Haze Removal using Dark Channel Prior

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Description

In computer vision and computer graphics, the model widely used to describe the formation of a hazy image is

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

where I is the observed intensity, J is the scene radiance, A is the global atmospheric light, and t is the medium transmission describing the portion of the light that is not scattered and reaches the camera. The goal of haze removal is to recover J, A, and t from I.

The dark channel prior is based on the following observation on outdoor haze-free images: In most of the non-sky patches, at least one color channel has some pixels whose intensity are very low and close to zero. Equivalently, the minimum intensity in such a patch is close to zero. To formally describe this observation, we first define the concept of a dark channel. For an arbitrary image J, its dark channel $\mathbf{J}^{\mathbf{dark}}$ is given by

$$J^{\text{dark}}(\mathbf{x}) = \min_{\mathbf{y} \in \Omega(\mathbf{x})} \left(\min_{c \in \{r,g,b\}} J^c(\mathbf{y}) \right),$$

We can use the dark channel 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. This method works well even when pixels at infinite distance do not exist in the image.

To determine the value of transmission we need to consider a practical scenario.In practice, even on clear days the atmosphere is not absolutely free of any particle. So the haze still exists when we look at distant objects. Moreover, the presence of haze is a fundamental cue for human to perceive depth. This phenomenon is called aerial perspective. If we remove the haze thoroughly, the image may seem unnatural and we may lose the feeling of depth. So, we can optionally keep a very small amount of haze for the distant objects by introducing a constant parameter w.

$$\tilde{t}(\mathbf{x}) = 1 - \omega \min_{\mathbf{y}\in\Omega(\mathbf{x})} \left(\min_c \frac{I^c(\mathbf{y})}{A^c} \right).$$

A key parameter in our algorithm is the patch size. On one hand, the dark channel prior becomes better for a larger patch size because the probability that a patch contains a dark pixel is increased. The larger the patch size, the darker the dark channel. Consequently, is less accurate for a small patch, and the recovered scene radiance is oversaturated. On the other hand, the assumption that the transmission is constant in a patch becomes less appropriate. If the patch size is too large, halos near depth edges may become stronger.

With the atmospheric light and the transmission map, we can recover the scene radiance according to (1). But the direct attenuation term Jxtx can be very close to zero when the transmission tx is close to zero. The directly recovered scene radiance J is prone to noise. Therefore, we restrict the transmission tx by a lower bound t 0 , i.e., we preserve a small amount of haze in very dense haze regions. The final scene radiance Jx is recovered by

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

(a) Original Image (b) Dark Channel Prior (c) Haze-Free Image

Libraries used openCV2, numpy, math(in python)