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Project Page

Depth-Centric Dehazing and Depth-Estimation from Real-World Hazy Driving Video

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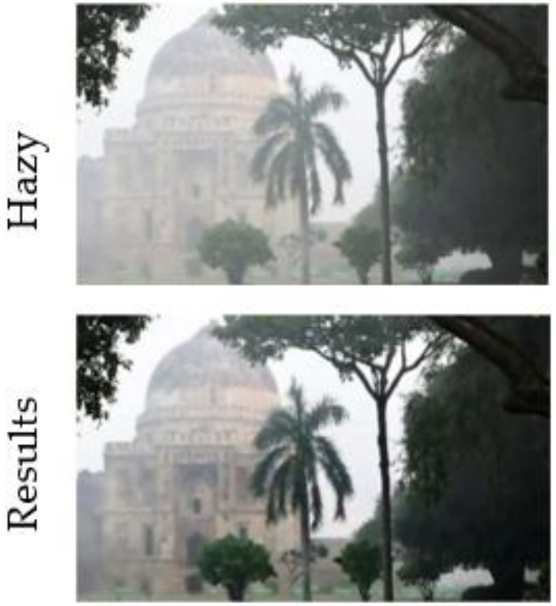
Limitations of Existing Works



MAP-Net CVPR '23

Methods	Data Type	Inf. time (S)	Ref.
DCP	Image	1.39	CVPR'09
RefineNet	Image	0.105	TIP'21
CDD-GAN	Image	0.082	ECCV'22
D^4	Image	0.078	CVPR'22
PSD	Image	0.084	CVPR'21
RIDCP	Image	0.720	CVPR'23
PM-Net	Video	0.277	ACMM'22
MAP-Net	Video	0.668	CVPR'23
NSDNet	Image	**0.075**	arXiv'23
DVD	Video	0.488	CVPR'24

Inference time

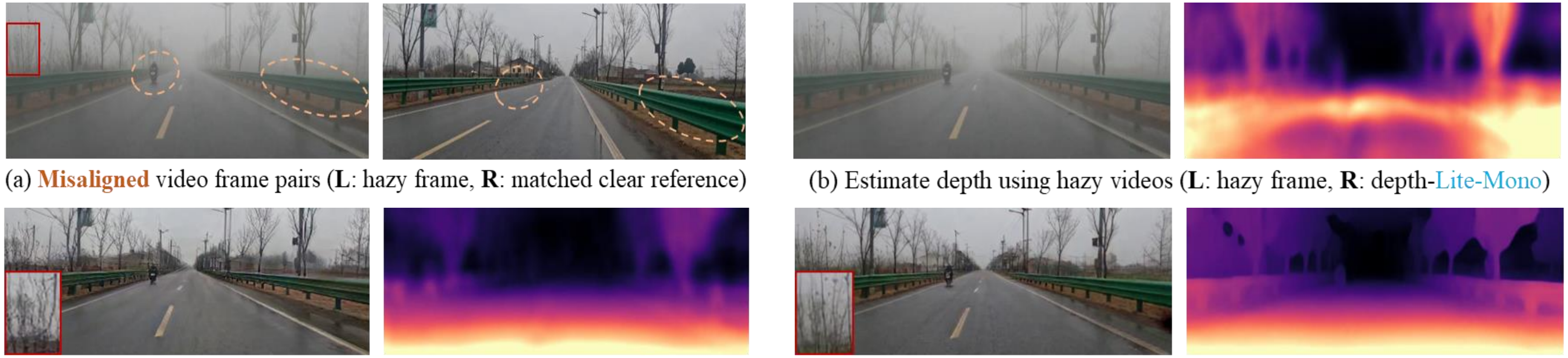
L: MAP-Net dehazing results on real-world scenes, R: Inference time comparison.

Motivation

- Obtaining clear RGB and accurate dense depth ground truth is challenging in real-world hazy scenes.

- Self-supervised depth estimation and physics-based dehazing are inherently complementary in real-world hazy scenes.

$$
\begin{cases}
I_t(x) = J_t(x)e^{-\beta \mathbf{d(x)}} + A_\infty(1 - e^{-\beta \mathbf{d(x)}}) \\
J_t(x) = \mathcal{S}(J_s, y), y \sim KP_{x \to y}\mathbf{d(x)}K^{-1}x
\end{cases}
$$



(a) Misaligned video frame pairs (**L**: hazy frame, **R**: matched clear reference)

(b) Estimate depth using hazy videos (**L**: hazy frame, **R**: depth-Lite-Mono)

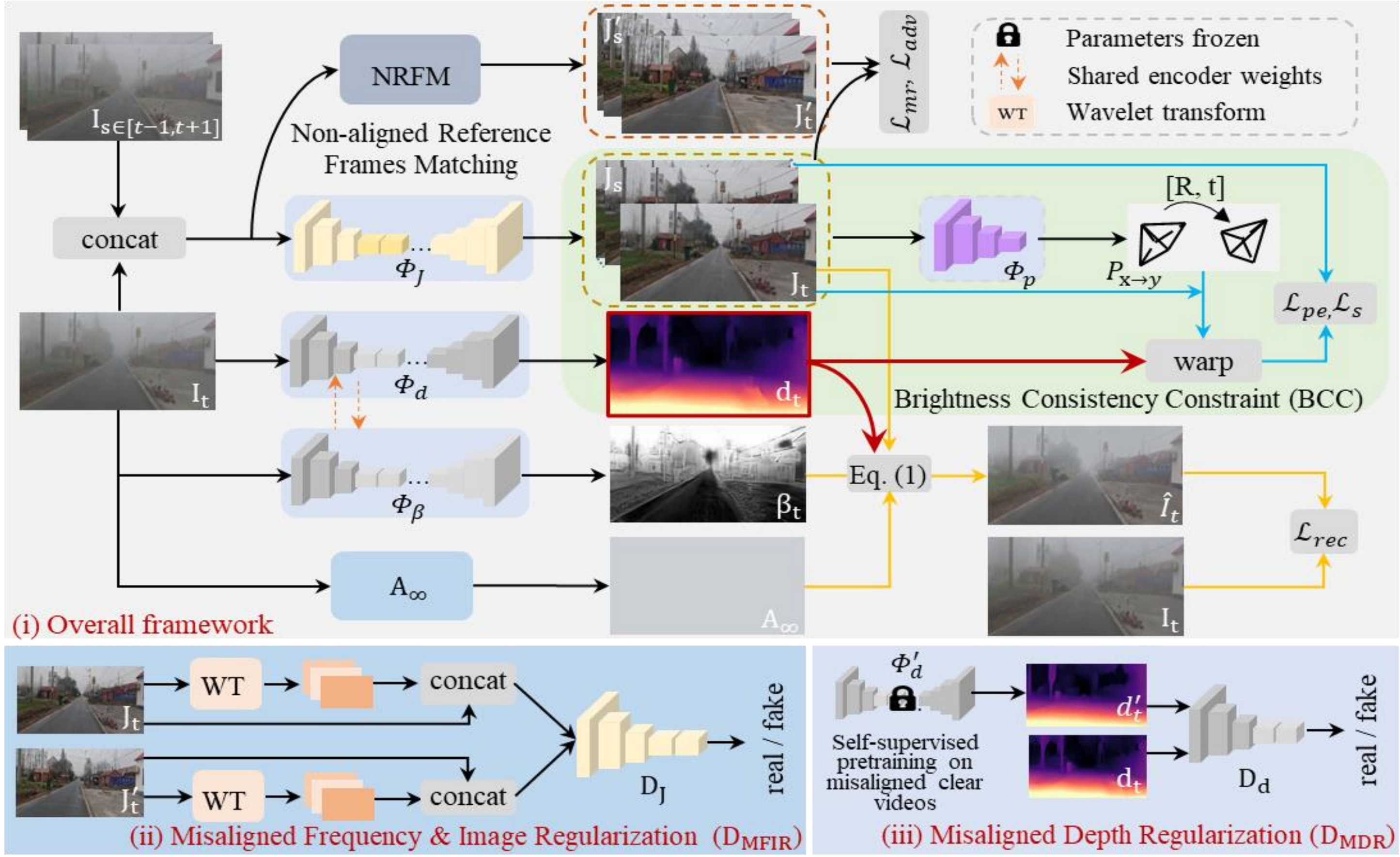
(c) Dehaze first, then estimate depth (**L**: dehazed-DVD, **R**: depth-Lite-Mono)

(d) Simultaneously dehaze and estimate depth (**L**: dehazed, **R**: depth) (Ours)

Comparison of different dehazing and depth estimation methods.

Depth-Centric Learning (DCL)

- We propose a novel Depth-Centric Learning (DCL) framework to simultaneously remove haze and estimate depth from real-world hazy videos.



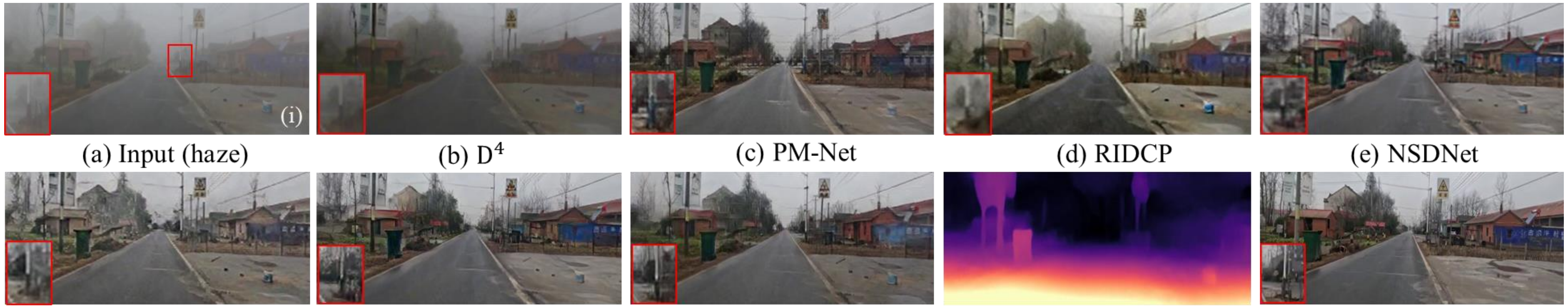
The pipeline of our Depth-Centric Learning (DCL) framework.

Quantitative Results

Quantitative dehazing results on three real hazy video datasets

Data Settings	Methods	Data Type	GoProHazy FADE ↓	GoProHazy NIQE ↓	DrivingHazy FADE ↓	DrivingHazy NIQE ↓	InternetHazy FADE ↓	InternetHazy NIQE ↓	Params (M)	FLOPs (G)	Inf. time (S)	Ref.
Unpaired	DCP	Image	1.0415	7.4165	1.1260	7.4455	0.9229	7.4899	-	-	1.39	CVPR'09
	RefineNet	Image	1.1454	6.1837	1.0223	6.5959	0.8535	6.7142	11.38	75.41	0.105	TIP'21
	CDD-GAN	Image	0.7797	6.0691	1.0072	6.1968	0.8166	6.1969	29.27	56.89	0.082	ECCV'22
	D^4	Image	1.5618	6.9302	0.9556	7.0448	0.6913	7.0754	**10.70**	**2.25**	0.078	CVPR'22
Paired	PSD	Image	0.9081	6.7996	0.9479	6.3381	0.8100	6.1401	33.11	182.5	0.084	CVPR'21
	RIDCP	Image	0.7250	5.2559	0.9187	5.3063	0.6564	5.4299	28.72	182.69	0.720	CVPR'23
	PM-Net	Video	0.7559	4.6274	1.0509	4.8447	0.7696	5.0182	151.20	5.22	0.277	ACMM'22
	MAP-Net	Video	0.7805	4.8189	1.0992	4.7564	1.0595	5.5213	28.80	8.21	0.668	CVPR'23
Non-aligned	NSDNet	Image	0.7197	6.1026	0.8670	6.3558	0.6595	4.3144	11.38	56.86	**0.075**	arXiv'23
	DVD	Video	0.7061	4.4473	0.7739	4.4820	0.6235	4.5758	15.37	73.12	0.488	CVPR'24
	DCL (Ours)	Video	**0.6914**	**3.4412**	**0.7380**	**3.5329**	**0.6203**	**3.5545**	11.38	56.86	**0.075**	-

Comparisons of video dehazing performance on GoProHazy dataset



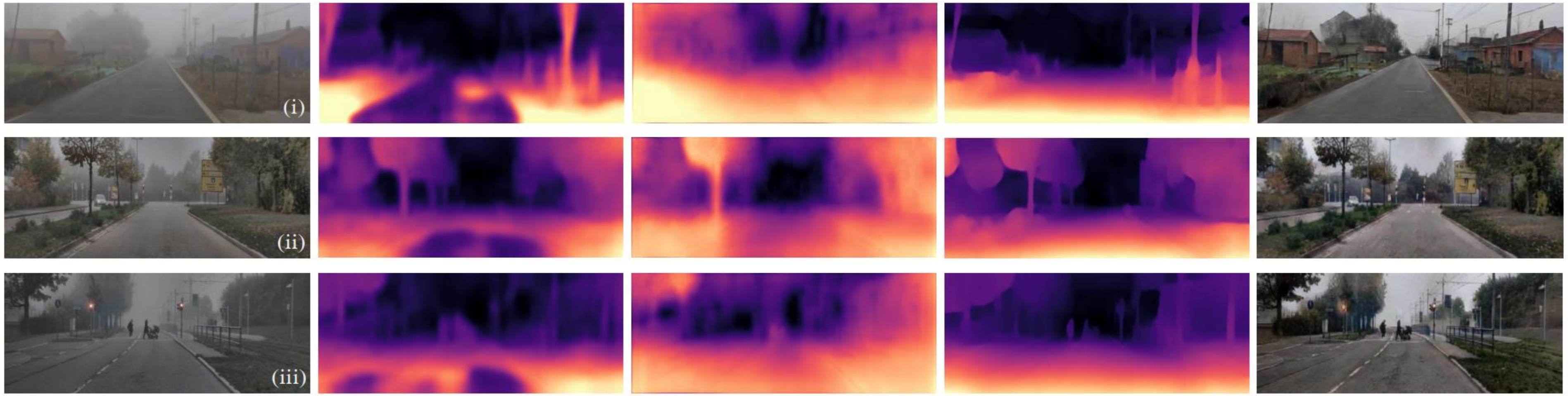
(a) Input (haze) (b) D^4 (c) PM-Net (d) RIDCP (e) NSDNet
(f) MAP-Net (g) DVD (h) Ours (dehaze) (i) Ours (depth) (j) Reference

Quantitative Results

- Quantitative depth estimation results on DENSE-Fog dataset

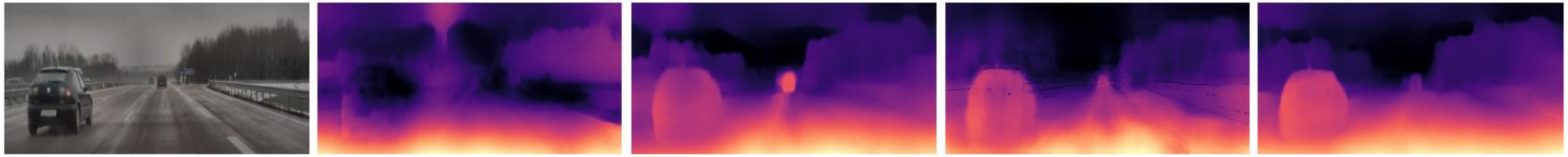
Method	DENSE-Fog (light)					DENSE-Fog (dense)					Params (M)	FLOPs (G)	Inf. time (S)	Ref.
	abs Rel↓	RMSE log↓	δ_1↑	δ_2↑	δ_3↑	abs Rel↓	RMSE log↓	δ_1↑	δ_2↑	δ_3↑				
MonoDepth2	0.418	0.475	0.499	0.735	0.847	1.045	0.632	0.530	0.771	0.864	14.3	8.0	**0.009**	ICCV'19
MonoViT	0.393	0.454	0.464	0.728	0.858	0.992	0.611	0.512	0.779	0.876	78.0	15.0	0.045	3DV'22
Lite-Mono	0.417	0.473	0.402	0.687	0.853	0.954	0.604	0.469	0.756	0.886	**3.1**	**5.1**	0.013	CVPR'23
RobustDepth	0.316	0.370	0.611	0.828	0.913	**0.605**	**0.515**	0.563	0.798	0.881	14.3	8.0	**0.009**	ICCV'23
Mono-ViFI	0.369	0.459	0.408	0.704	0.864	0.609	0.528	0.489	0.771	0.883	14.3	8.0	**0.009**	ECCV'24
DCL (Ours)	**0.311**	**0.364**	**0.623**	**0.839**	**0.920**	1.182	0.596	**0.612**	**0.829**	**0.900**	14.3	8.0	**0.009**	-

- Visual results on GoProHazy (i) and DENSE-Fog (ii-dense, iii-light).



(a) Input (haze) (b) MonoViT (c) Mono-ViFI (d) Ours (depth) (e) Ours (dehaze)

Ablation Study

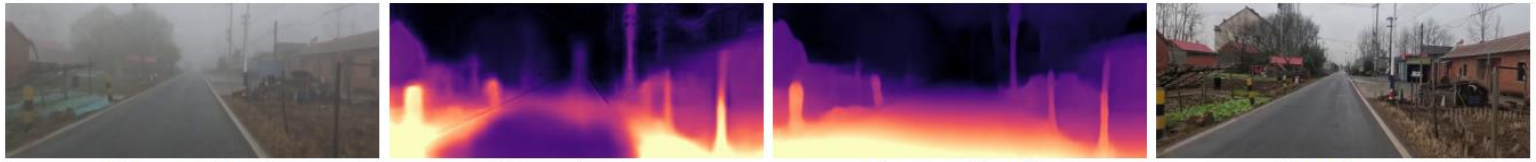


(a) Input (haze) (b) w/o BCC (c) w/o D_{MFIR} (d) w/o D_{MDR} (e) DCL (Ours)

Ablation visualization of BCC, D_{MFIR} and D_{MDR} on DENSE-Fog (light)

Method	BCC	D_{MFIR}	D_{MDR}	Abs Real↓	RMSE log↓	δ_1↑
DCL w/o BCC		✓	✓	0.636	0.569	0.439
DCL w/o D_{MFIR}	✓		✓	0.320	0.366	0.621
DCL w/o D_{MDR}	✓	✓		0.340	0.392	0.562
DCL (Ours)	✓	✓	✓	**0.311**	**0.364**	**0.623**

Ablation study on DENSE-Fog (light)



(a) Input (haze) (b) wo/D_{MDR} (c) Ours (depth) (d) Reference

(a) Input (haze) (b) wo/D_{MFIR} (c) Ours (dehaze) (d) Reference

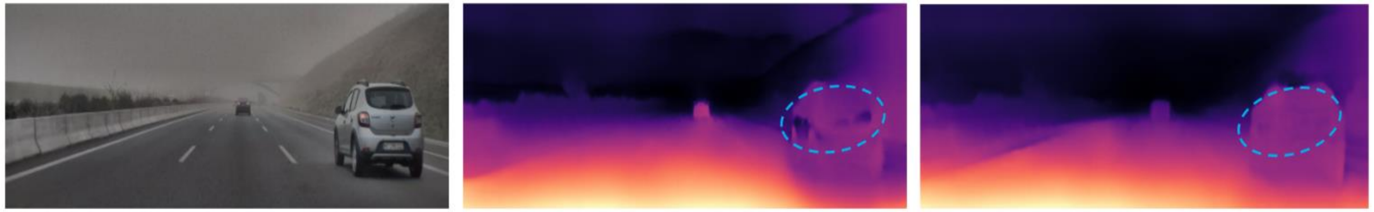
Ablation visualizations of D_{MFIR} and D_{MDR} are shown respectively on the depth and dehaze results from the GoProHazy dataset.

Ablation Study

Method	$\mathcal{L}_{pe}$	$\mathcal{L}_{s}$	$\mathcal{L}_{rec}$	FADE↓	NIQE↓
DCL w/o $\mathcal{L}_{pe}$		✓	✓	0.6959	3.4785
DCL w/o $\mathcal{L}_{s}$	✓		✓	0.8163	3.5973
DCL w/o $\mathcal{L}_{rec}$	✓	✓		0.7581	3.7030
DCL (Ours)	✓	✓	✓	**0.6914**	**3.4412**

Ablation studies on different losses on GoProHazy

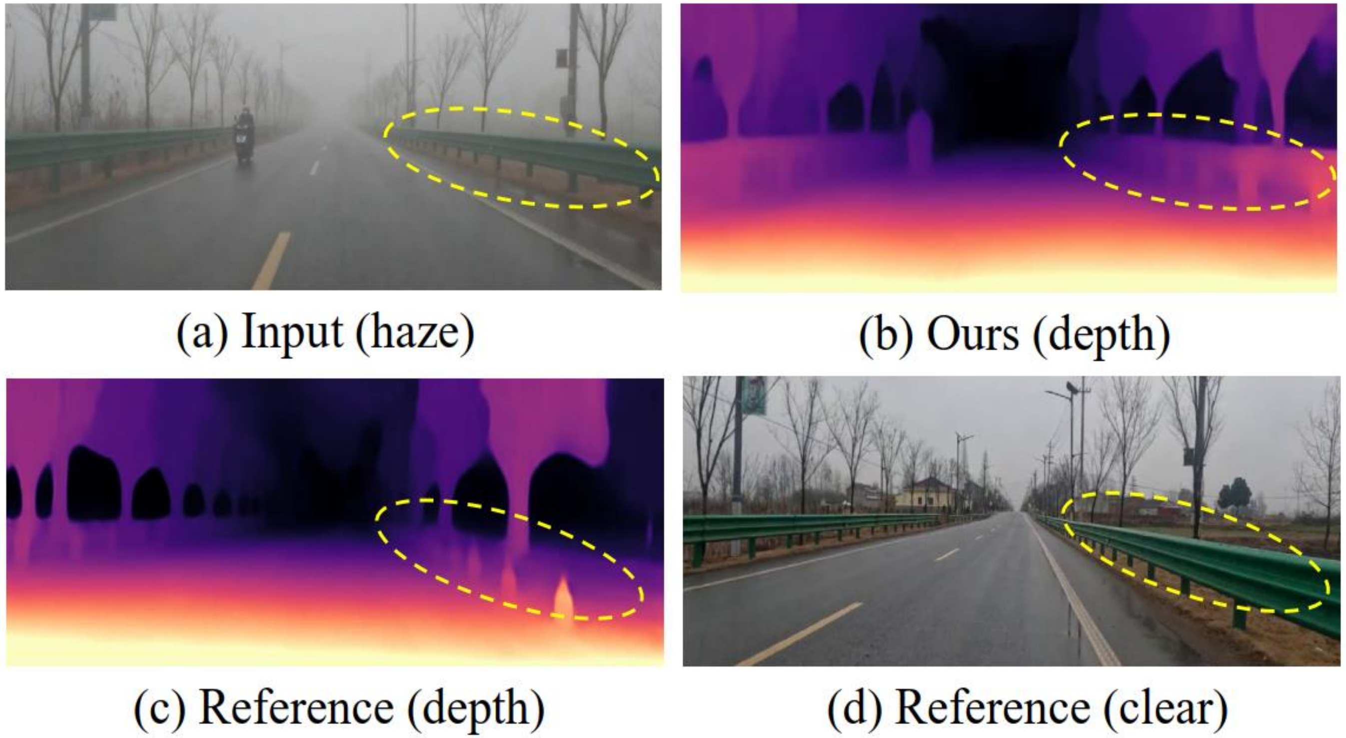
Shape of β	Type	Abs Rel↓	RMSE log↓	δ_1↑
(1, 1, 1)	Constant	0.325	0.371	0.621
(1, 192, 640) (Ours)	Non-uniform	**0.311**	**0.364**	**0.623**



(a) Input (haze) (b) Constant β (depth) (c) Ours (depth)

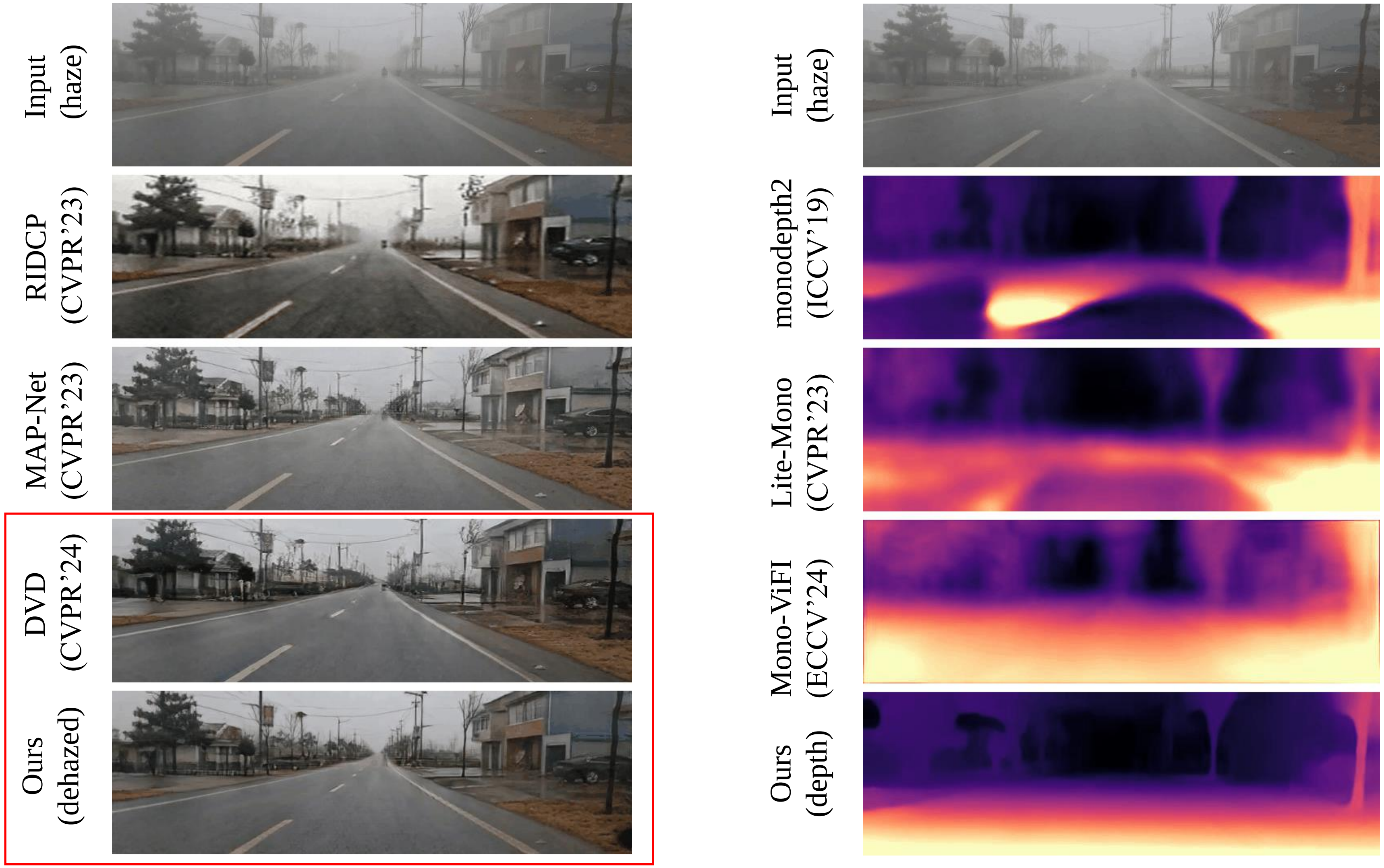
Comparison of depth estimation across different β types on DENSE-Fog (light)

Discussion



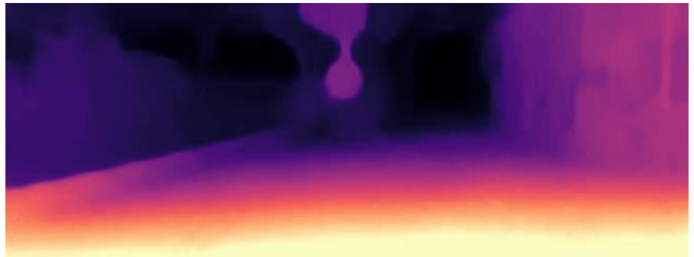
Visualizing the gains brought by ASM constraints to depth estimation.

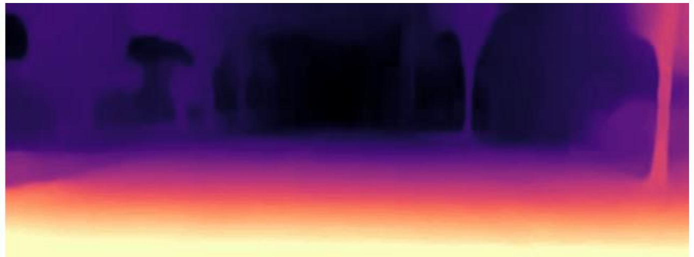
Video Demo


Input (haze)
RIDCP (CVPR’23)
MAP-Net (CVPR’23)
DVD (CVPR’24)
Ours (dehazed)
Input (haze)
monodepth2 (ICCV’19)
Lite-Mono (CVPR’23)
Mono-ViFI (ECCV’24)
Ours (depth)

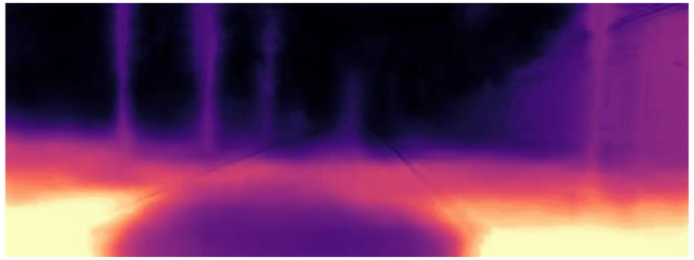
Video Demo

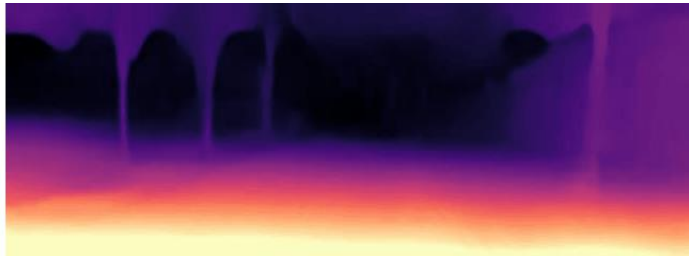

Input (haze)


wo / BCC


Ours (depth)


Input (haze)


wo / D_{MDR}


Ours (depth)


Input (haze)


wo / D_{MFIR}


Ours (dehaze)

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Thank you！

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