Dehazing single image using Dark Channel Prior

DIP Project

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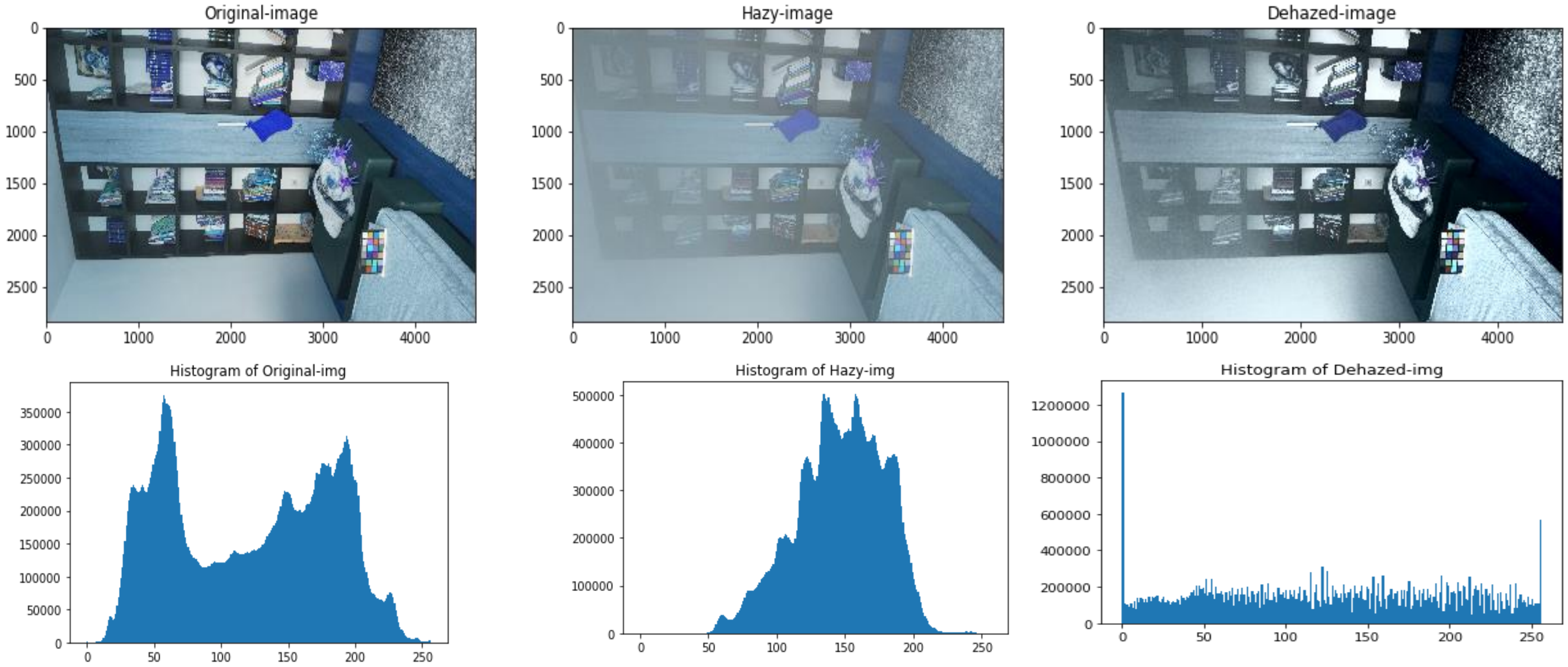
Introduction

- Haze, fog, and smoke lead to low visibility in image. Outdoor images often degraded by them.
- Haze-free image: more visually pleasing, highly desired in computational photography and computer vision applications
- Baseline model is **Histogram Equalization.** Dehazing using Histogram Equalization:



- In this project, we used **Dark Channel prior** combined with **Haze imaging model** to remove haze from images [1]

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

I(x) : observed intensity at pixel x; J(x) : Scene Radiance at x;
A : Atmospheric light; t(x) : medium transmission at pixel x

- **Dark Channel prior:** In most of the local regions except sky, some pixels (called dark pixels) very often have very low intensity in at least one color (RGB) channel. In hazy images, the intensity of these dark pixels in that channel is mainly contributed by the airlight.
- **Limitation**: limitation. The dark channel prior may be invalid when the scene object is inherently similar to the airlight (e.g., snowy ground or a white wall) over a large local region and no shadow is cast on it.

- Dark Channel image equation: $J^{\mathrm{dark}}(\mathbf{x}) = \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_{c \in \{r,g,b\}} J^c(\mathbf{y}) \right)$

Jc : color channel of haze free image
Ohm(x) is a local patch (15x15) centered at x.

- For haze free regions in image: $J^{\mathrm{dark}} \rightarrow 0.$ i.e. $J^{\mathrm{dark}}(\mathbf{x}) = \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c J^c(\mathbf{y}) \right) = 0.$

- We normalize each color channel independently : $\frac{I^c(\mathbf{x})}{A^c} = t(\mathbf{x}) \frac{J^c(\mathbf{x})}{A^c} + 1 - t(\mathbf{x}).$ => $\min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c \frac{I^c(\mathbf{y})}{A^c} \right) = \tilde{t}(\mathbf{x}) \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c \frac{J^c(\mathbf{y})}{A^c} \right) + 1 - \tilde{t}(\mathbf{x}).$

- Thus eliminate the multiplicative term and estimate the transmission t~: $\tilde{t}(\mathbf{x}) = 1 - \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_c \frac{I^c(\mathbf{y})}{A^c} \right)$

- The above transmission is unrefined

- Refine the transmission using **guided filter**: $q_i = a_k I_i + b_k, \forall i \in \omega_k$;

- Parameters:

$$a_k = \frac{\frac{1}{|\omega|}\sum_{i\in\omega_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \epsilon}$$

$$b_k = \bar{p}_k - a_k \mu_k.$$

$$\begin{aligned} q_i &= \frac{1}{|\omega|}\sum_{k:i\in\omega_k}(a_k I_i + b_k) \\ &= \bar{a}_i I_i + \bar{b}_i \end{aligned}$$

where $\bar{a}_i = \frac{1}{|\omega|}\sum_{k\in\omega_i} a_k$ and $\bar{b}_i = \frac{1}{|\omega|}\sum_{k\in\omega_i} b_k$.

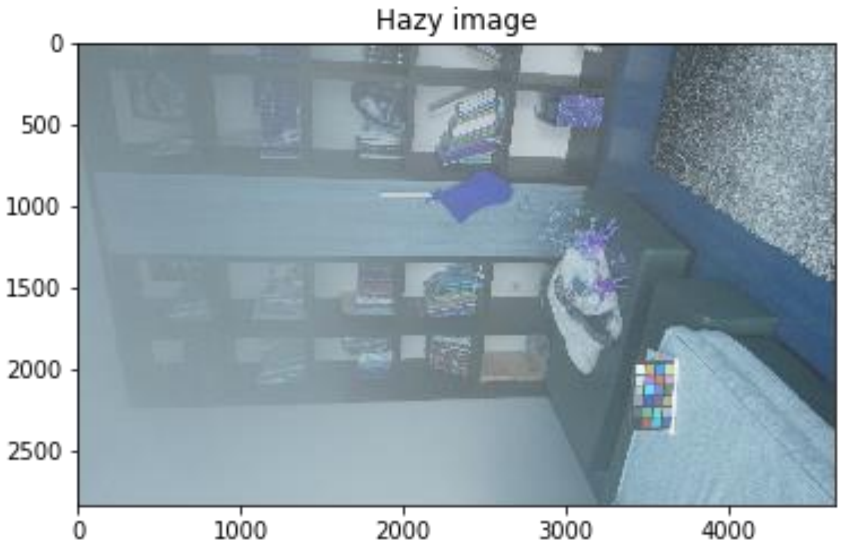
- Q is the refined transmission map and p is the input unrefined transmission map

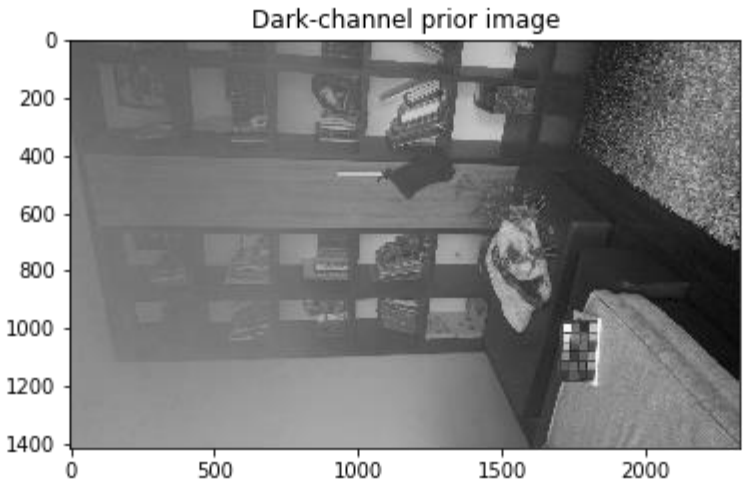
Dehazing using deep channel prior

- Use the dark channel image to detect the most haze-opaque region and improve the atmospheric light estimation.
- We first pick the top 0.1 percent brightest pixels in the dark channel. These pixels are usually most haze-opaque.
- Among these pixels, the pixels with highest intensity in the input image I are selected as the atmospheric light.
- Recovered Image:

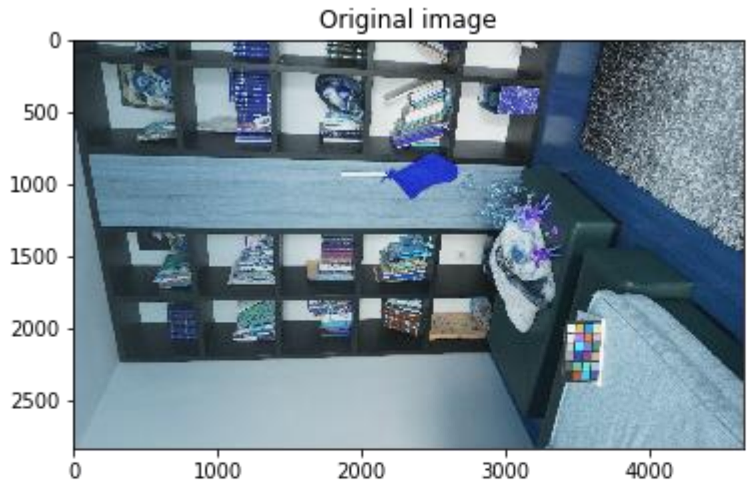
$$\mathbf{J}(\mathbf{x}) = \frac{\mathbf{I}(\mathbf{x}) - \mathbf{A}}{\max(t(\mathbf{x}), t_0)} + \mathbf{A}$$

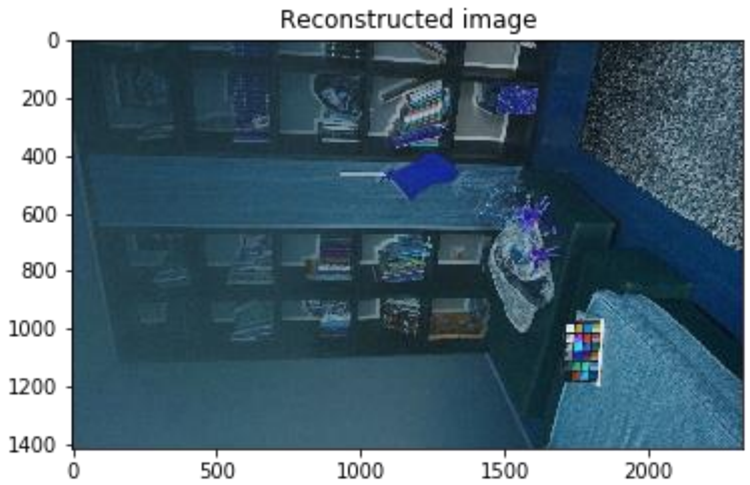
Dehazing using deep channel prior





Dehazing using deep channel prior





References

- **Single Image Haze Removal Using Dark Channel Prior** by Kaiming He, Jian Sun et. al.
- **Guided Image Filtering** by Kaiming He, Jian Sun et. al.
- **Simplest Color Balance** by Nicolas Limare et.al

Thank You