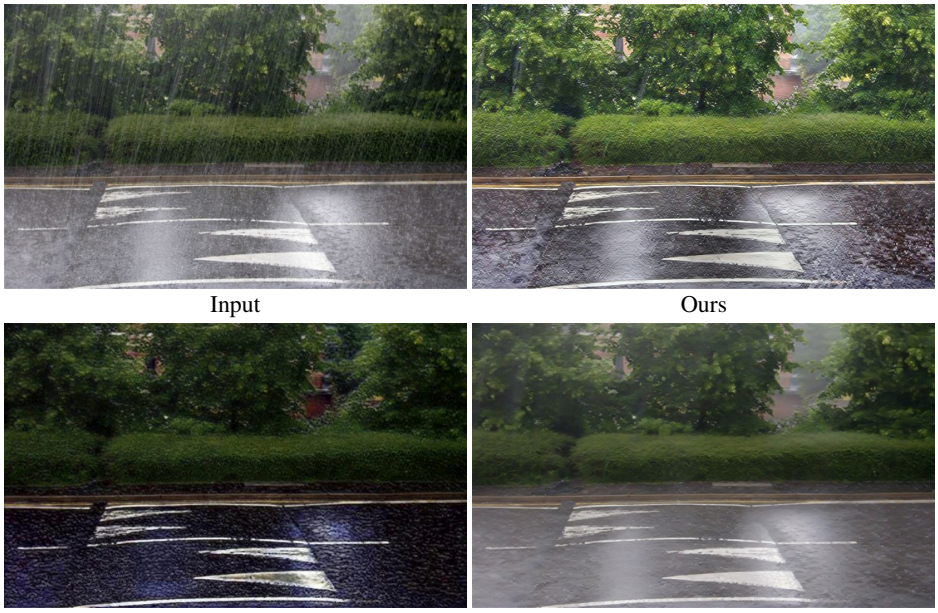
Supplementary Material for "Heavy Rain Image Restoration: Integrating Physics Model and Conditional Adversarial Learning"

Ruoteng Li[1], Loong-Fah Cheong[1], and Robby T. Tan[*1,2]

[1]National University of Singapore
[2]Yale-NUS College

1. Real-world Rain Results

Despite heavy rain scenarios, our method also works well in comparatively light rain scenes (with or without veiling effects). In the following figures, we directly choose the rain images from recent state of the art rain removal papers. We compare the derained image produced by our method with the results of baseline methods reported in their papers.



Input | Ours

JORDER [9] | RESCAN [6]

Figure 1: While JORDER [9] is able to remove rain streaks, it also changes the appearance of the background tree leaves. The haze removal step, as a post processing, also results in dark regions on the bushes, where many genuine details are lost. By contrast, our method is able to retain the correct color, shape and details of the background trees and bushes.

Input Ours DSC [8] LP [7] DDN [3]

Figure 2: LP [7] and DDN [3] render blur results on background grass. Ours is able to recover fine textural details.

(a) Input (b) Ours

(c) RESCAN [6] (d) CNN [2]

Figure 3: This example is reported in [2]. One can see that the result of CNN method [2] still contains observable fringes of rain streaks. In contrast, our method is able to remove rain streaks thoroughly and enhance the background genuine details. In addition, we run the state of the art RESCAN [6] method on this example, rain streaks are still apparently observed in the results.

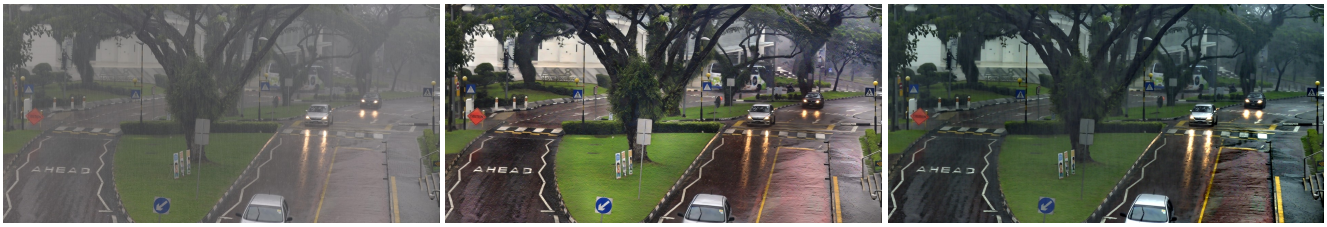


Figure 4: A comparison between ours results and RESCAN [6] + [1].

2. Synthetic Rain Results

In this section, we show more qualitative results of synthetic rain data in the following figures. From the figures below, one can see that all the combination of derain methods and dehaze methods cannot remove rain streaks or rain accumulation effectively because the appearance of the rain images are different from the ones in the training sets of the deraining methods. Pix2Pix[5] trained on *Outdoor-Rain* dataset also fails to remove atmospheric veils around object's boundary because the transmission information is not particularly provided during the training process.

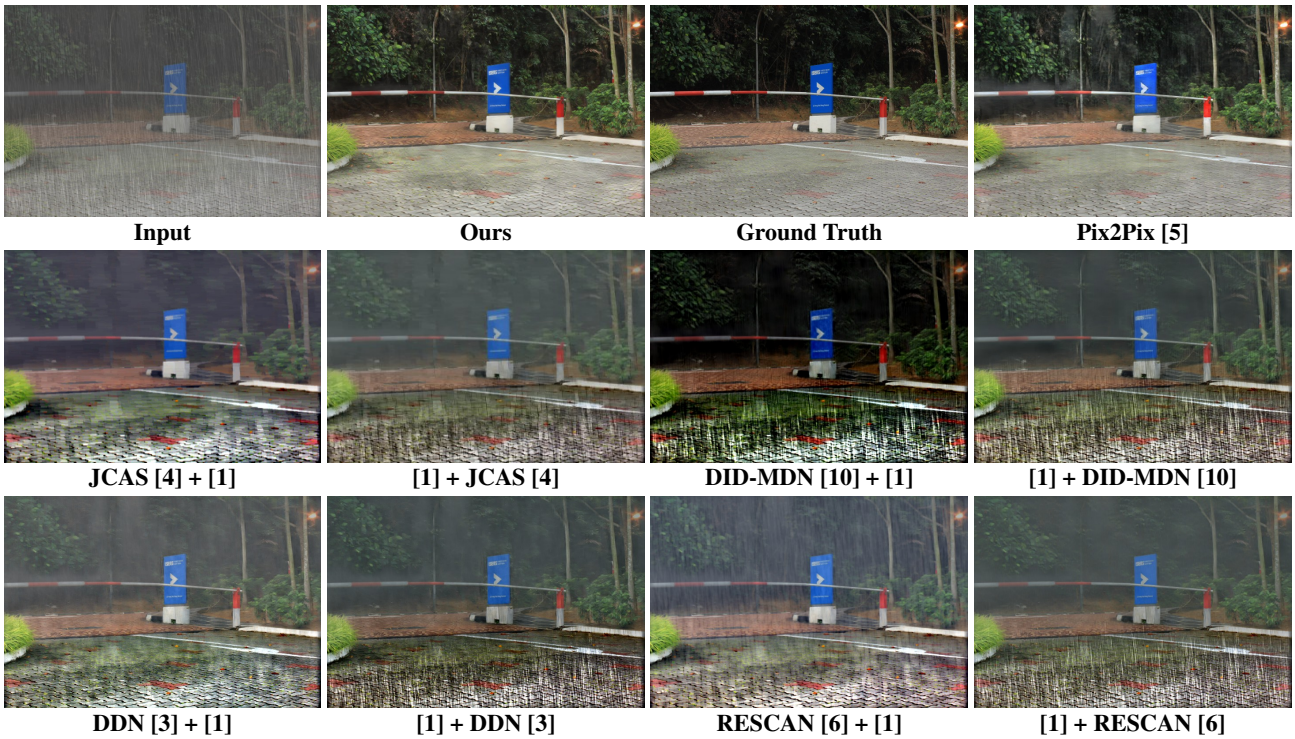
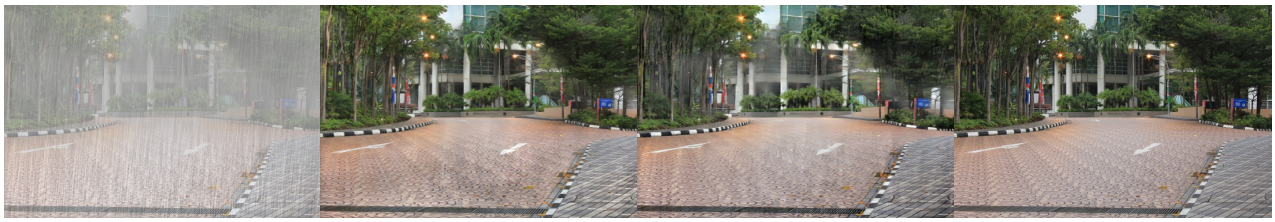
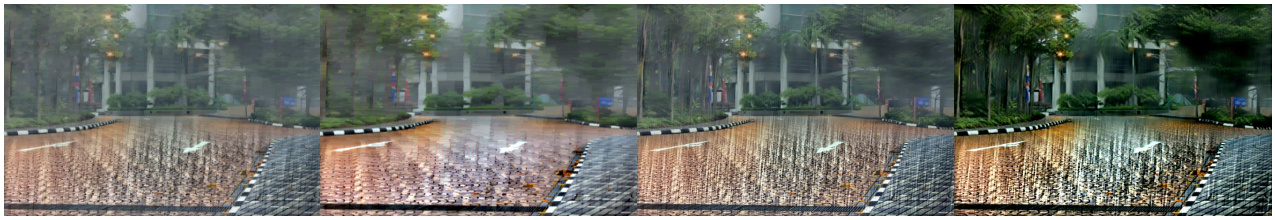


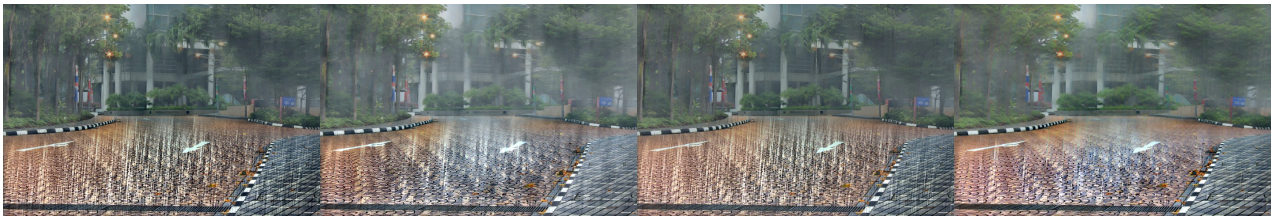
Figure 4: Pix2Pix[5] trained on *Outdoor-Rain* dataset can remove rain streaks. But it produces some atmospheric veils around object's boundary. Our method does not only removes rain streaks, but also enhance the background.



(a) Input (b) Ours (c) pix2pix [5] (d) Ground Truth



(e) JCAS [4] + [1] (f) [1] + JCAS [4] (g) DID-MDN [10] + [1] (h) [1] + DID-MDN [10]



(i) DDN [3] + [1] (j) [1] + DDN [3] (k) RESCAN [6] + [1] (l) [1] + RESCAN [6]

Figure 5: A comparison between our method with baseline methods on synthetic Test1 dataset.

(a) Input (b) Ours (c) pix2pix [5] (d) Ground Truth

(e) JCAS [4] + [1] (f) [1] + JCAS [4] (g) DID-MDN [10] + [1] (h) [1] + DID-MDN [10]

(i) DDN [3] + [1] (j) [1] + DDN [3] (k) RESCAN [6] + [1] (l) [1] + RESCAN [6]

Figure 6: A comparison between our method with baseline methods on synthetic Test1 dataset.

References

[1] D. Berman, T. Treibitz, and S. Avidan. Non-local image dehazing. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2016.

[2] X. Fu, J. Huang, X. Ding, Y. Liao, and J. W. Paisley. Clearing the skies: A deep network architecture for single-image rain removal. *IEEE Transactions on Image Processing*, 26:2944–2956, 2017.

[3] X. Fu, J. Huang, D. Zeng, Y. Huang, X. Ding, and J. Paisley. Removing rain from single images via a deep detail network. In *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, July 2017.

[4] S. Gu, D. Meng, W. Zuo, and L. Zhang. Joint convolutional analysis and synthesis sparse representation for single image layer separation. In *The IEEE International Conference on Computer Vision (ICCV)*, Oct 2017.

[5] P. Isola, J.-Y. Zhu, T. Zhou, and A. A. Efros. Image-to-image translation with conditional adversarial networks. *arxiv*, 2016.

[6] X. Li, J. Wu, Z. Lin, H. Liu, and H. Zha. Recurrent squeeze-and-excitation context aggregation net for single image deraining. In *The European Conference on Computer Vision (ECCV)*, September 2018.

[7] Y. Li, R. T. Tan, X. Guo, J. Lu, and M. S. Brown. Rain streak removal using layer priors. In *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, June 2016.

[8] Y. Luo, Y. Xu, and H. Ji. Removing rain from a single image via discriminative sparse coding. In *2015 IEEE International Conference on Computer Vision (ICCV)*, pages 3397–3405, Dec 2015.

[9] W. Yang, R. T. Tan, J. Feng, J. Liu, Z. Guo, and S. Yan. Deep joint rain detection and removal from a single image. In *2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 1685–1694, July 2017.

[10] H. Zhang and V. M. Patel. Density-aware single image deraining using a multi-stream dense network. In *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, June 2018.