Variational Regularized Transmission Refinement For Image Dehazing

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Introduction

- Hazy Image Generation Process

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

- Physically Grounded Priors

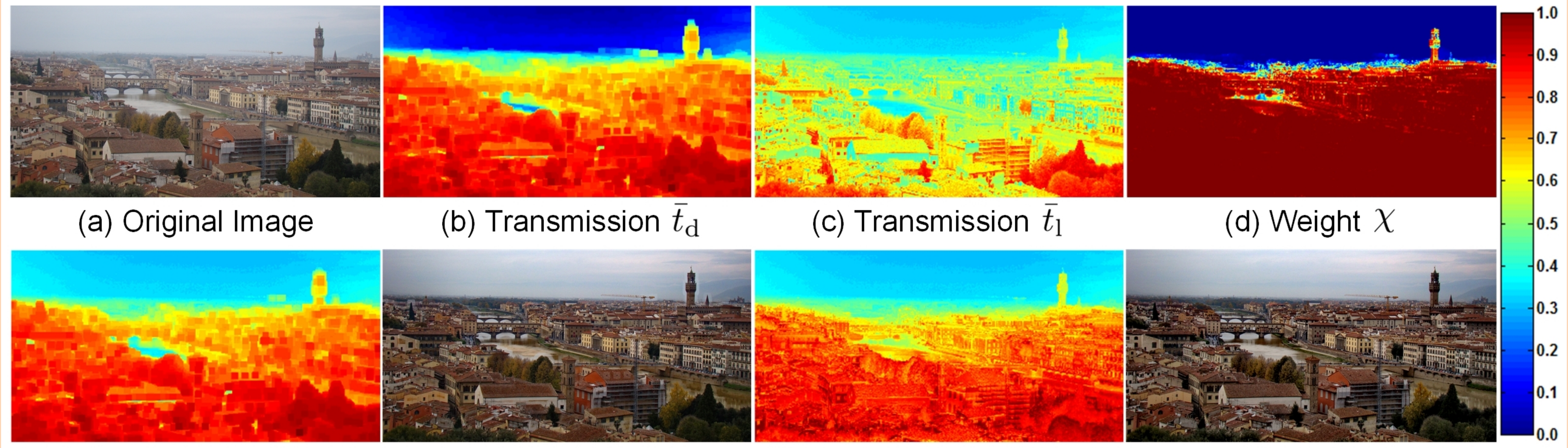
  Dark channel prior (DCP, *PAMI*, 2011); Color lines prior (*TOG*, 2014); Color attenuation prior (*TIP*, 2015); Non-local prior (*CVPR*, 2016); Color ellipsoid prior (*TIP*, 2018).

- Deep Learning Methods

  Dehaze-Net (*TIP*, 2016); Multi-scale CNN (*ECCV*, 2016); AOD-Net (*ICCV*, 2017); FEED-Net (*ICME*, 2018); Flexible cascaded CNN (*Access*, 2018); Proximal Dehaze-Net (*ECCV*, 2018).

- Motivations
  - DCP-based methods easily fail since DCP assumption is based on statistical analysis in non-sky regions.
  - Learning-based dehazing performance is dependent upon the diversity and volume of training datasets.

Two-Step Framework



(a) Original Image (b) Transmission $\bar{t}_{\mathrm{d}}$ (c) Transmission $\bar{t}_{\mathrm{l}}$ (d) Weight χ

(e) Coarse Transmission $\bar{t}$ (f) Dehazing with (e) (g) Fine Transmission t (h) Dehazing with (g)

Step 1: Coarse transmission via DCP and luminance fusion

Step 2: Fine transmission via variational regularized model

Coarse Transmission

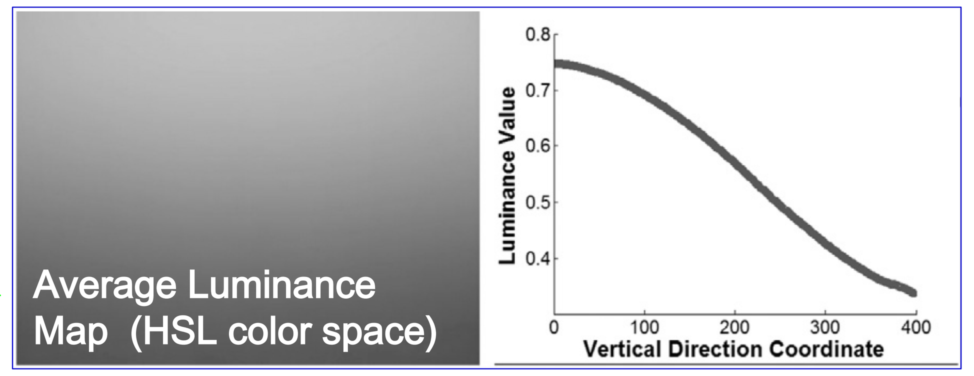
- DCP-Based Transmission

$$\bar{t}_{\mathrm{d}}(\mathrm{x}) = 1 - \omega \min_{c\in\{r,g,b\}}\left(\min_{\mathrm{y}\in\Omega(\mathrm{x})} \frac{I_c(\mathrm{x})}{A_c}\right)$$

- Luminance-Based Transmission

$$\bar{t}_{\mathrm{l}}(\mathrm{x}) = e^{-\frac{\beta\tau}{L^*}L(\mathrm{x})}$$

$$\beta = \begin{cases} 0.3324 & \text{Red channel} \\ 0.3433 & \text{Green channel} \\ 0.3502 & \text{Blue channel} \end{cases}$$



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- Fused Coarse Transmission

$$\bar{t}(\mathrm{x}) = \chi(\mathrm{x})\bar{t}_{\mathrm{d}}(\mathrm{x}) + \big(1 - \chi(\mathrm{x})\big)\bar{t}_{\mathrm{l}}(\mathrm{x})$$

with transmission weight

$$\chi(\mathrm{x}) = \frac{1}{1 + e^{-\theta_1\bar{t}_{\mathrm{d}}(\mathrm{x}) - \theta_2}}$$

Fine Transmission

- Image Degradation Model

$$\bar{\mathbf{I}}(\mathrm{x}) = \bar{\mathbf{J}}(\mathrm{x})t(\mathrm{x}) \text{ with } \bar{\mathbf{I}} = \mathbf{A} - \mathbf{I} \text{ and } \bar{\mathbf{J}} = \mathbf{A} - \mathbf{J}$$

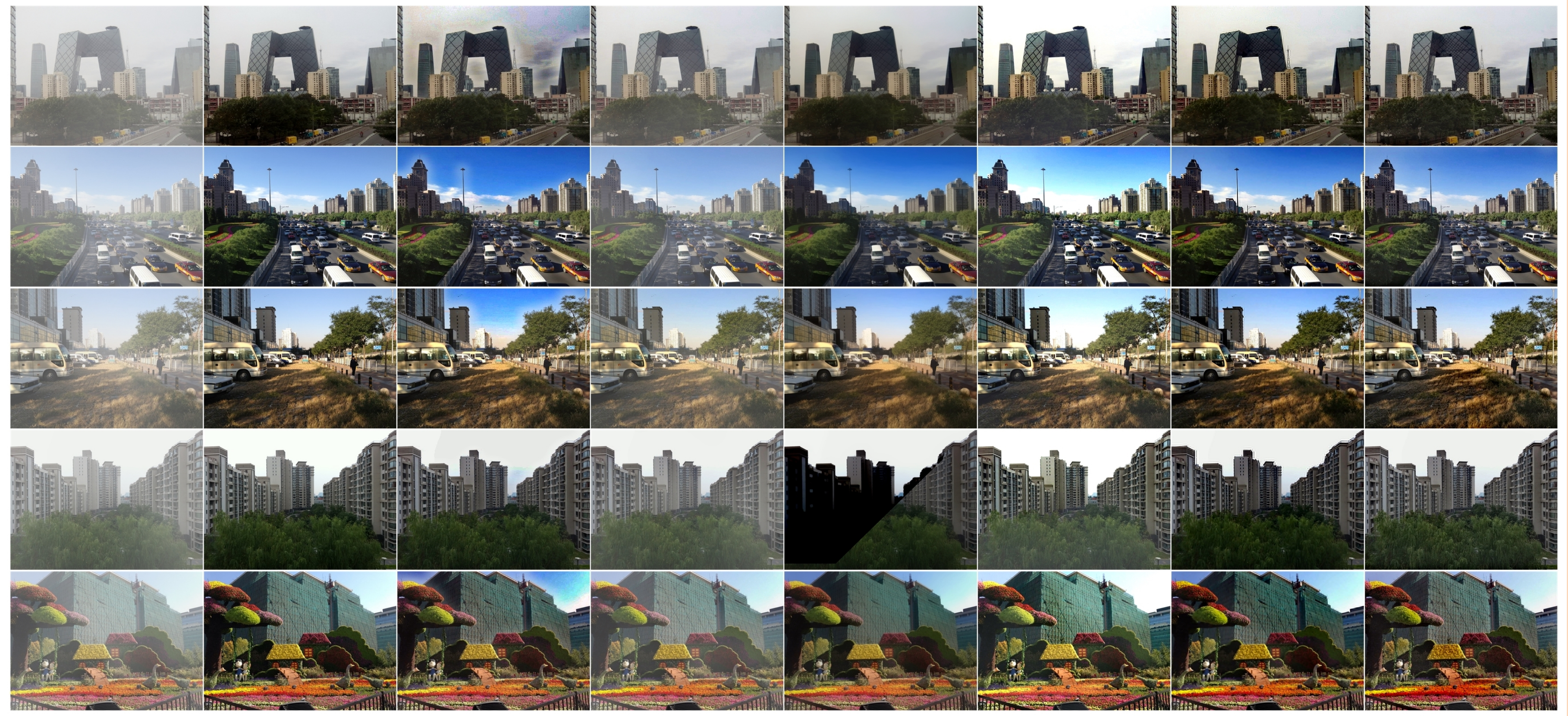
- Variational Regularized Model (Solver: ADMM)

$$\min_{\bar{J},t} \frac{\lambda_1}{2}\|\bar{I} - \bar{J}t\|_2^2 + \frac{\lambda_2}{2}\|t - \bar{t}\|_2^2 + \lambda_3\|W \circ (\nabla t - \nabla I)\|_1 + \lambda_4\|\nabla\bar{J}\|_1 + \lambda_4\|\nabla t\|_1$$

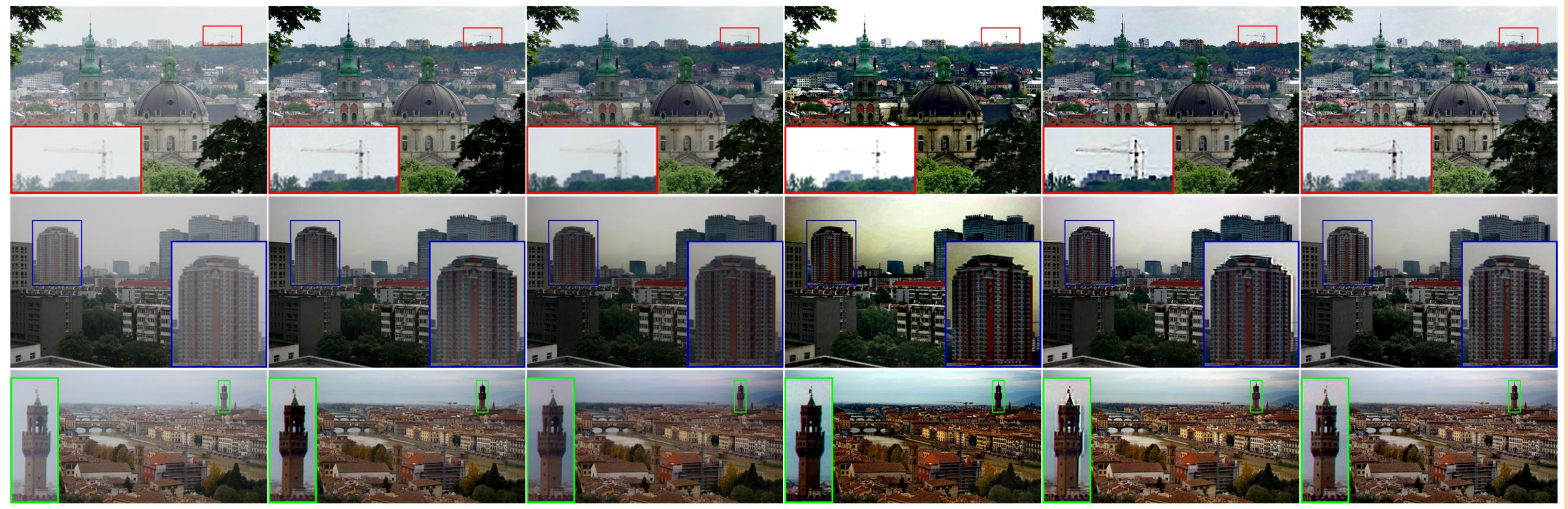
where $I = \mathbf{I}_c$, $\bar{I} = \bar{\mathbf{I}}_c$ and $\bar{J} = \bar{\mathbf{J}}_c$ for $c \in \{r, g, b\}$.

Experiments

The source code is available at http://mipc.whut.edu.cn/



(a) Hazy (b) Original (c) He-13 (d) Ren-16 (e) Chen-16 (f) Berman-16 (g) Liu-17 (h) Ours



(a) Hazy (b) Ren-16 (c) Chen-16 (d) Berman-16 (e) Liu-17 (f) Ours

He-13: *IEEE TPAMI*, 2013, 35(6): 1397-1409; **Ren-16:** *ECCV*, 2016, 154-169; **Chen-16:** *ECCV*, 2016, 576-591; **Berman-16:** *IEEE CVPR*, 2016, 1674-1682; **Liu-17:** *CVIU*, 2017, 162: 23-33.

Conclusions

- A joint variational regularized model with hybrid constraints was proposed to implement transmission map refinement and haze-free image estimation.
- The resulting nonsmooth optimization problem was effectively solved via an ADMM-based numerical method.