Nighttime Image Dehazing Based on Variational Decomposition Model

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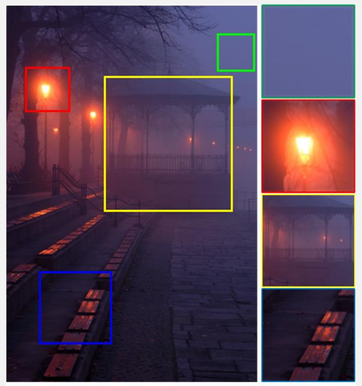
Multiple complex degraded factors-Nighttime hazy scenes



Nighttime hazy image

- Hidden noises
- Glow effects
- Haze interference
- Low illumination

Traditional daytime haze removal methods cannot deal with nighttime hazy scenes.

Input DCP [10] MSCNN [30] Our

Linear Model

$$I(x) = S(x) + D(x) + N(x) + G(x)$$

Variational Decomposition Model

$$\arg\min_{\mathbf{S},\mathbf{D},\mathbf{N}} \|\mathbf{S}+\mathbf{D}+\mathbf{N}-\mathbf{H}\|_2^2 + \alpha\|\nabla\mathbf{S}\|_1 + \beta\|\nabla\mathbf{D}-\nabla\mathbf{H}\|_0 + \delta\|\mathbf{N}\|_2^2$$

Solutions-ADMM

Algorithm 1 Solution of Proposed Model (2)

Input: pre-processed image $\mathbf{H}$, parameters α, β, and δ, maximum iterations K.

Initialization: $\mathbf{R}_0 = t_0(x)$, $\mathbf{N}_0 = \mathbf{0}$, $k = 0$.

1: **for** $k = 1$ to K **do**
2: Update $\mathbf{S}^{k+1}$ using (6);
3: Update $\mathbf{D}^{k+1}$ using (8);
4: Update $\mathbf{N}^{k+1}$ using (9);
5: Update $\mathbf{T}^{k+1}$ using (11);
6: Update $\mathbf{L}^{k+1}$ using (13);
7: Update $\mathbf{Z}_1^{k+1}$, $\mathbf{Z}_2^{k+1}$ and μ^k using (14);
8: **End**

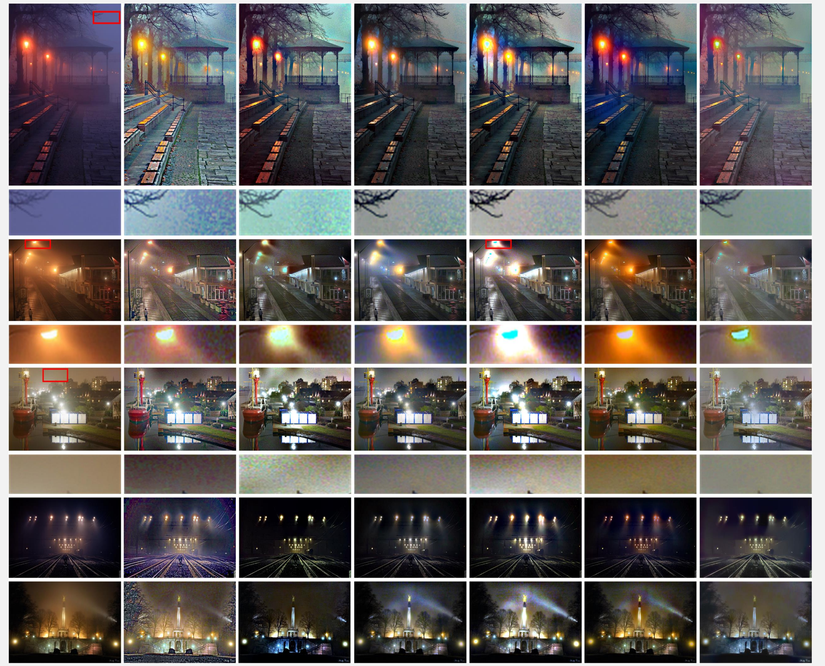
Output: Final $\mathbf{S}^k$, $\mathbf{D}^k$, and $\mathbf{N}^k$.

Multi-scale decomposition

$$\arg\min_{\mathbf{B}} \|\mathbf{B}-\mathbf{S}'\|_2^2 + \lambda\|\nabla\mathbf{B}\|_1$$

Noise Suppression

Qualitative Comparisons on Real-world Nighttime hazy Images



Quantitative comparisons on synthetic images

Table 1. Quantitative comparisons on synthetic nighttime hazy images in Fig. 4.

Examples	NDIM [40]		GS [21]		MRP [39]		MRP_Faster [39]		OSFD [41]		Our	
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
E1	12.3621	0.6162	13.7171	0.6645	14.1856	0.7247	13.7692	0.6869	14.4284	0.7277	**15.8444**	**0.7498**
E2	14.6954	0.6829	14.9221	0.7145	14.8665	0.7400	15.8630	0.7332	14.3735	0.7488	**16.6698**	**0.7895**
E3	14.9046	0.6092	14.3896	0.6284	15.7950	0.6683	14.5727	0.6462	16.5706	0.6793	**16.6678**	**0.6887**
E4	12.9891	0.5956	14.7477	0.6447	14.0008	0.6617	14.2825	0.6465	14.1065	0.6753	**15.7061**	**0.7013**
E5	13.4413	0.6130	12.8841	0.6252	14.9017	0.6893	15.1977	0.6527	14.6146	0.6940	**16.8963**	**0.7543**

Quantitative comparisons on synthetic dataset NHM

Methods	PSNR	SSIM
NDIM [40]	12.4924	0.5752
GS [21]	11.8963	0.5899
MRP [39]	12.9928	0.6299
MRP_Faster [39]	13.1847	0.6164
OSFD [41]	13.3027	0.6435
Our	**13.6196**	**0.6734**

Convergence Speed of Proposed Model