Fast Region-Adaptive Defogging and Enhancement for Outdoor Images Containing Sky (# 2267)

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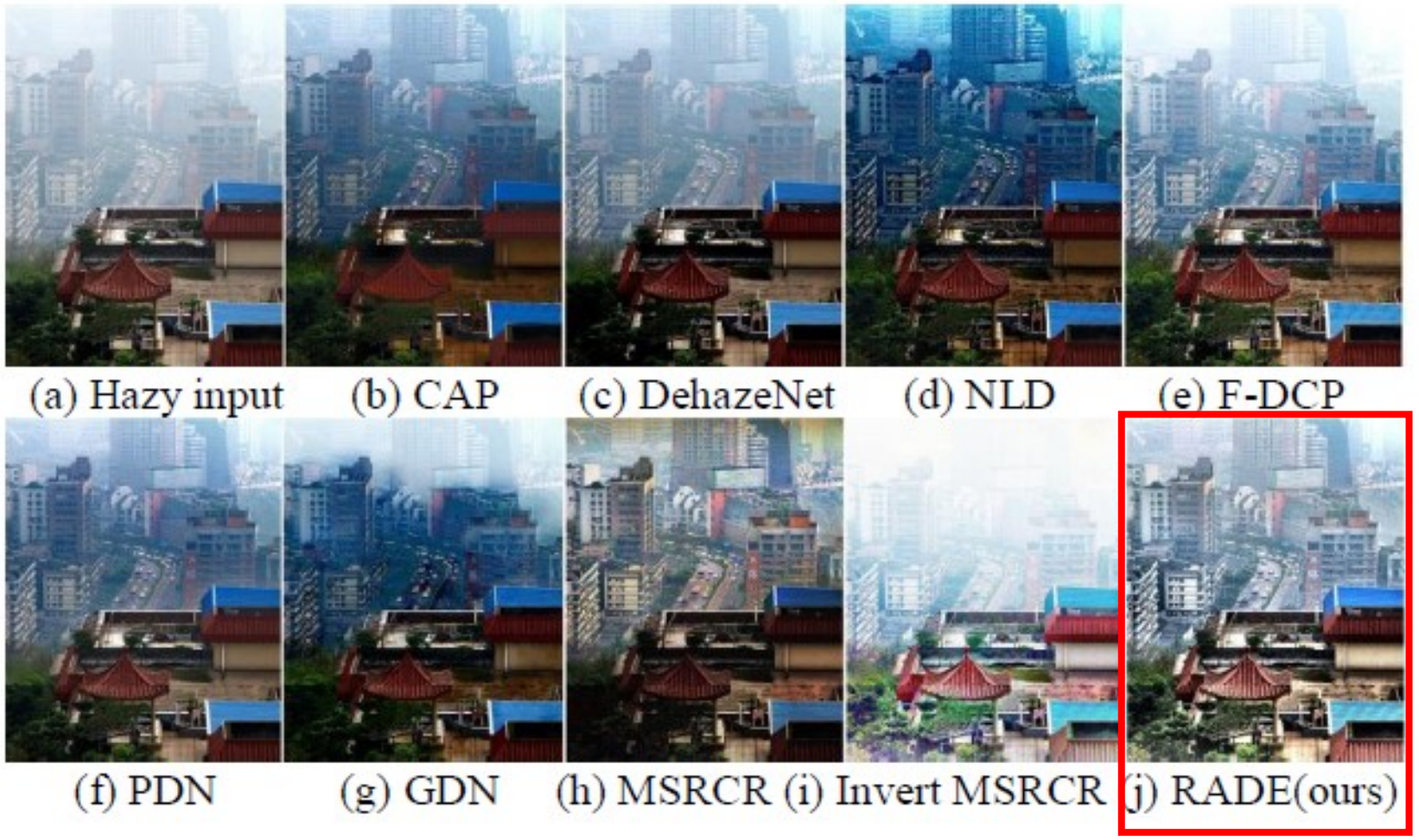
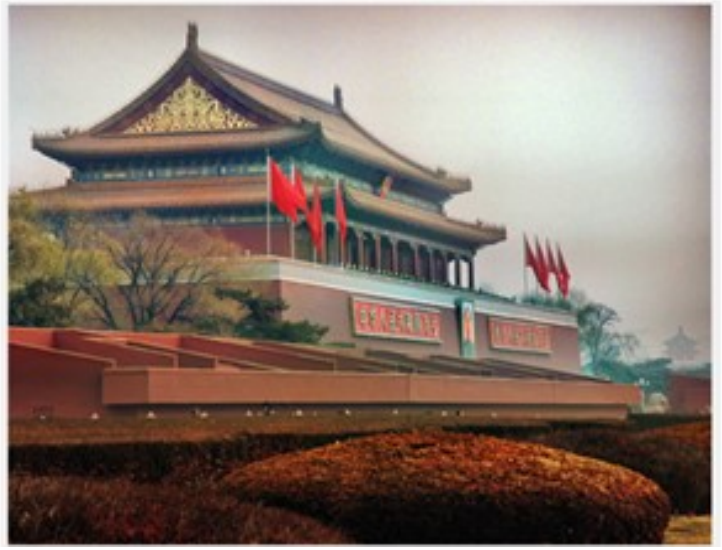
Introduction

Outdoor images has a much larger depth of field (DOF) that spans from the infinite sky to the nearby objects.



Challenge

Dehazing by traditional image enhancement techniques



- Outdoor scenes -- large span of depth of field (DOF) ;
- White objects and the sky regions tend to be over-enhanced with color distortions and halos;
- Complexity & efficiency

Contributions

- RADE -- region-adaptive image dehazing and enhancement for real-world hazy outdoor scenes with a large range of DOF.
  - ✓ Replaceable plug-in region segmentation module;
  - ✓ Luminance-inverted MSRCR (a Retinex-based method);
  - ✓ Region-ratio-based adaptive Gamma correction;
  - ✓ Seamless stitching.

Method

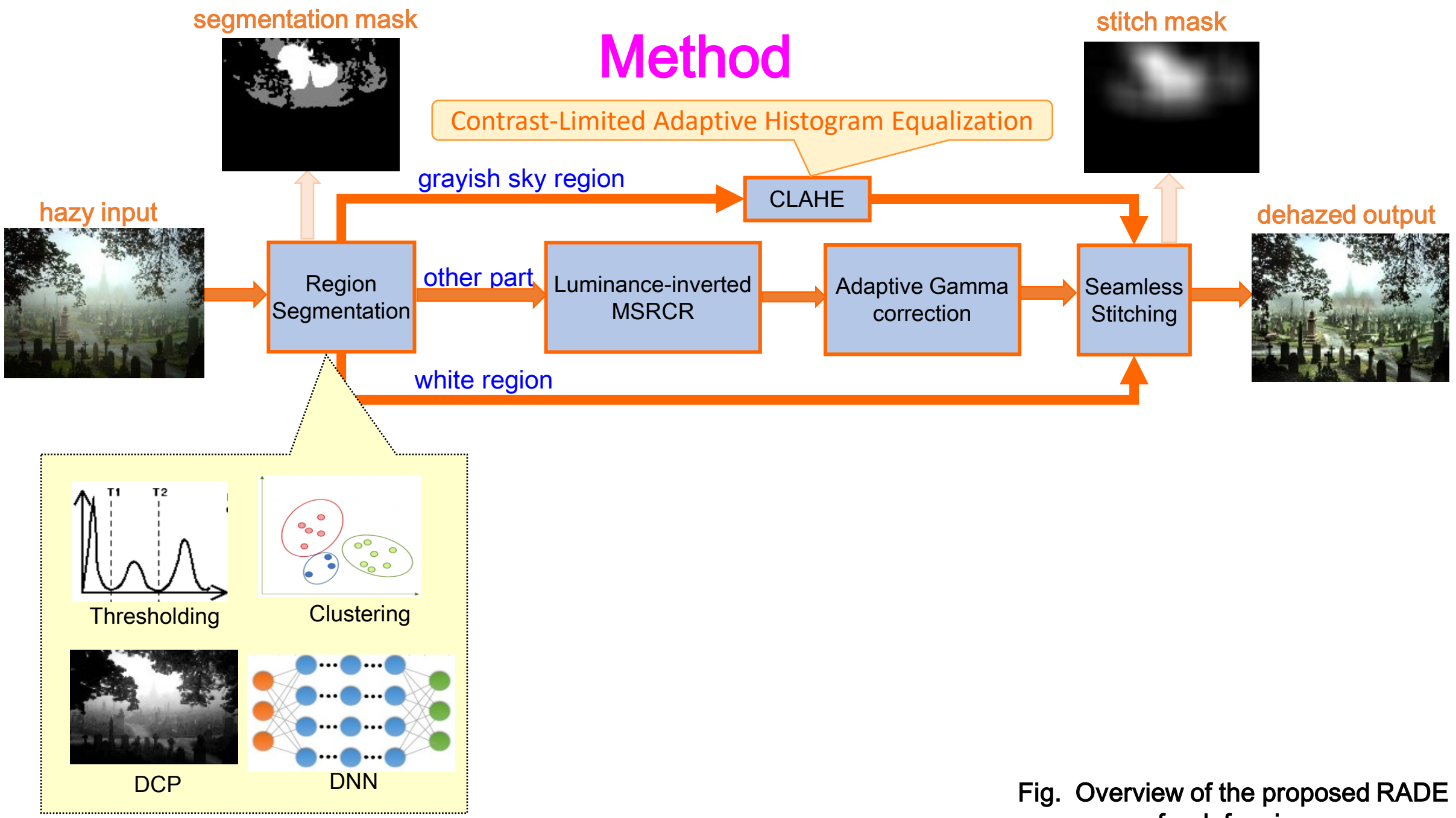
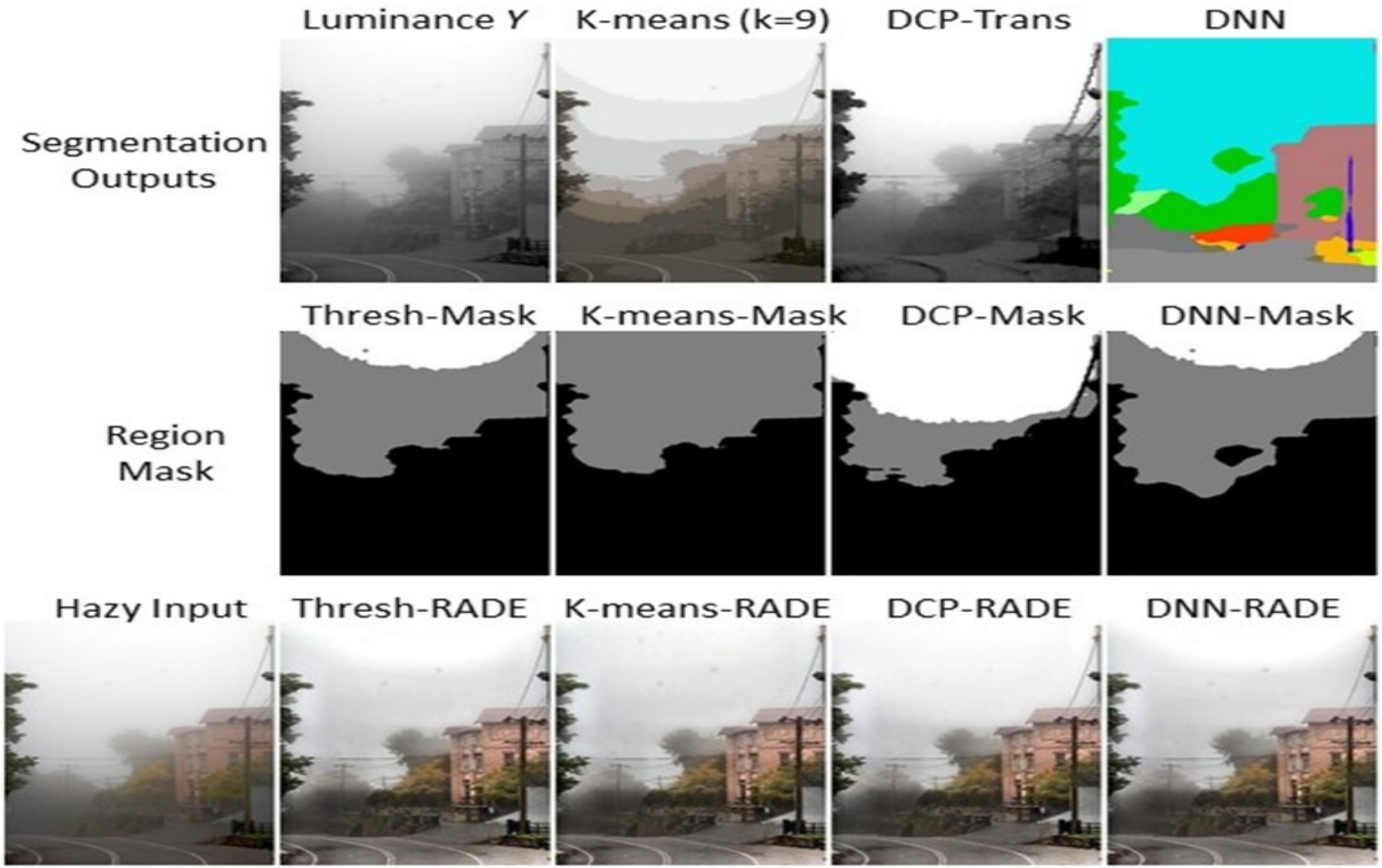


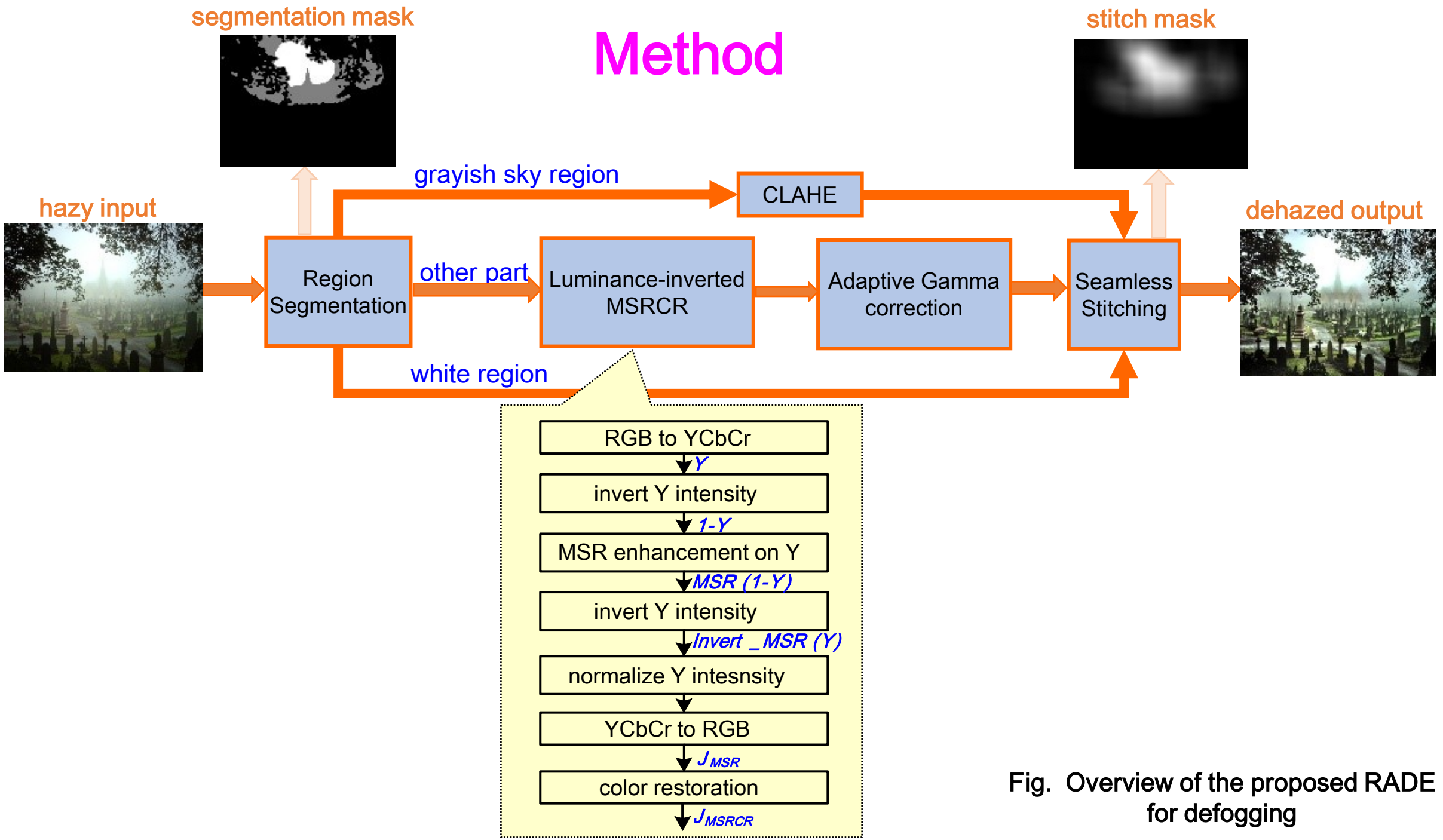
Fig. Overview of the proposed RADE for defogging

Method

➢ Step 1: Segmentation



Method



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Method

➢ Step 2: Luminance-inverted MSRCR

Multi-Scale Retinex (MSR) with Color Restoration

✓ Original MSRCR

$$R_{MSRCRi} = C_i \cdot R_{MSRi}, \quad (2) \qquad C_i = \beta ln\left(aI_i / \sum_{c=1}^{N} I_c\right), \quad (3)$$

✓ Invert intensity (CVPR'18): Retinex-based method → Image dehazing

$$Dehazing(I) = 1 - Retinex(1 - I), \quad (4)$$

✓ Luminance-inverted MSRCR:

$$Invert\_MSR(Y) = 1 - MSR(1 - Y), \quad (5)$$

$$J_{MSRCRi} = e^{R_{MSRCRi}} = e^{C_i \cdot R_{MSRi}} = (e^{R_{MSRi}})^{C_i} = (J_{MSRi})^{C_i}, \quad (6)$$

(a) Input (b) luminance Y (c) Segmentation (e) J_{MSR} (f) CR(J_{MSRCR})

Method

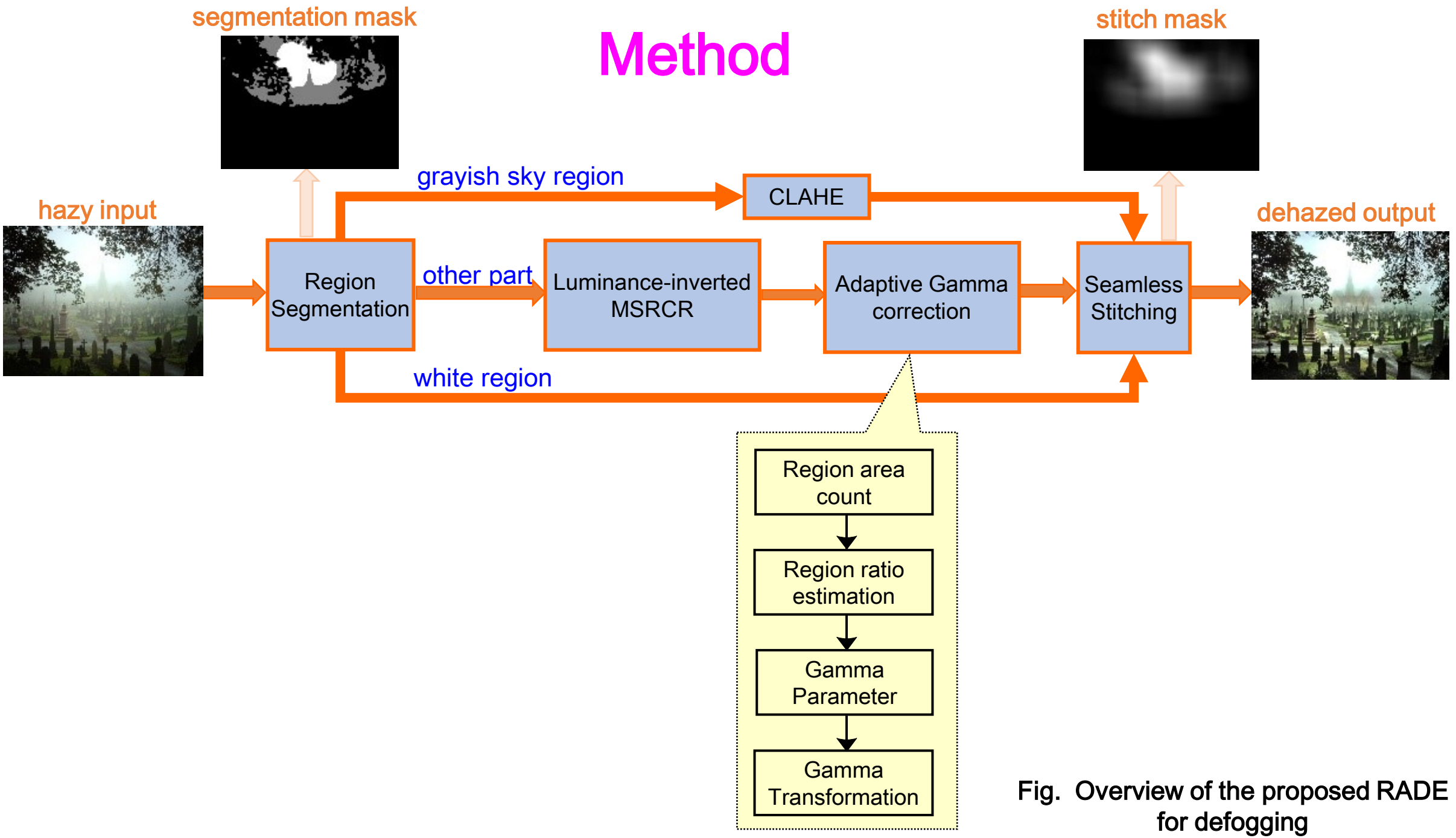

Fig. Overview of the proposed RADE for defogging

Method

- **Step 3: Region-ratio-based Adaptive Gamma Correction**

$$ratio = \frac{the\ sky\ area + white\ objects\ area}{image\ size} \tag{7}$$

$$G(J) = J^{\gamma} = J^{1+\alpha(1-ratio)}, \quad 0 < \alpha < 1, \tag{8}$$

(c) Segmentation (e) J_{MSR} (f) CR(J_{MSRCR}) (g) Gamma(39.54%)

Method

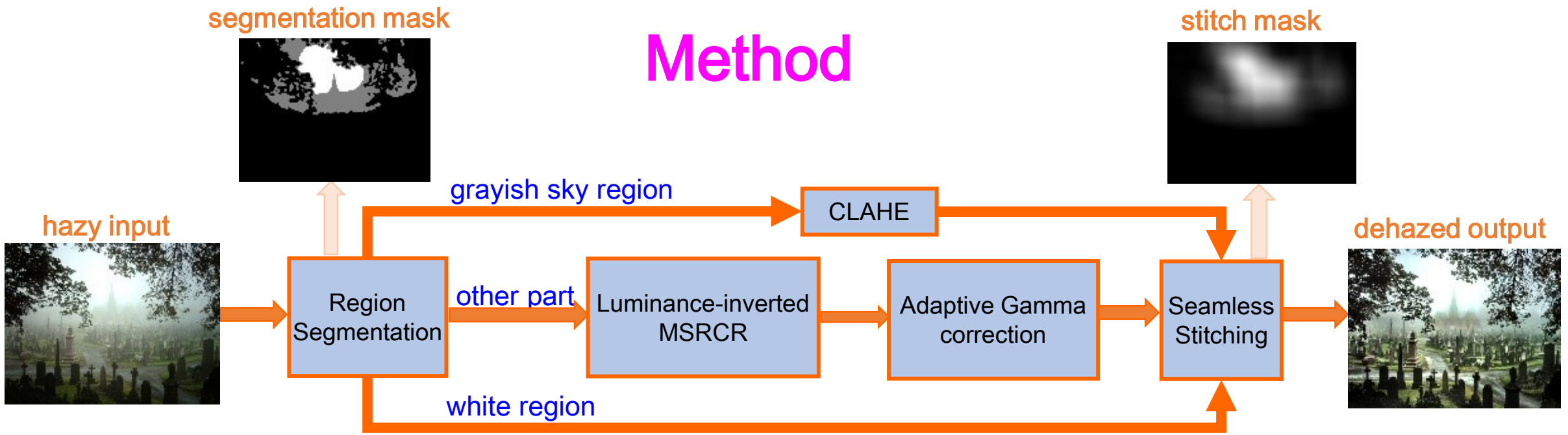

Fig. Overview of the proposed RADE for defogging

Method

➢ Step 4: Seamless Stitching -- fade-in & fade-out

$$J_{out} = \left(1 - F_{k\times k} * M_{gray}\right) \cdot J_{other} + \left(F_{k\times k} * M_{gray}\right) \cdot J_{gray}, \qquad (9)$$

a mean filter

convolution operator

$$M_{gray} = Mask_{gray}(x, y) = \begin{cases} 1 & (t_1 < Y(x, y) < t_2) \\ 0 & otherwise \end{cases}, \qquad (10)$$

(a) Input (b) luminance Y (c) Segmentation (ratio=39.54%) (d) Stitching Mask

Method

Summary of Differences from Previous Work

Method	Ours	[4]	[5]	[13]	[14]	[15]	[16]	[17]	[18]
Prior-based		✓			✓	✓		✓	✓
Retinex-based	✓	✓	✓	✓					
Sky segmentation	✓				✓	✓	✓	✓	✓
Region-adaptive	✓						✓		
Plug-in segmentation	✓								
Luminance MSRCR	✓								
White objects	✓								
Invert intensity	✓		✓						
Adaptive Gamma	✓			✓		✓	✓		

Experiments

Experiment

Hazy Input

Advantages of RADE:

✓ Better visibility & less color distortions

CAP (TIP'15)

DehazeNet (TIP'16)

NLD (CVPR'16)

F-DCP (ICIVC'18)

PDN (ECCV'18)

GDN (ICCV'19)

MSRCR

RADE (ours)

CLAHE

Inv-MSRCR (CVPR'18)

Experiment

Hazy Input

Advantages of RADE:

- ✓ Better visibility & more details
- ✓ Color fidelity & sky-preserved

CAP (TIP'15)

DehazeNet (TIP'16)

NLD (CVPR'16)

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MSRCR

RADE (ours)

CLAHE

Inv-MSRCR (CVPR'18)

Experiment

- ✓ average gradient (AG), contrast (σ^2), information entropy (IE)

  color correlation (COR), fog aware density evaluator (FADE)

Table. Quantitative comparisons on LIVE 500 foggy image set

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

Experiment

➢ Efficiency

Table. Comparisons of average runtime (in seconds)

Method	CAP [8]	DehazeNet [9]	NLD [6]	F-DCP [7]	PDN [10]	GDN [11]	RADE (ours)
LIVE-500	0.928	3.362	7.775	0.815	3.541	10.726	0.670
Test-48	1.177	3.438	7.928	0.983	4.059	13.873	0.815

Experiment

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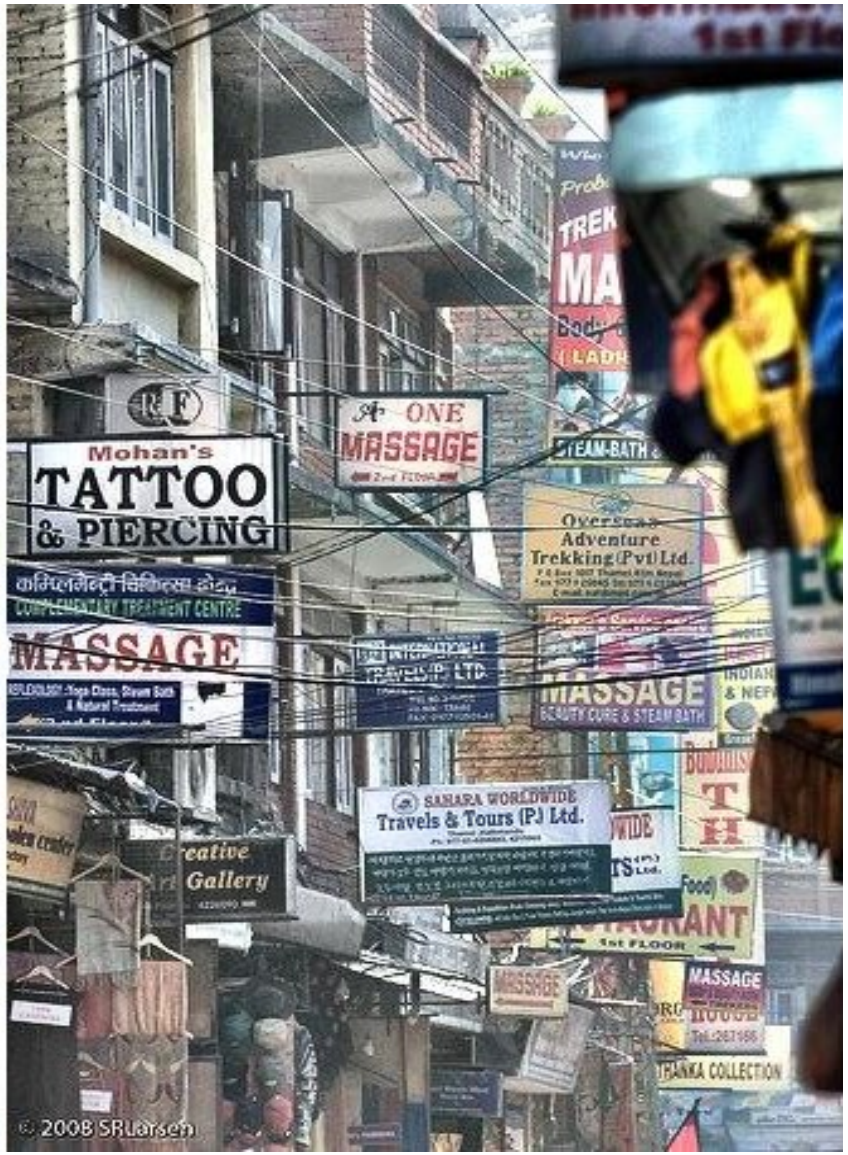
➢ Ablation Study

Table. 4 Major processes & 4 segmentation methods

Step	AG	σ^2	IE	COR	FADE
J_{MSR}	13.50	7.57	16.44	1.0000	0.626
CR	17.03	7.20	18.58	1.0000	0.595
Gamma	22.55	7.33	20.27	0.9997	0.409
Treshold+RADE	19.00	7.59	20.05	0.9998	0.439
K-means+RADE	18.95	7.60	20.05	0.9998	0.440
DCP+RADE	17.76	7.48	19.04	0.9999	0.679
DNN+RADE	17.47	7.58	19.48	0.9999	0.496

More examples



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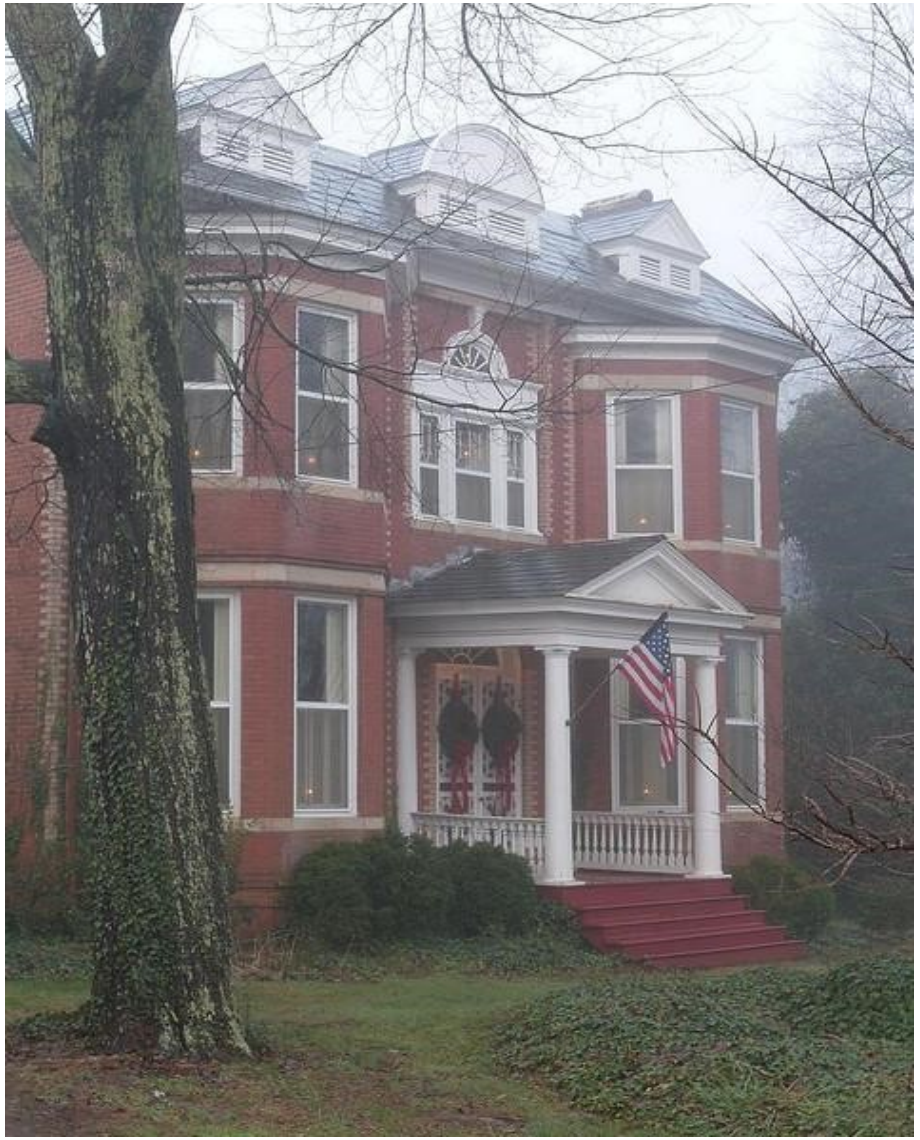

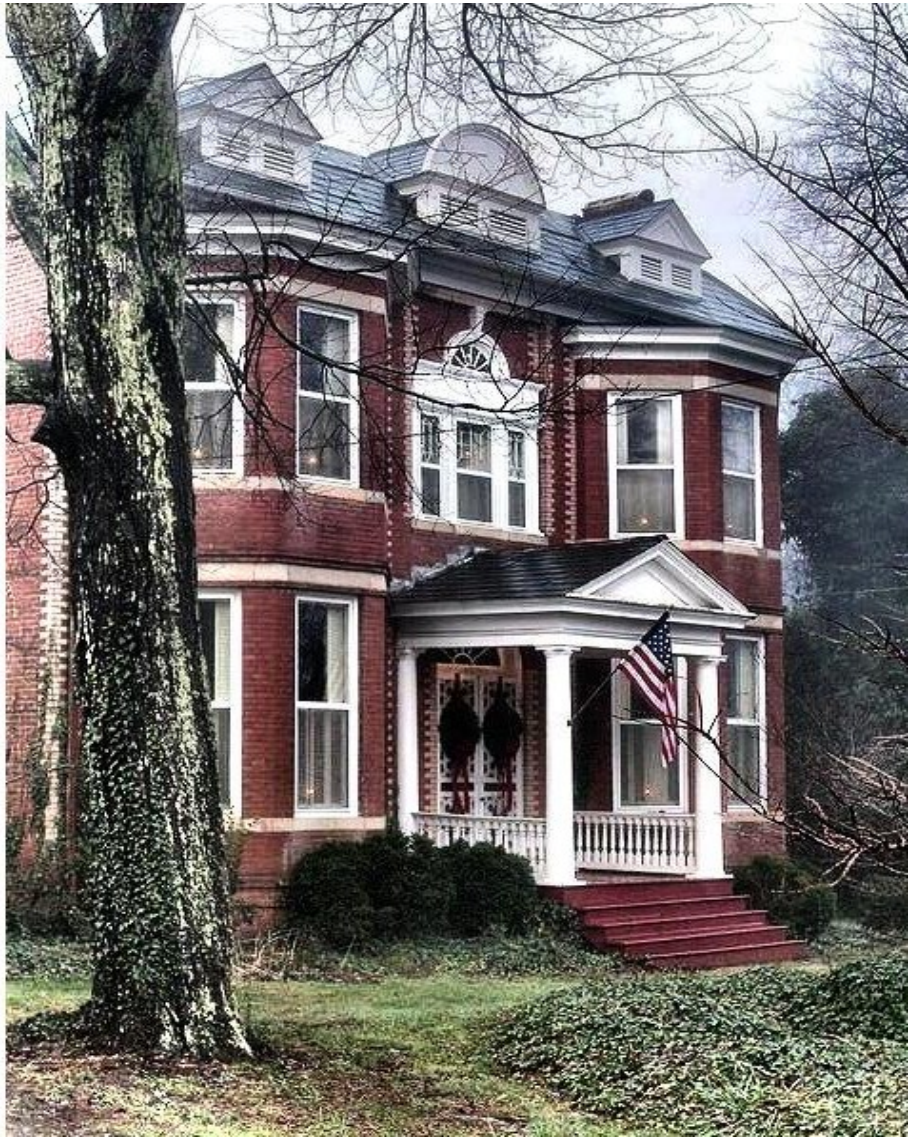

More examples

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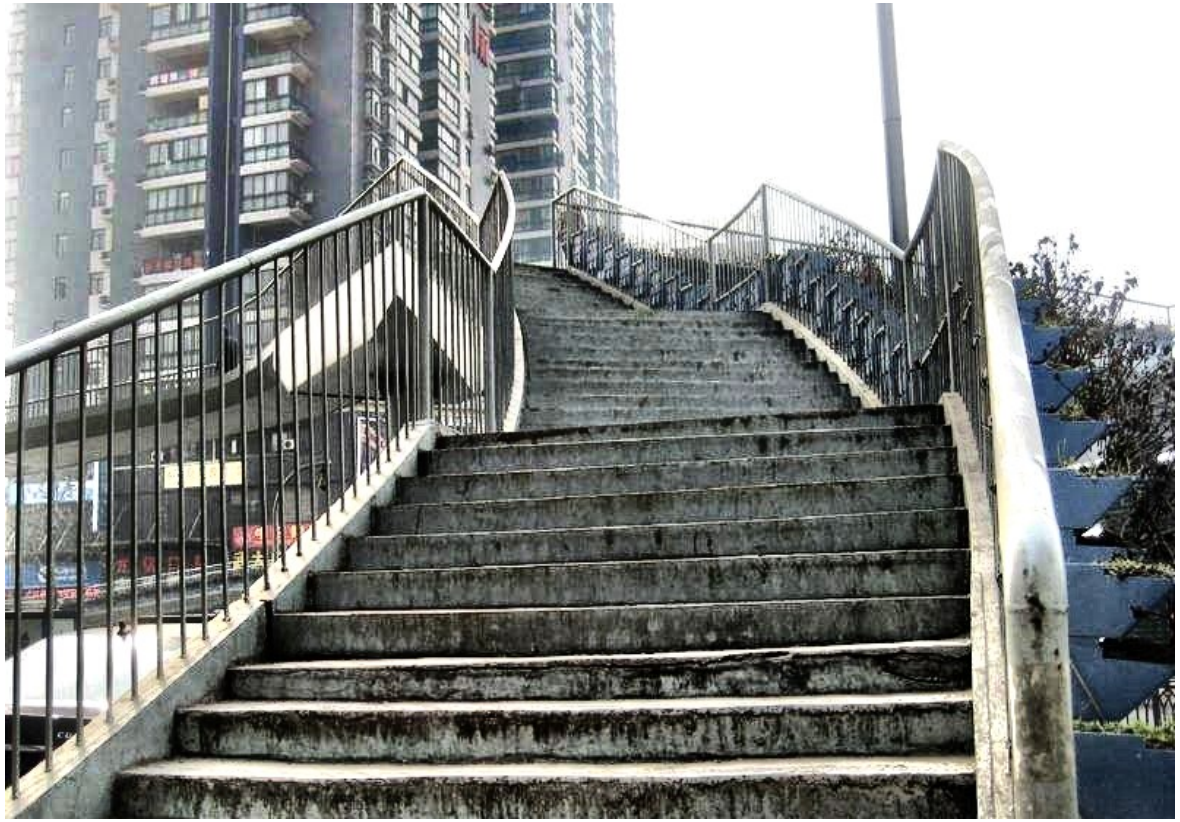


More examples

Conclusions

Conclusions

➢ Summary

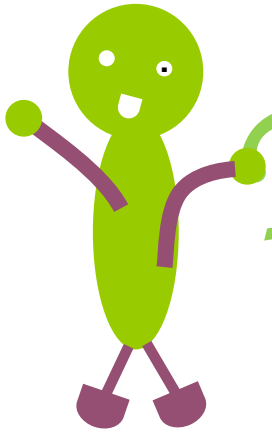
We proposed RADE for image dehazing of both distant and nearby regions.

- ✓ Better visibility & more details;
- ✓ Effective & efficient;
- ✓ With color fidelity & sky-preserved.

➢ Future

- ✓ more accurate and adaptive segmentation for extreme cases;
- ✓ a global consistency regularization for more reasonable fusion.

Welcome to our poster!
#2267



Thank You !

The MATLAB code for our paper: https://github.com/lizhangray/FADE