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Accelerated haze removal for a single image by dark channel prior

Key words: Haze removal; Dark channel prior; Hazy image model; Bilateral filtering

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Motivation

Haze removal is highly desired; however, it is difficult to achieve, especially for a single image:

(1) The criterion of haze is ambiguous. In practice, the air atmosphere is not free of haze even on clear days. Besides, humans perceive scene depth due to the existence of haze.

(2) Sunlight easily influences the estimation of atmospheric light.

(3) It is difficult to achieve scene depth from a single image, and a transmission map is related to scene depth.

Main idea

- We propose an accelerated dehazing method based on single pixels. Unlike methods based on regions, our method estimates the transmission map and atmospheric light for each pixel independently, so that all parameters can be evaluated in one traverse, which is a key to acceleration.
- Then, the transmission map is bilaterally filtered to restore the relationship between pixels.
- After restoration via the linear hazy model, the restored images are tuned to improve the contrast, value, and saturation, in particular to offset the intensity errors in different channels caused by the corresponding wavelengths.

Method

1. Achieving the dark channel:

$$J_{\text{dark}}(x) = \min_{c \in \{R,G,B\}} J_c(x).$$

2. Filtering the transmission map:

$$\tilde{t}(x) = 1 - \omega \min_{c \in \{R,G,B\}} J_c(x),$$

3. Restoring the hazy image:

$$J(x) = \frac{I(x) - \min(\tilde{A}, A_0)}{\max\left(\tilde{t}(x), t_0\right)} + \min(\tilde{A}, A_0),$$

4. Tuning the color channel:

$$J_c(x) = \frac{I(x) - \min\left(\tilde{A}, A_0\right)}{\max\left(\tilde{t}_c(x), t_0\right)} + \min\left(\tilde{A}, A_0\right).$$

Major results

Comparison of hazy images with restored images

Major results

Table 2 MSE and PSNR comparison among the methods proposed by Fattal (2008), He et al. (2010), Nishino et al. (2012), Gibson and Nguyen (2013), Berman et al. (2016) and our method

Method	MSE			PSNR (dB)		
	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3
Fattal (2008)'s	99.35	108.35	103.36	8.218	7.4344	7.874
He et al. (2010)'s	107.26	105.45	104.82	7.543	7.670	7.772
Nishino et al. (2012)'s	105.45	103.19	100.22	7.707	7.858	8.112
Gibson and Nguyen (2013)'s	96.36	100.85	102.89	8.485	8.057	7.883
Berman et al. (2016)'s	105.85	109.43	109.04	7.706	7.348	7.379
Ours	107.78	101.82	94.824	7.543	7.975	8.642

Table 3 Differences in detectable marginal rates of the methods proposed by Fattal (2008), He et al. (2010), Nishino et al. (2012), Gibson and Nguyen (2013), Berman et al. (2016) and our method

Method	r_{hazy}			Δr		
	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3
Fattal (2008)'s	39.195	30.558	10.103	23.436	30.832	33.672
He et al. (2010)'s	39.195	30.558	10.103	12.648	27.596	4.930
Nishino et al. (2012)'s	39.195	30.558	10.103	6.059	36.184	24.299
Gibson and Nguyen (2013)'s	39.195	30.558	10.103	37.781	34.658	35.871
Berman et al. (2016)'s	39.195	30.558	10.103	20.926	33.900	38.837
Ours	39.195	30.558	10.103	30.651	32.744	26.510

Table 4 Information entropy differences of the methods proposed by Fattal (2008), He et al. (2010), Nishino et al. (2012), Gibson and Nguyen (2013), Berman et al. (2016) and our method

Method	Information entropy difference		
	Image 1	Image 2	Image 3
Fattal (2008)'s	0.004	0.152	0.369
He et al. (2010)'s	0.100	0.297	0.402
Nishino et al. (2012)'s	0.206	0.393	0.610
Gibson and Nguyen (2013)'s	0.140	0.374	0.440
Berman et al. (2016)'s	0.355	0.147	0.046
Ours	0.228	0.281	0.421

Conclusions

We have proposed an approach to remove haze for a single image. The transmission map and atmospheric light have been achieved in a single circulation. A bilateral filter has been used to refine the transmission map. The atmospheric light has been corrected by the experience and the statistics to constrain the overestimation. We have restored images by the channels based on different wavelengths. To evaluate the performance of this approach, our method has been compared with the existing dehazing algorithms.

Experimental results show that the proposed algorithm outperforms other methods in terms of efficiency and dehazing effects.