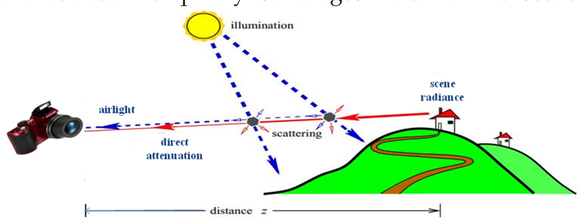
Single Image Fog Removal Based on Fusion Strategy

V. Thulasika and A. Ramanan
Department of Computer Science, University of Jaffna, Sri Lanka.
v.thula.sika@gmail.com, a.ramanan@jfn.ac.lk

SLSWCS Student Workshop on Computer Science

Introduction

Outdoor images are often suffered by suspended atmospheric particles, such as fog, mist, haze and smoke that reduce the quality of images taken in the scene.



FOG MODEL

Foggy Image = Direct Attenuation + Airlight

$$I(x) = J(x)t(x) + A(1 - t(x))$$

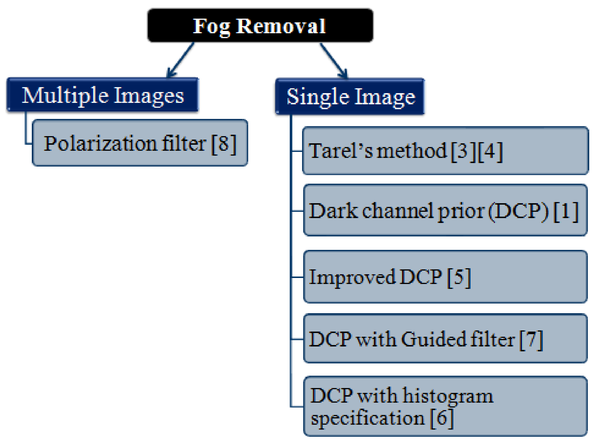
- $I(x)$ – Observed Intensity
- $J(x)$ – Scene Radiance
- A – Global Atmospheric light
- $t(x)$ – transmission map

- **Airlight** adds whiteness into the scene.
- **Attenuation** decreases the contrast in the scene.

Motivation

To detect the airlight in each regions of degraded image, increase the direct attenuation and restore that image.

Related Work



Statistical-based Method

He's method [1] is the state-of-the-art statistical-based method for fog removal.

Step 1	Step 2	Step 3	Step 4
Airlight Estimation	**Transmission map Estimation**	**Restoration**	**Soft Matting**
• Dark channel Estimation • Pick the top 0.1% brightest pixels in the dark channel • Find the average value for each channel	• Normalize $I(x) = J(x)t(x) + A(1 - t(x))$ by A. • Recalculate the dark channel on the normalized image • According to dark channel prior the dark channel of J is close to zero	✓ Airlight ✓ Transmission map ✓ Scene radiance J is recovered.	• Derive the matting Laplacian matrix • Perform a bilateral filter on transmission map to smooth its scale textures

Contrast-based Method

Tarel's method [3][4] is the state-of-the-art contrast-based method for fog removal.

Step 1	Step 2	Step 3	Step 4
White Balance	**Visibility Enhancement Algorithms**	**Atmospheric Veil Inference**	**Restoration**
• Remove unrealistic colour casts. • I_s is set to (1,1,1)	• Road specific enhancement (Planar assumption) • Estimate the extinction coefficient of the atmosphere.	• W = min(I) • A = median(W) • B = A-median(|W-A|) • V = max(min(pB,W),0)	✓ Veil ✓ I_s=[1,1,1] ✓ R = (I-V)/(1-V/Is)

Proposed Method

S: Statistical-based method
- Works well for outdoor images
- Can only handle homogenous fog

C: Contrast-based method
- Works well for outdoor images
- Can handle both homogenous and heterogeneous fog

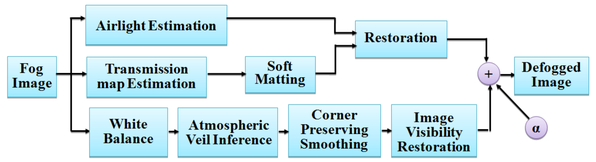
I: Proposed method
- Works well for outdoor and In-vehicle images
- Can handle both homogenous and heterogeneous fog

These derived images, S and C, are then weighted by a specific weight map:

$$I = \frac{S + \alpha C}{1 + \alpha}$$

where α is positive scalar.

Fusion Strategy



Block diagram of defogging by fusion strategy

The novel parameter α is set to $\lceil 10\sqrt{MSE} \rceil$ based on Empirical result.

Evaluation Criteria

- *MSE*: The mean square error represents the cumulative squared error between the compressed and the original image. The lower the value of MSE, the lower the error.
- *PSNR*: Peak Signal-to-Noise Ratio is computed in decibels between two images. Higher the PSNR, the better the quality of the compressed or reconstructed image.

Dataset

Synthetic image

- Foggy Road Image Database (FRIDA)[3].
- FRIDA consists of a total number of 66 colour images of different scenes with resolution 640×480.

Real image

- Resolution 600×400 [2].

Quantitative Results

Comparison of MSE

Image	Contrast based method [2]	Statistical based method [4]	Fused method [Ours]
1	0.0114	0.0117	0.0112
10	0.0097	0.0098	0.0095
11	0.0222	0.0226	0.0201
20	0.0134	0.0138	0.0131
21	0.0175	0.0188	0.0173
30	0.0206	0.0207	0.0204
31	0.0162	0.0181	0.0161
40	0.0145	0.0157	0.0145
41	0.0199	0.0194	0.0192
50	0.0217	0.0221	0.0213
51	0.0218	0.0221	0.0215
60	0.0205	0.0178	0.0192
Average	0.0171	0.0182	**0.0165**

MSE (Mean Square Error)

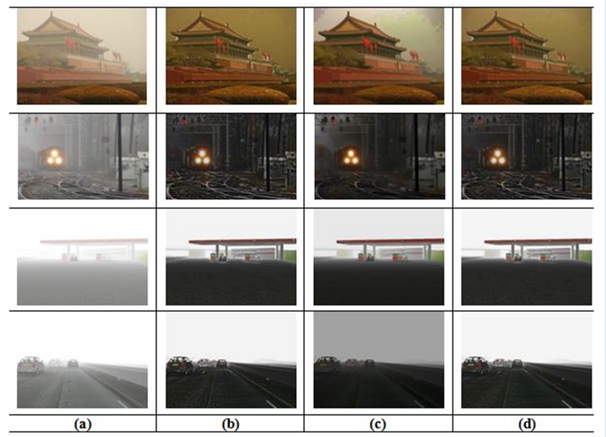
Comparison of PSNR

Image	Contrast based method [2]	Statistical based method [4]	Fused method [Ours]
1	67.5509	67.4545	67.6467
10	68.2442	68.2119	68.3646
11	64.6625	64.5966	65.1051
20	66.3743	66.2571	66.51
21	66.3174	66.0871	66.566
30	64.9967	64.9789	65.0451
31	65.4234	65.3583	65.5417
40	66.416	66.1842	66.5158
41	67.0691	66.3794	67.2119
50	64.7735	64.8943	64.8412
51	64.7442	64.8589	64.8161
60	66.8175	68.0919	66.8434
Average	66.1385	65.7917	**66.2123**

PSNR (Peak Signal-to-Noise Ratio)

The results reported in Table 1 and 2 are of $\alpha = 2$.

Qualitative Results



Comparison of contrast and statistical based techniques with our fusion based strategy. (a) Input image: First two rows are camera images whereas the last two rows are road images (b) Tarel's results (c) He's results (d) Our results.

Conclusion

1. Simple but efficient method to improve single image defogging.
2. Works well for synthetic and real images.
3. Based on selection of an appropriate weight map for fusion.
4. Outperforms other single image based defogging techniques.
5. Restored images are more natural and visually pleasing.

References

1. K.He, J.Sun, and X.Tang, "Single image haze removal using dark channel prior", In CVPR, pp. 1956-1963, 2009.
2. Real images:https://sites.google.com/site/computervisionadinastoica/final-project.
3. J.P.Tarel and N.Hautiere, "Fast visibility restoration from a single color or gray level image", In ICCV, pp. 2201-2208, 2009.
4. J.P.Tarel, N.Hautiere, A.Cord, D.Gruyer, and H.Halmaoui, "Improved visibility of road scene images under heterogeneous fog", In IEEE Intelligent Vehicle Symposium, pp. 478-485, 2010.
5. Yan Wang and Bo Wu, "Improved Single Image Dehazing using Dark Channel Prior", In IEEE Intelligent Computing and Intelligent Systems, pp. 789-792, 2010.
6. S. Yang, Q. Zhu, J. Wang, D. Wu and Y. Xie, "An Improved Single Image Haze Removal Algorithm Based on Dark Channel Prior and Histogram Specification", Proc. 3rd International Conf. On Multimedia Technology, Atlantis Press, pp. 279-292, 2013.
7. J.Pang, A.Oscar, and G.Zheng, "Improved single image dehazing using guided filter", In APSIPA Annual Summit and Conference, ACM, pp.1-4, 2011.
8. Y.Y.Schechner, S.G.Narasimahan and S.Nayar, "Polarization-based vision through haze", Applied Optics, pp. 511-525, 2003.