Fast Region-Adaptive Defogging and Enhancement for Outdoor Images Containing Sky

Zhan Li[1], Xiaopeng Zheng[2] , Bir Bhanu[3], Shun Long[1], Qingfeng Zhang,[1] Zhenghao Huang[4]

1 Dept. of Computer Science Jinan University
2 School of Data and Computer Science Sun Yat-sen University
3 Dept. of Electrical and Computer Engineering University of California, Riverside
4 Neural Technologies Limited

Introduction

To naturally dehaze and enhance both distant and nearby regions and to preserve the colors of sky regions in an outdoor scene, we propose a region-adaptive image defogging and enhancement (RADE) method.

Our major contributions are as follows:

- we introduce a replaceable plug-in region segmentation module and discuss typical segmentation methods for splitting the grayish sky, white objects, and other areas.
- we propose a luminance-inverted MSRCR as a color-preserving and fast version of the traditional MSRCR.
- we propose a region-ratio-based local Gamma transformation as a further adaptive enhancement and color correction.

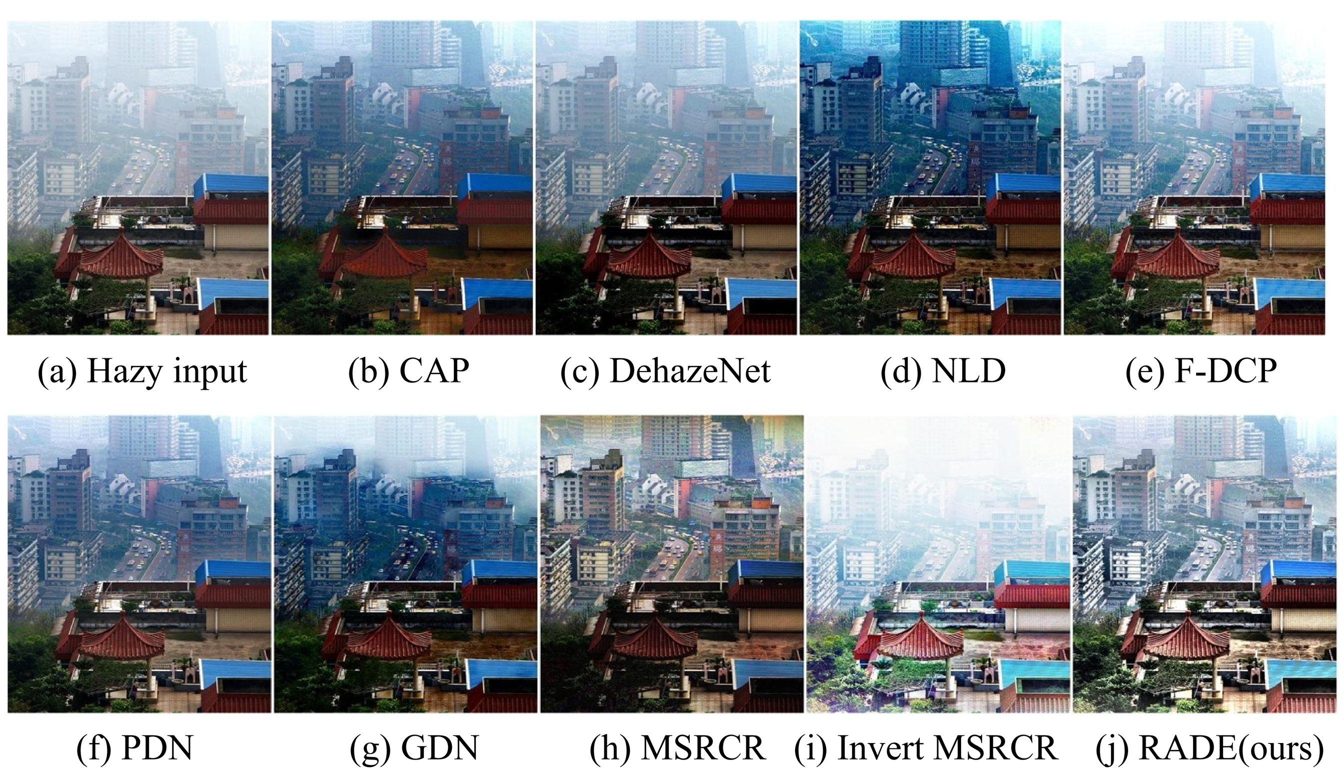

Fig. 1. Example of haze removal for a real-world outdoor image from the UTexas LIVE Image Defogging Database

Method

RADE applies selective techniques to three types of regions: white or near-white objects, the grayish sky regions and other parts. Fig. 2 describes the main flowchart of the proposed method:

- **Region segmentation** is implemented as a replaceable plug-in segmentation module. We tested four typical methods based on thresholding, K-means clustering, transmission maps in DCP, and semantic segmentation DNN (show in Fig. 3).
- **Luminance-inverted MSRCR** (multiscale Retinex with color restoration) is designed as a color-preserving / and fast version of the original one.
- **Adaptive Gamma correction** based on the region ratio of the sky and white objects area to the total image size is proposed to further recover the color.
- **CLAHE** (contrast-limited adaptive histogram equalization) is applied on grayish region, which is frequently related to the sky or haze-covered buildings or trees.
- **Seamless stitching** is implemented as a technique of fade-in and fade-out by employing mean-filtered region masks. .

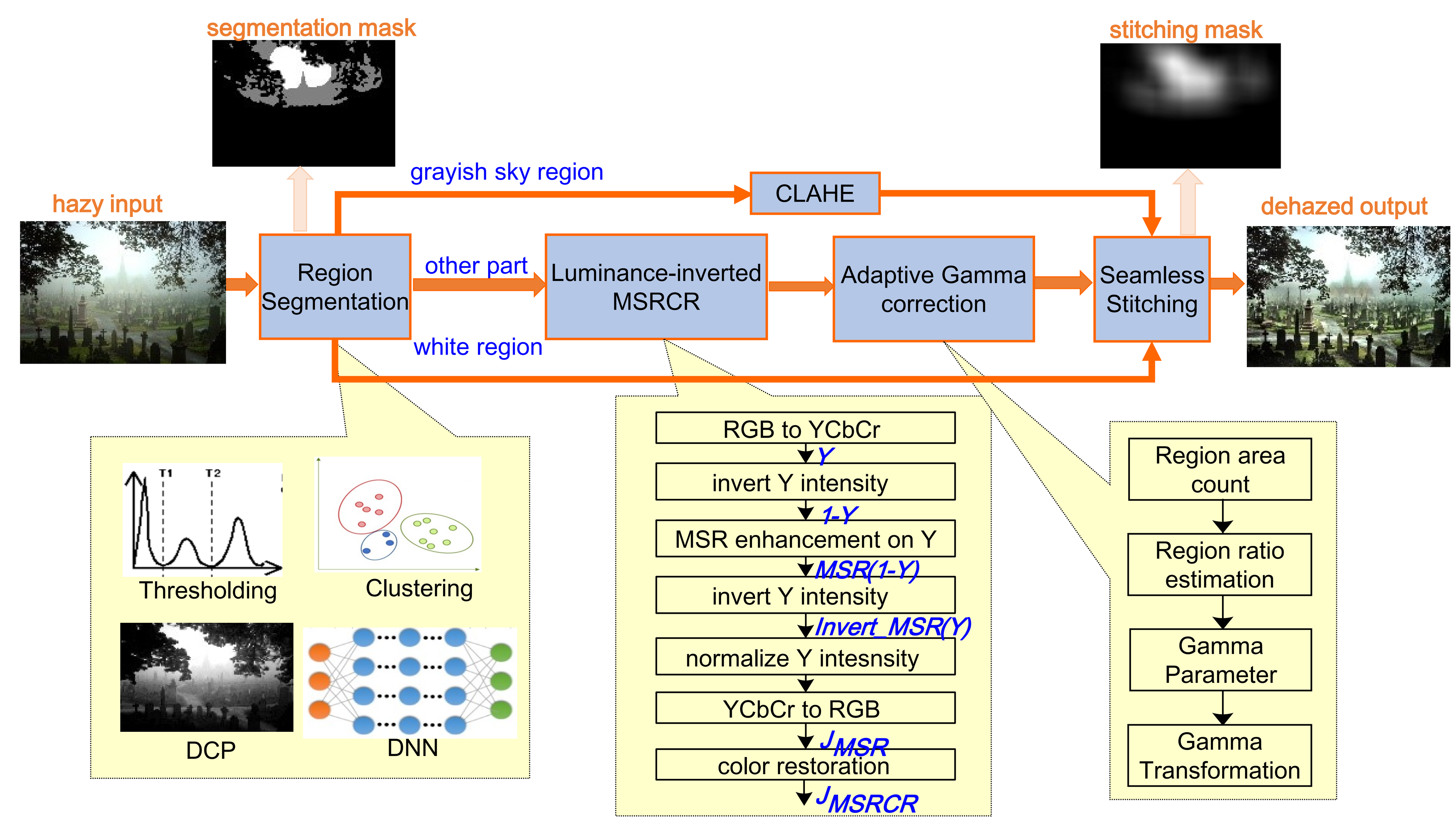

Fig. 2. Overview of the proposed region-adaptive method (RADE) for defogging.

Results

Dataset: Utexas LIVE: 500 natural foggy images of outdoor scenes

Criteria:

average gradient (AG), contrast (σ2),information entropy (IE), color correlation (COR), fog aware density evaluator (FADE)

Table 1. Quantitative comparisons on LIVE foggy image set.

Method	AG	σ^2	IE	COR	FADE	RT (s)
Input	11.85	7.14	6.63	1.0000	1.600	-
CAP [9]	15.36	7.15	6.59	0.9982	0.740	0.928
DehazeNet [10]	15.20	7.25	7.87	0.9994	0.778	3.362
NLD [7]	18.76	7.35	13.06	0.9970	0.312	7.775
F-DCP [8]	20.00	7.36	11.05	0.9993	0.821	0.815
PDN [11]	13.49	7.24	8.14	0.9991	0.758	3.541
GDN [12]	15.80	7.20	7.79	0.9978	0.557	10.726
MSRCR [4]	13.95	7.56	13.78	0.9988	0.431	0.443
Invert MSRCR [6]	14.09	7.19	15.45	0.9990	1.002	0.451
CLAHE [20]	11.92	7.41	16.07	0.9996	0.664	0.054
RADE (ours)	19.00	7.59	20.05	0.9998	0.439	0.670

Our method RADE produces outputs with more clear visibility as well as natural colors for both nearby and distant scenes.

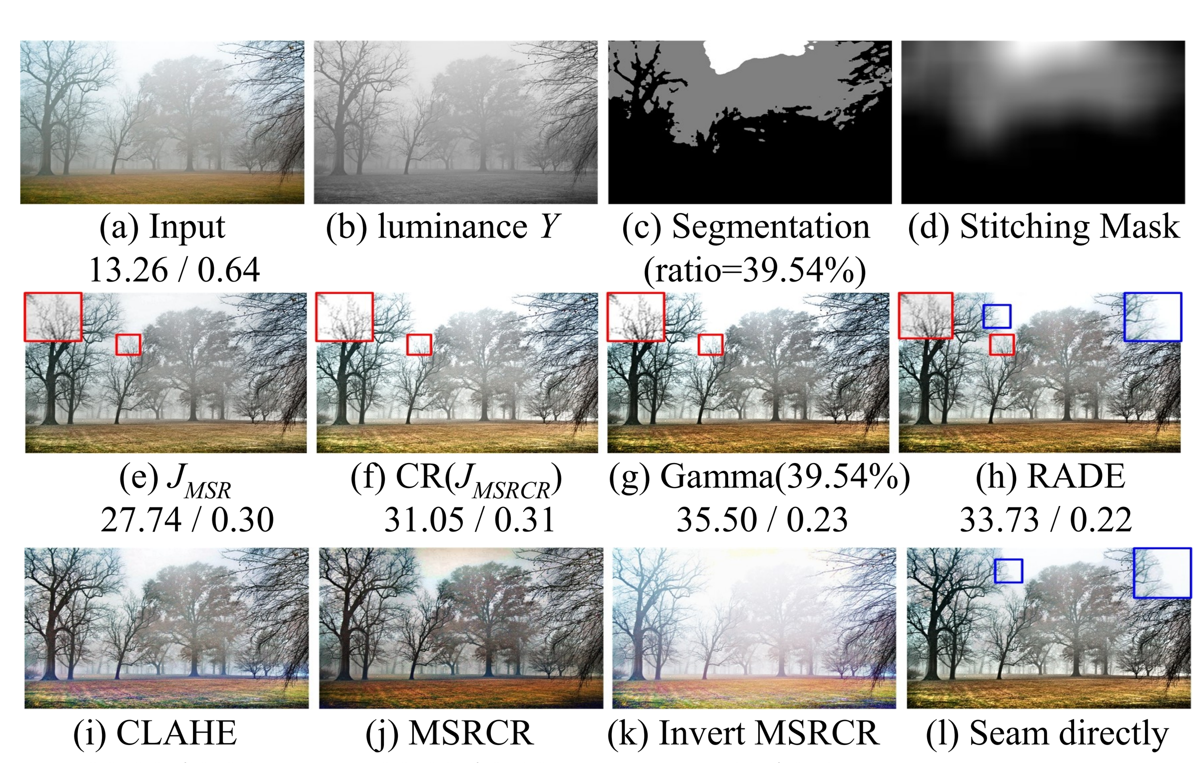

Fig. 4. Example of evaluating different steps and related methods with IE/FADE.

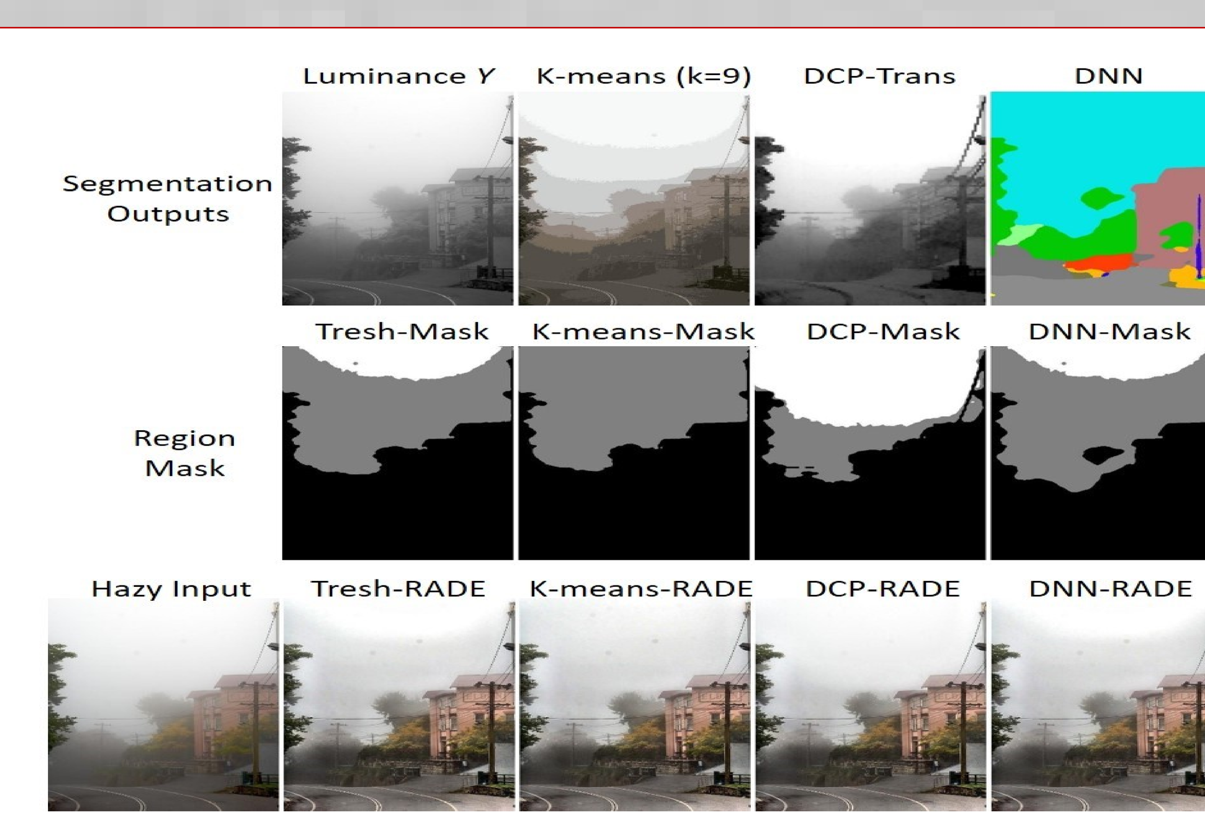

Fig. 3. Example of different segmentation results and their corresponding region masks and dehazed outputs.

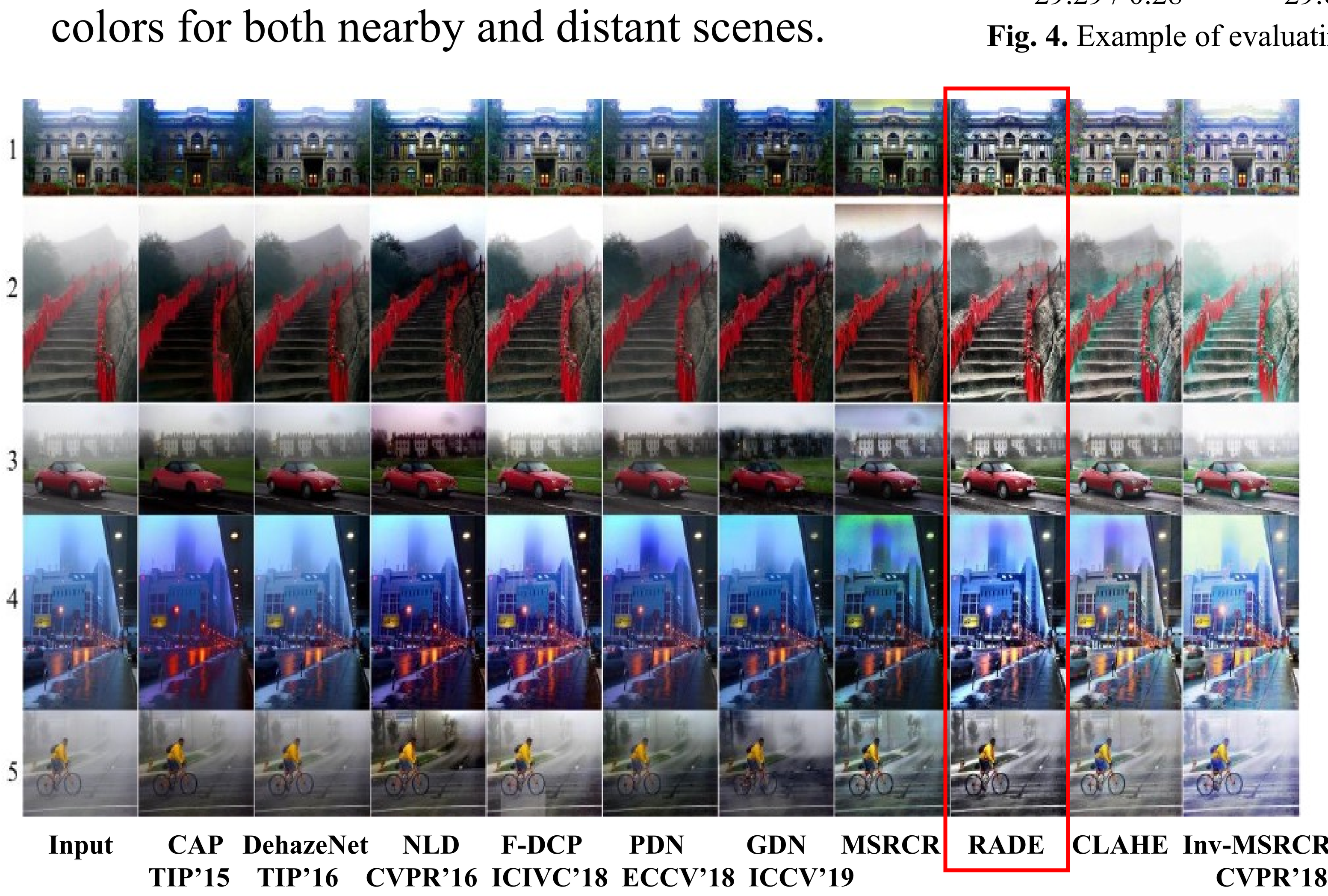

Fig. 5. Qualitative comparison of different methods on LIVE dataset.

Discussion

Our methods may fail for some images with light colors (but not for grayish backgrounds at a distance) due to mistaken segmentation. An example is showed in Fig. 6. Therefore, our future work will focus on more accurate and adaptive segmentation for these extreme cases. In addition, a global consistency regularization will be considered for more reasonable fusion.

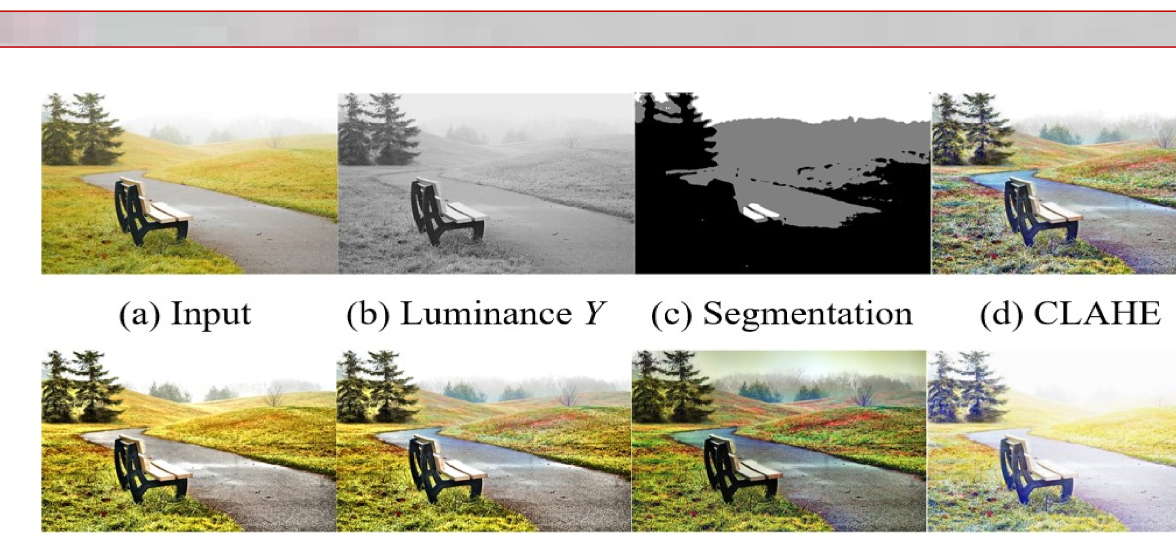

Fig. 6. An example of segmentation failure (ratio = 45.6%)