could generate more color fresh results with the help of CLAHE prior, however, the results of PSD are still heavily influenced by the color cast and generate unreal dehazing results. As for the fully supervised method FFA-Net [5], although FFA-Net could achieve satisfying results in synthetic data, they fail to handle real-world haze either from color distortion or low-contrast due to the gap between synthetic and real data. Compared with these methods, the proposed PDI2A solves the varicolored haze removal task by firstly handling the color distortion and then enhancing the contrast step by step. Such strategy resolves the complex varicolored haze removal task to two sub-tasks: color correction and haze removal. Benefitting from the former color correction, the latter haze removal could focus on reducing the haze density and enhancing the contrast, leading to better dehazing results without the color cast effect.

3. Additional Ablation Studies and Analyses

3.1. Analysis of Physically Disentangle Strategy for Color Correction

We further illustrate the importance of physically disentangle strategy for color correction. In Fig. 14, we visualize the color correction results with and without physically disentangle, in which we adopt one single generator for image-to-image color correction. We can observe that without physically disentangle strategy, the color correction result may face difficulties in distinguishing the effect of color-related atmospheric light and the identity background, thus only brightening the scene homogeneously. On the contrary, thanks to physically disentangle strategy and specific translation on color-related atmospheric light, the proposed PDI2A could achieve better color correction results and fully get rid of the color distortion.

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3.2. Analysis of Physically Disentangle Results

In this supplementary, we provide more analysis about the disentanglement through visualizing the disentanglement results in the intra-domain adaptation module. As shown in Fig. 15, we visualize the disentangle results on varicolored haze images. We can observe that the proposed method could disentangle the varicolored haze image into the clear background, transmission map, and atmospheric light well. Furthermore, by specifically translating the varicolored atmospheric light to the color-balanced one, the proposed method could physically reconstruction process could perform satisfactory color correction while keeping the identity background unchanged, greatly easing the difficulties of the latter inter-domain adaptation.

4. More Implementation Details

We implement the proposed PDI2A in Pytorch. The experiments are carried out with a single NVIDIA RTX 3090 GPU. We firstly pre-train the synthetic path utilizing synthetic data via supervised disentangle loss [Eq. 7] in the main manuscripts and adversarial loss with Adam optimizer and 1e-3 learning rate for 90 epochs. During training, we initialize the weights through normalized initialization and set the mini-batch to 2 with patchsize of 256*256. The learning rate decreases linearly to 0 after 90 epochs. After pretraining utilizing synthetic data, we jointly finetune the whole network utilizing both synthetic and real data with 1e-5 learning rate for 90 epochs. The size of mini-batch is 2 and the learning rate does not decrease during finetuning.

References

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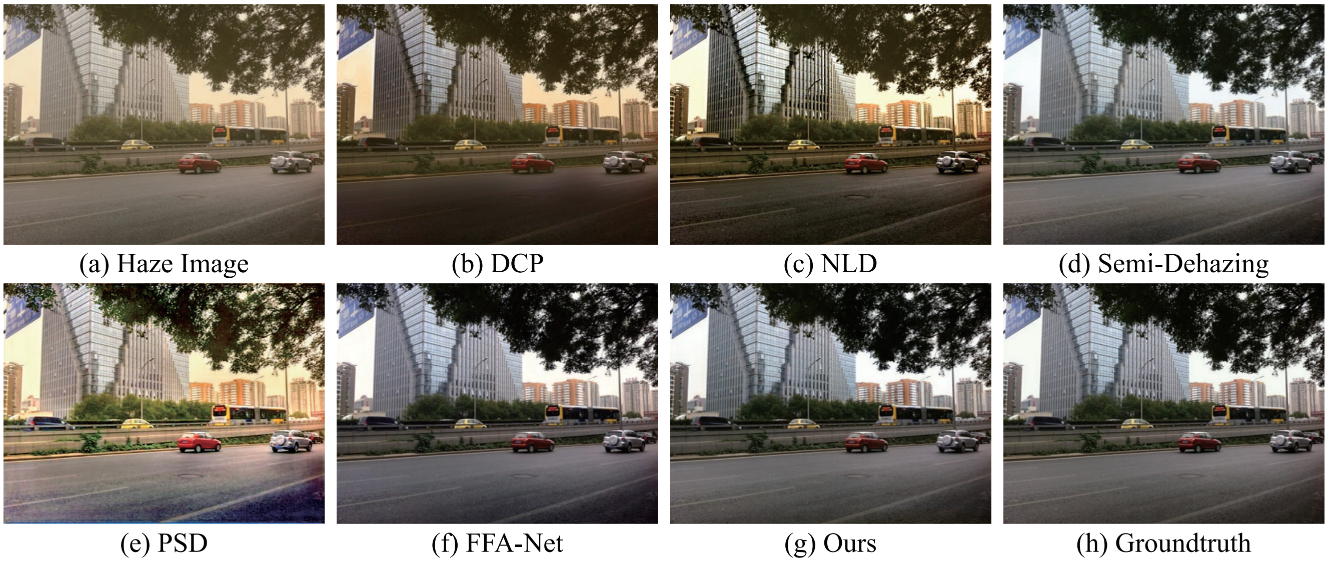


Figure 1. Visual comparison on synthetic varicolored haze images (orange color).

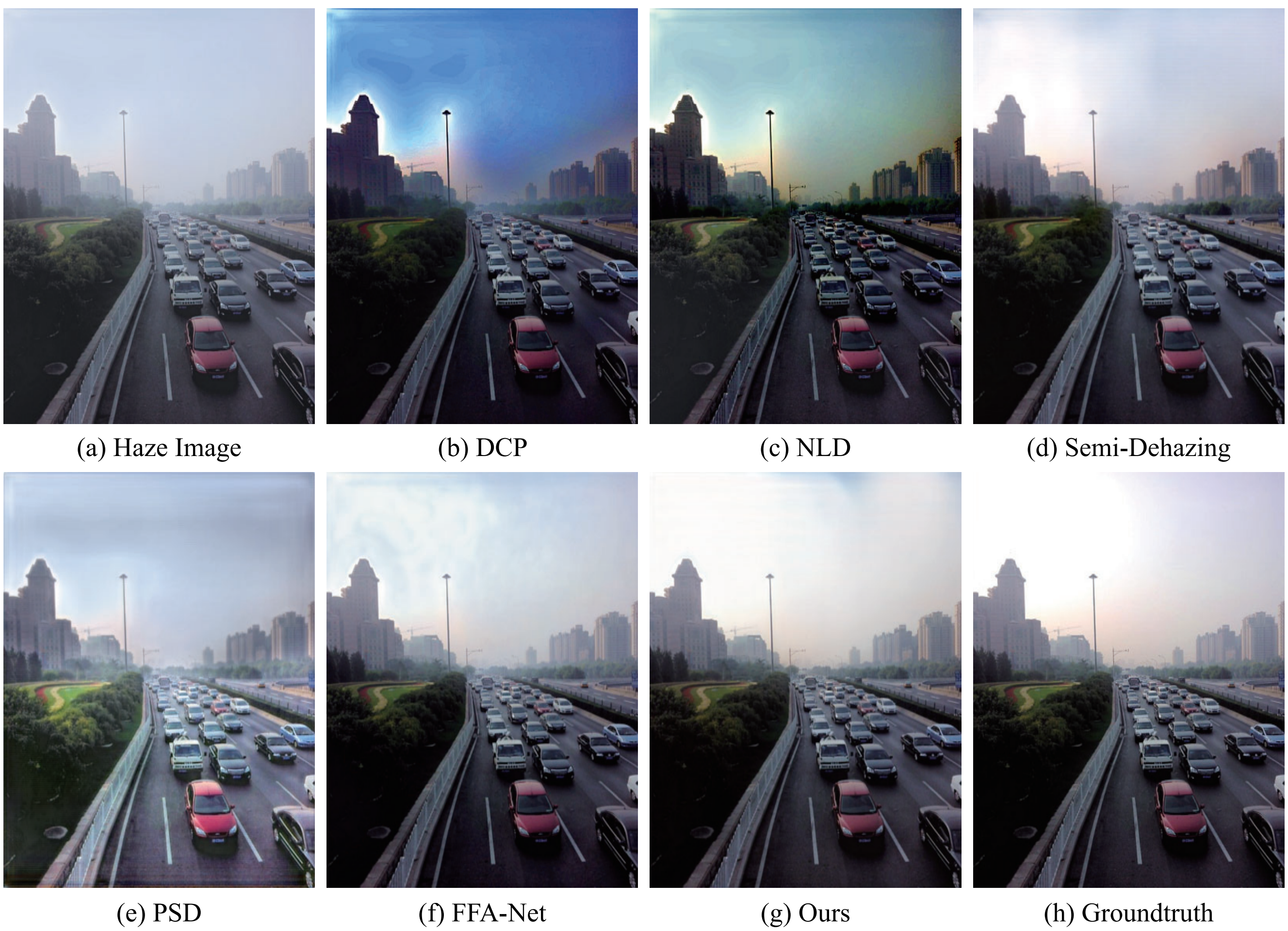
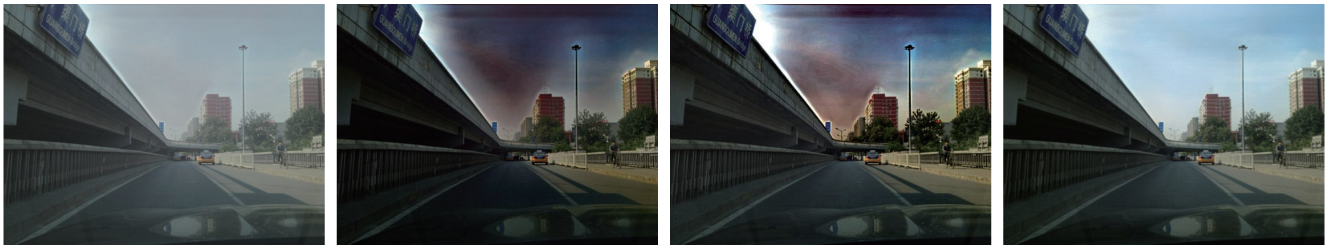


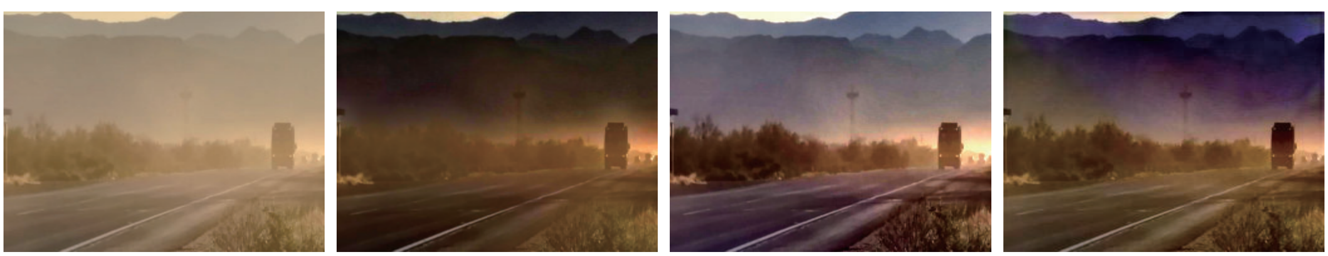
Figure 2. Visual comparison on synthetic varicolored haze images (bluish color).



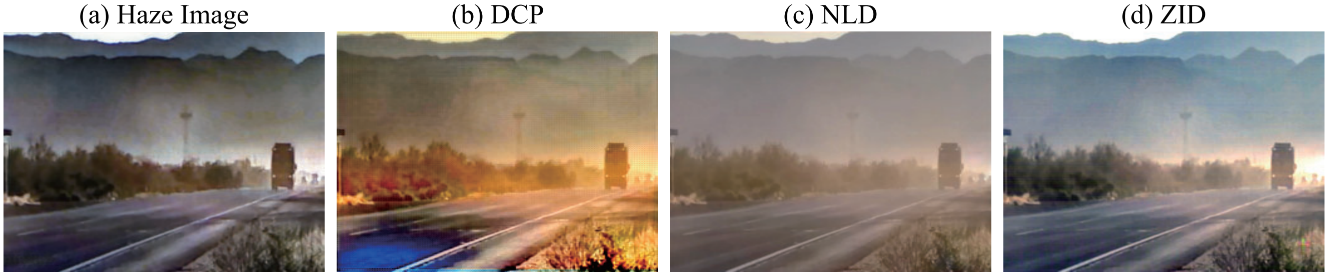
(a) Haze Image (b) DCP (c) NLD (d) Semi-Dehazing

(e) PSD (f) FFA-Net (g) Ours (h) Groundtruth

Figure 3. Visual comparison on synthetic varicolored haze images (grayish color).

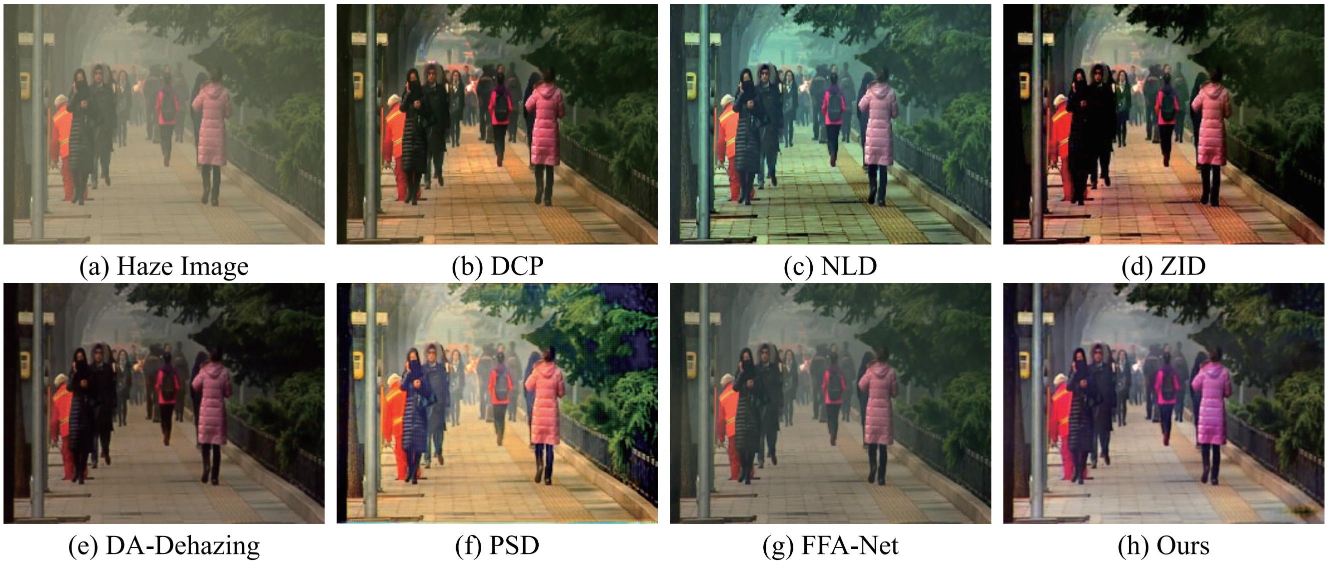


(a) Haze Image (b) DCP (c) NLD (d) ZID



(e) DA-Dehazing (f) PSD (g) FFA-Net (h) Ours

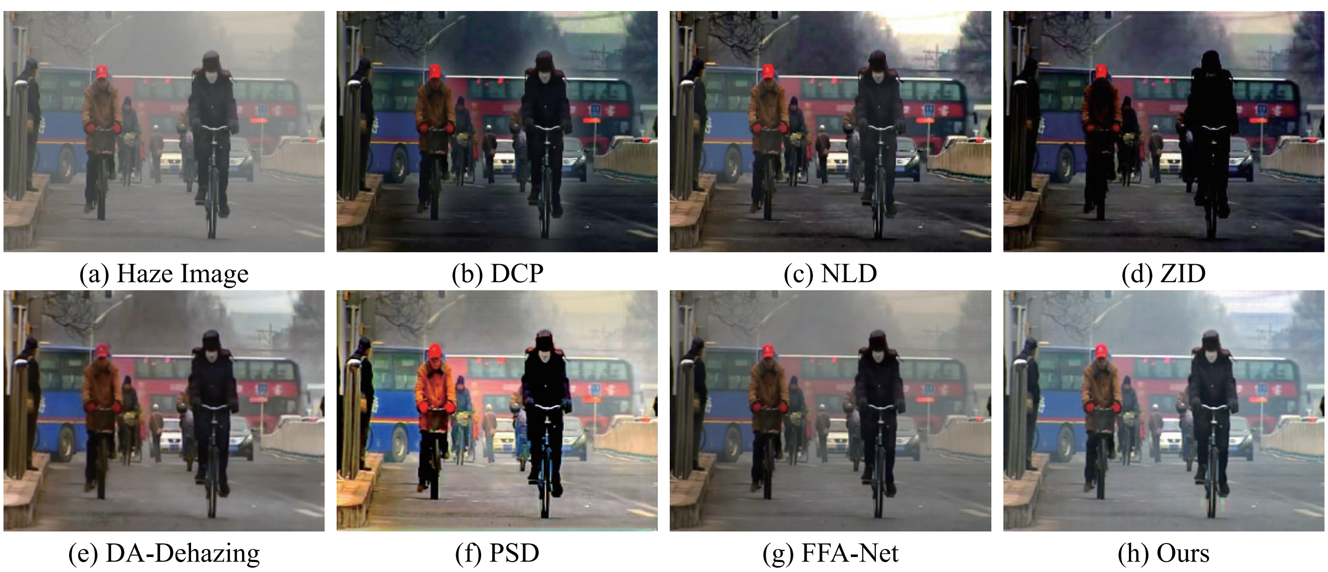
Figure 4. Visual comparison on real-world varicolored haze images (orange color). Images are better observed by zooming in on screen.



(a) Haze Image (b) DCP (c) NLD (d) ZID

(e) DA-Dehazing (f) PSD (g) FFA-Net (h) Ours

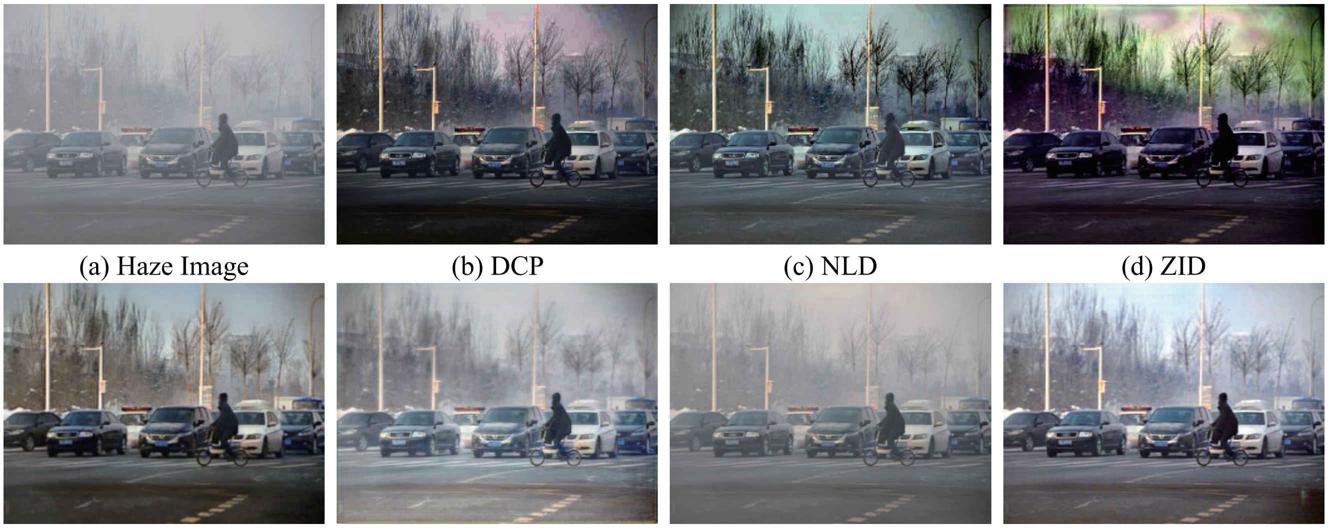
Figure 5. Visual comparison on real-world varicolored haze images (orange color). Images are better observed by zooming in on screen.



(a) Haze Image (b) DCP (c) NLD (d) ZID

(e) DA-Dehazing (f) PSD (g) FFA-Net (h) Ours

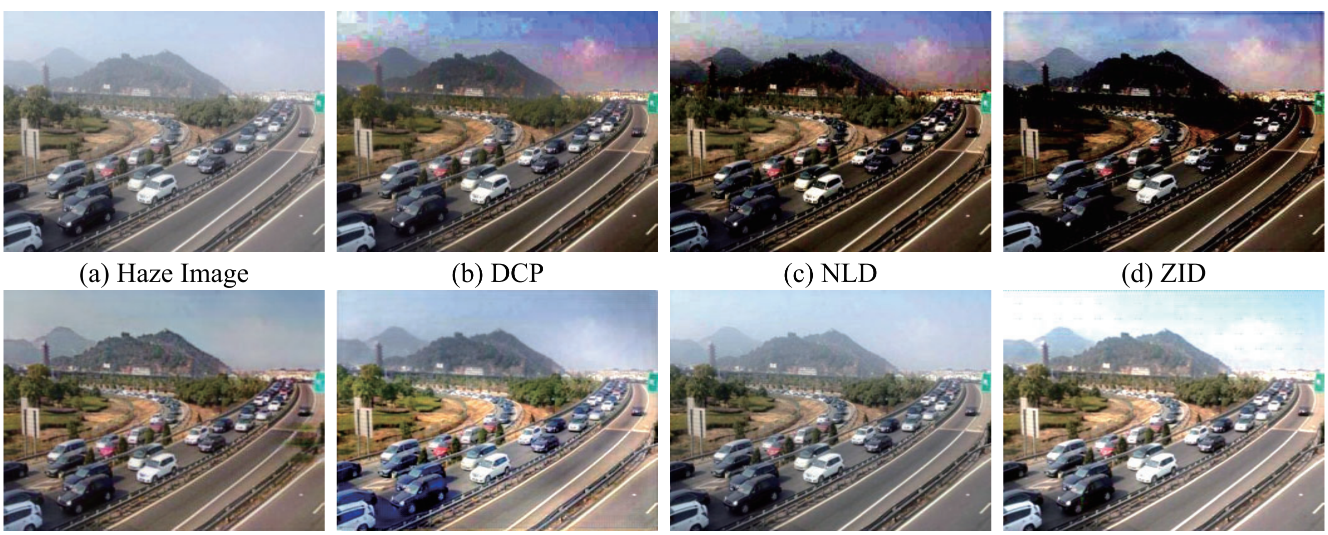
Figure 6. Visual comparison on real-world varicolored haze images (orange color). Images are better observed by zooming in on screen.



(a) Haze Image (b) DCP (c) NLD (d) ZID

(e) DA-Dehazing (f) PSD (g) FFA-Net (h) Ours

Figure 7. Visual comparison on real-world varicolored haze images (bluish color). Images are better observed by zooming in on screen.



(a) Haze Image (b) DCP (c) NLD (d) ZID

(e) DA-Dehazing (f) PSD (g) FFA-Net (h) Ours

Figure 8. Visual comparison on real-world varicolored haze images (bluish color). Images are better observed by zooming in on screen.

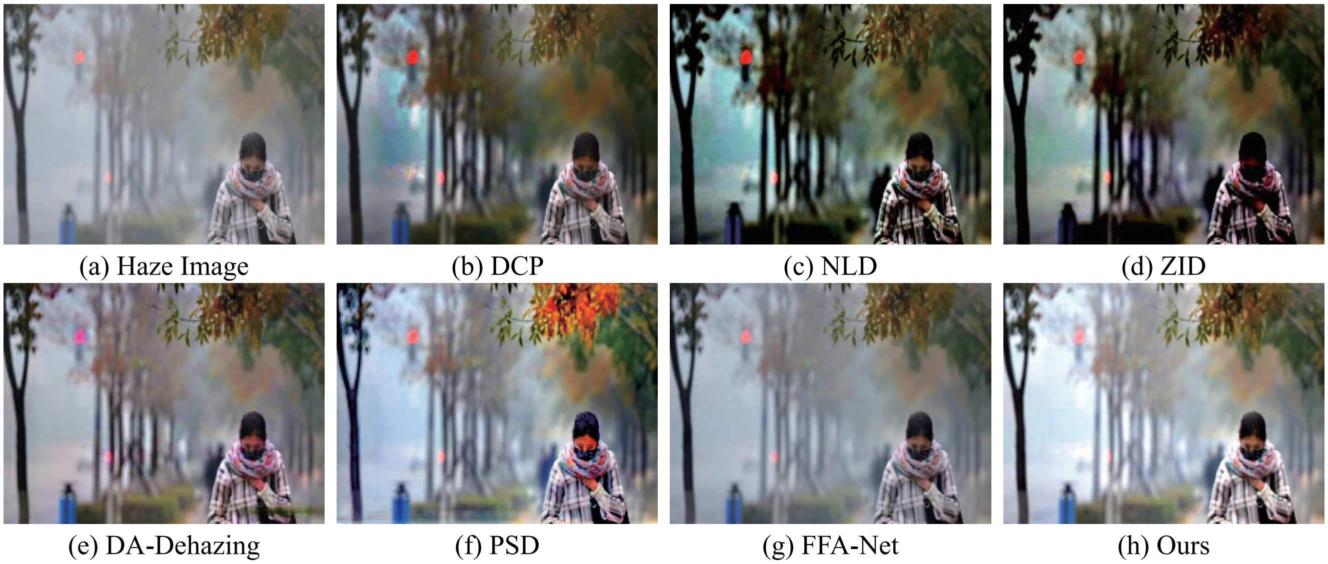


Figure 9. Visual comparison on real-world varicolored haze images (bluish color). Images are better observed by zooming in on screen.

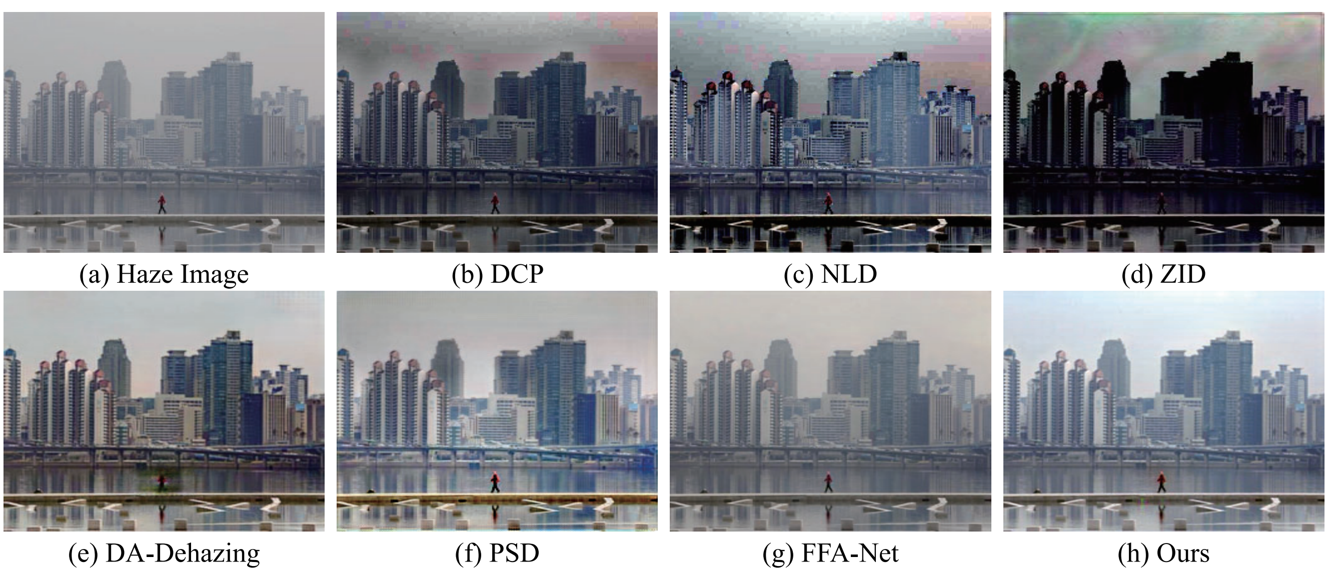


Figure 10. Visual comparison on real-world varicolored haze images (grayish color). Images are better observed by zooming in on screen.

Figure 11. Visual comparison on real-world varicolored haze images (grayish color). Images are better observed by zooming in on screen.

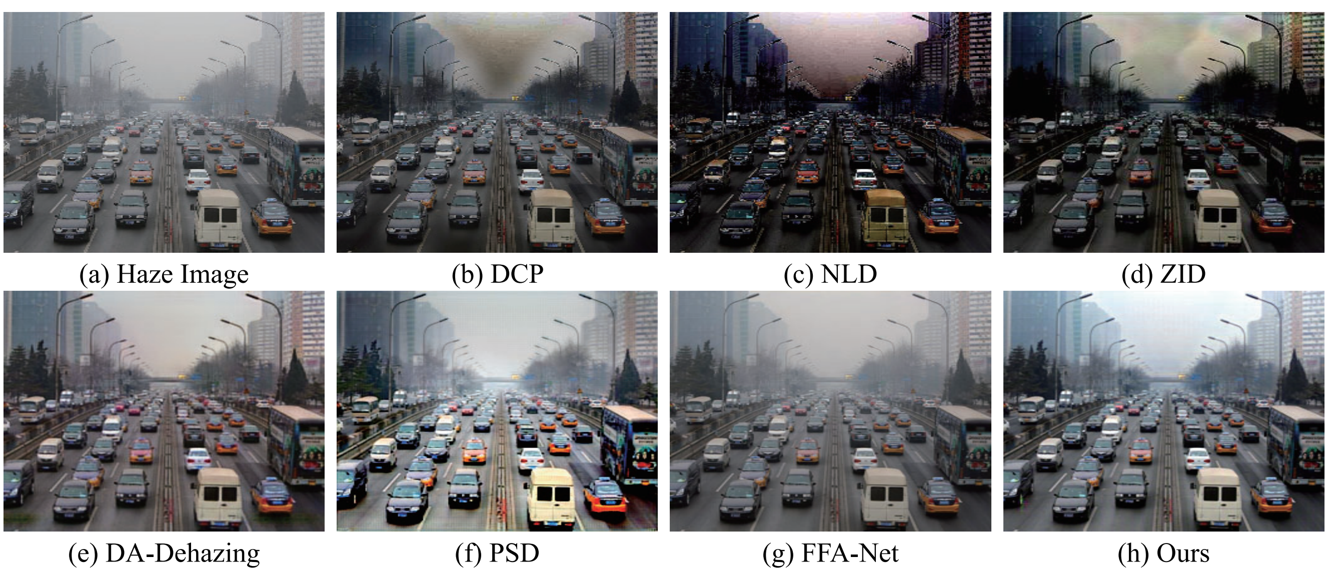
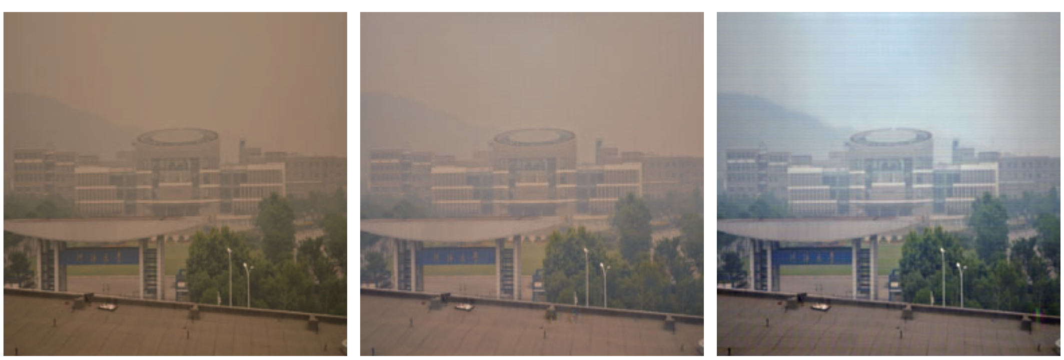


Figure 12. Visual comparison on real-world varicolored haze images (grayish color). Images are better observed by zooming in on screen.

(a) Haze Image (b) DCP (c) NLD (d) ZID

(e) DA-Dehazing (f) PSD (g) FFA-Net (h) Ours

Figure 13. Visual comparison on real-world varicolored haze images (grayish color). Images are better observed by zooming in on screen.



Haze Image w/o Physically Disentangle w/ Physically Disentangle

Figure 14. Visualization of color correction results w/ and w/o physically disentanglement and translation strategy. We can observe that the proposed methods could better distinguish color-related atmospheric light and identity background and better get rid of the color distortion, thanks to the physically disentangle and specific translation strategy.

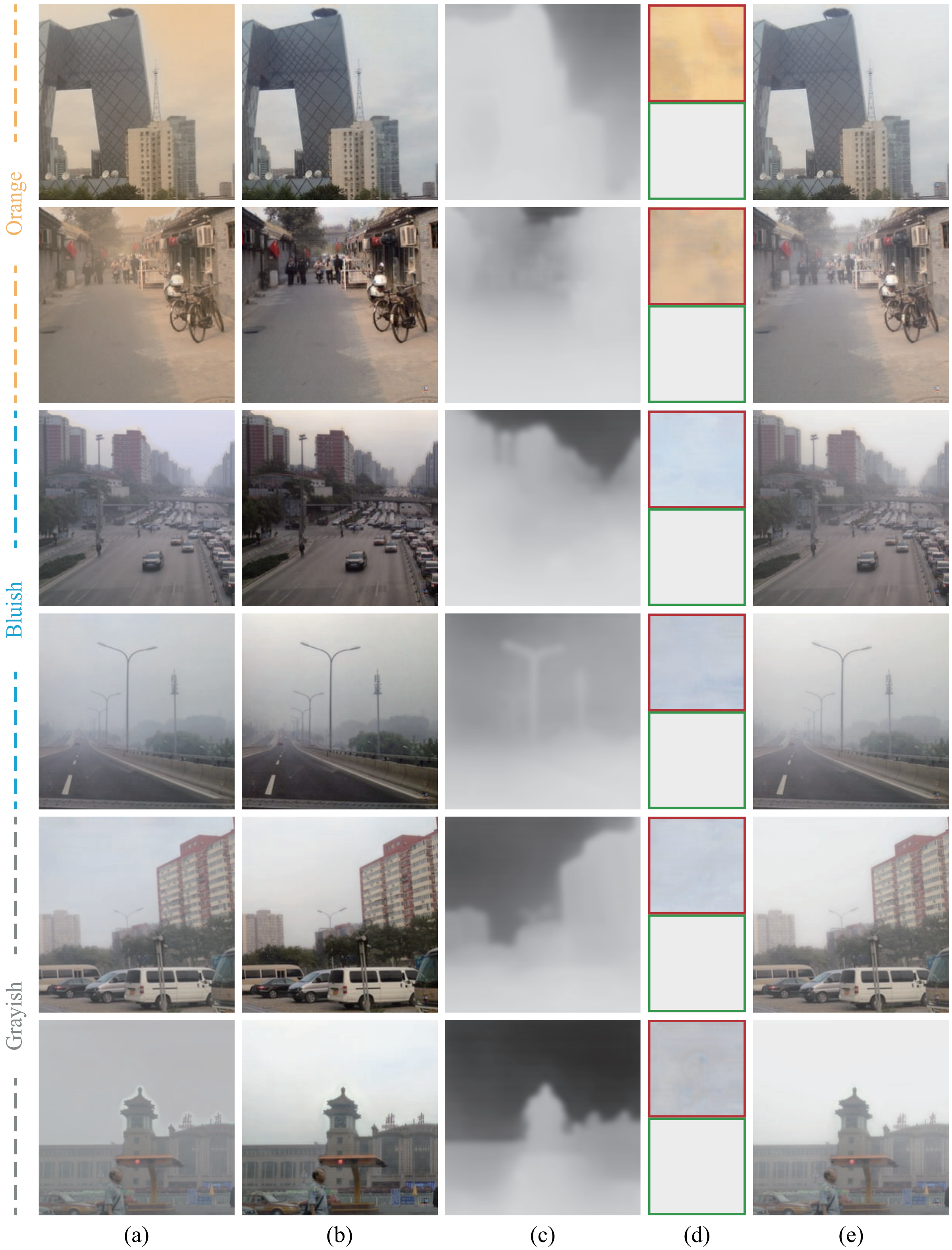


Figure 15. Visualization of the disentangle results on varicolored haze image in intra-domain adaptation module. (a) Input haze images. (b) Disentangled clear background. (c) Transmission map prediction. (d) Atmospheric light before and after translation, red rectangles are the atmospheric light disentangled from varicolored haze image, green rectangle represents the translated color-balanced atmospheric light. (e) Color corrected haze images generated from the physical reconstruction.