Image Dehazing by Joint Estimation of Transmittance and Airlight using Bi-Directional Consistency Loss Minimized FCN

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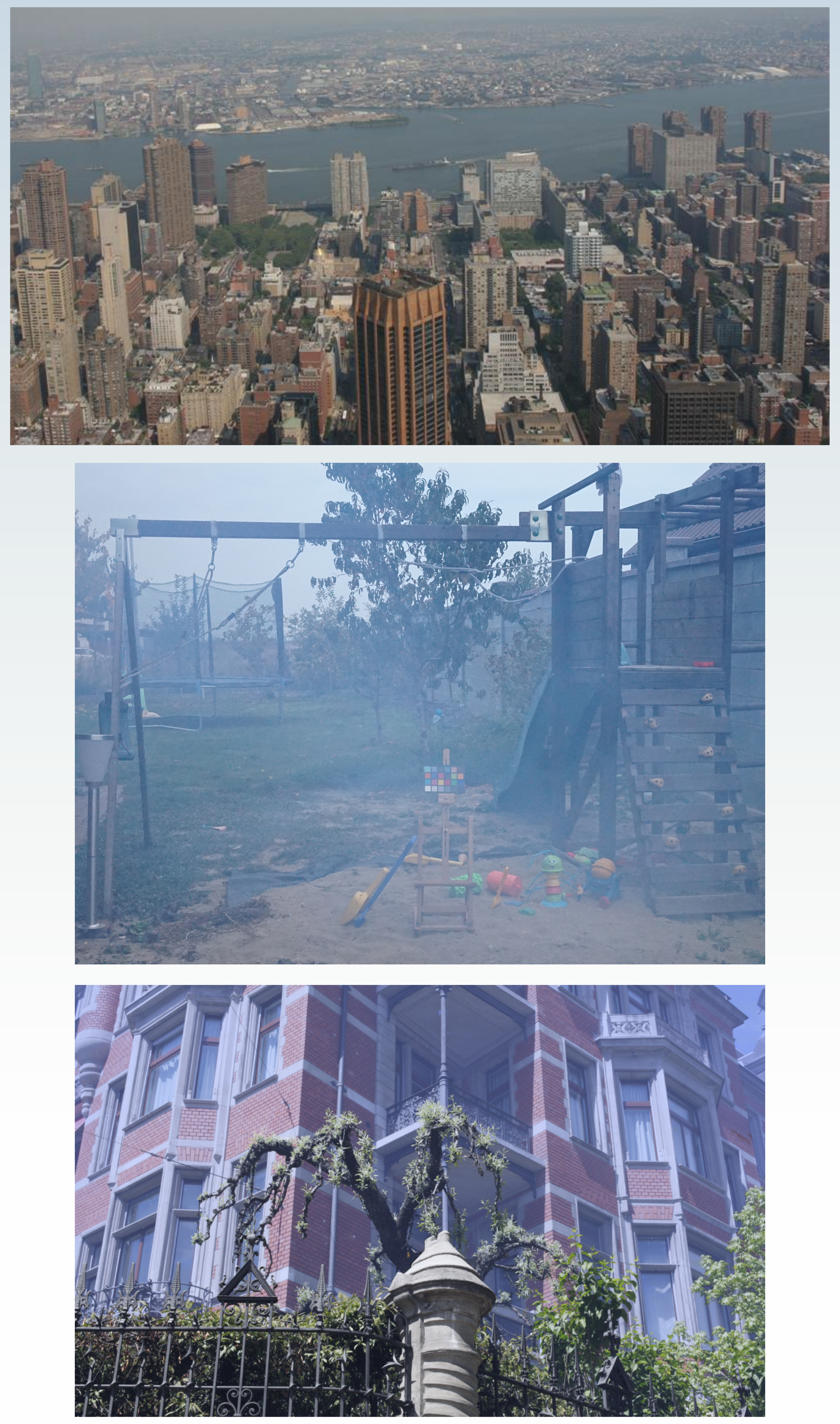

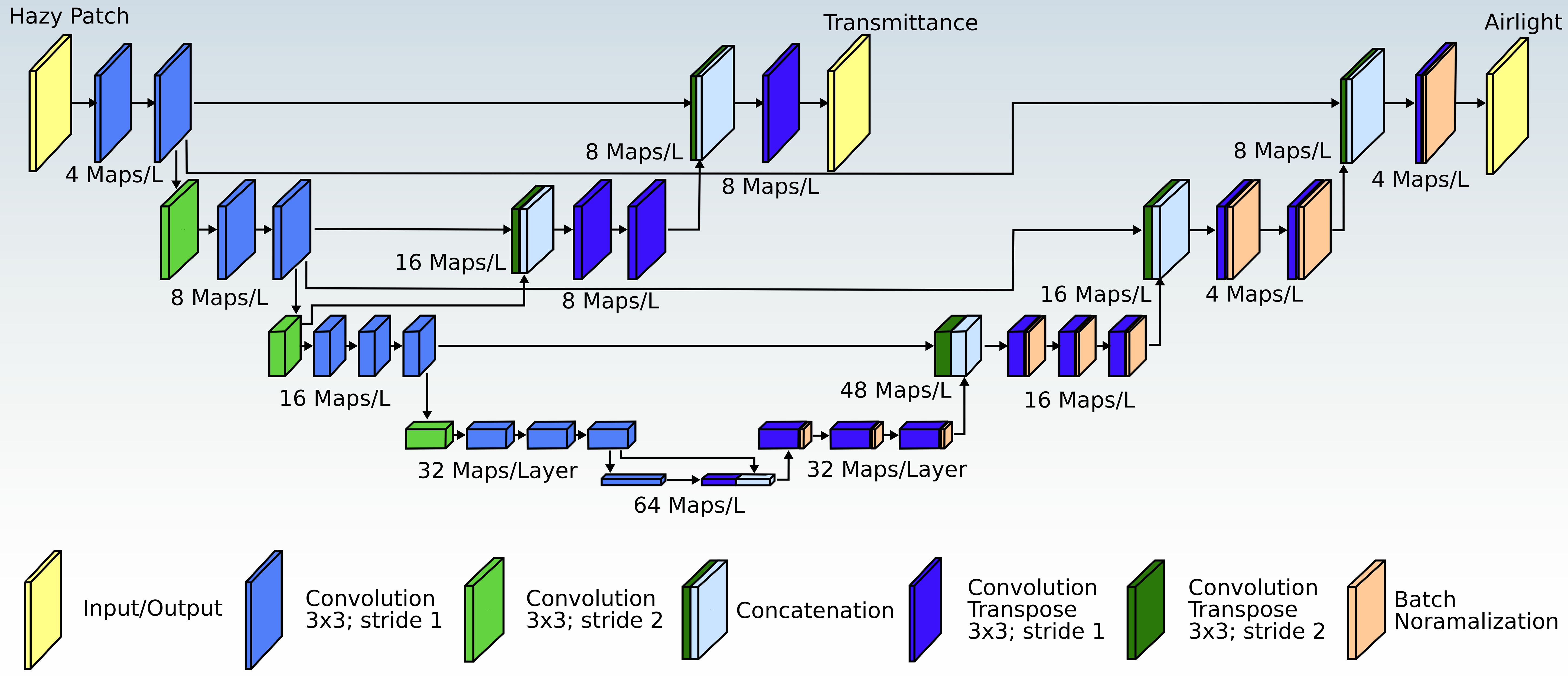

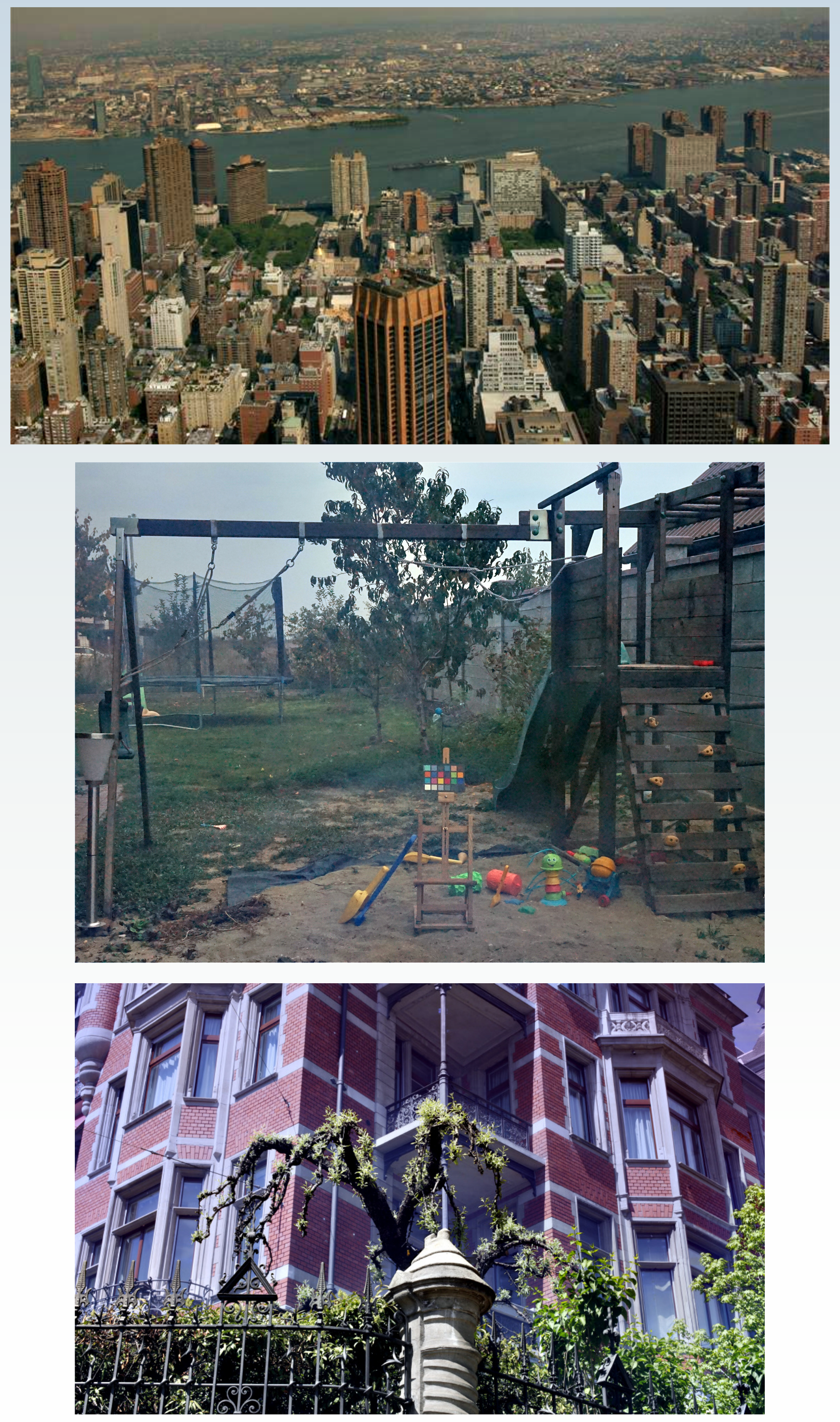

Image Formation Equation

Usual Model

$$I(\mathbf{x}) = J(\mathbf{x})t(\mathbf{x}) + (1 - t(\mathbf{x}))A$$

Relaxed to

$$\begin{aligned} I(\mathbf{x}) &= J(\mathbf{x})t(\mathbf{x}) + (1 - t(\mathbf{x}))A(\mathbf{x}), \\ &= J(\mathbf{x})t(\mathbf{x}) + K(\mathbf{x}). \end{aligned}$$

Bidirectional Consistency Loss

$$L = \frac{1}{N}\sum_{\mathbf{x}} (L_1(\mathbf{x}) + L_2(\mathbf{x}))$$

$$L_1(\mathbf{x}) = |I(\mathbf{x}) - J(\mathbf{x})t'(\mathbf{x}) - K'(\mathbf{x})|$$ → The error of generating hazy image from the clear image.

$$L_2(\mathbf{x}) = \left| J(\mathbf{x}) - \frac{I(\mathbf{x}) - K'(\mathbf{x})}{\max\{t'(\mathbf{x}), \epsilon\}} \right|$$ → The error of getting clear image by dehazing the input.

Training Data Generation

- We extract patch hazy and haze free patch pairs from the training data in multiple levels.
- We start with a patch of size PxP, where P = min{Height,Width}.
- In the next level, we extract patches of size $\frac{P}{2} \times \frac{P}{2}$ and $\frac{P}{4} \times \frac{P}{4}$ in the next one. This halving process is repeated until the patch size falls below 128x28.
- All the extracted patches are resized to 128x128 before they are used for training.

$t(\mathbf{x})$ and $K(\mathbf{x})$ estimation

- Due to resource constrains, we first downscale the image.
- Estimate the $t_i(\mathbf{x})$ and $K_i(\mathbf{x})$ at three levels with patch sizes 256x256, 384x384 and 512x512.
- Feed the patches to the network to get $t(\mathbf{x})$ and $K(\mathbf{x})$ maps for the patches.
- In each level, aggregate the patches by averaging to get full size $t(\mathbf{x})$ and $K(\mathbf{x})$-maps.

Aggregation of $t(\mathbf{x})$ and $K(\mathbf{x})$

$$t(\mathbf{x}) = \frac{\sum_{i=1}^{l} w_i^{(t)} t_i(\mathbf{x})}{\sum_{i=1}^{l} w_i^{(t)}}$$

$$K(\mathbf{x}) = \frac{\sum_{i=1}^{l} w_i^{(K)} K_i(\mathbf{x})}{\sum_{i=1}^{l} w_i^{(K)}}$$

Regularization using Guided Filter

- Due to the patch based processing, the $t(\mathbf{x})$ and $K(\mathbf{x})$ maps that we obtain, contain halos at the border of the patches.
- For this reason, we used Guided Filter[1] to smooth the maps.

[1] K. He, J. Sun, and X. Tang. Guided Image Filtering. IEEE Trans.on Pattern Anal. and Mach. Intell., 2013.

Recovery of haze-free image

- The smooth transmittance map and airlight map is resized back to the original image size i.e. HxW.
- The dehazed image is obtained as follows,

$$J'(\mathbf{x}) = \frac{I(\mathbf{x}) - K(\mathbf{x})}{\max\{t(\mathbf{x}), \epsilon\}}$$

- The output is clipped between 0 and 1 so that the output stays within the valid image intensity range.

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