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Simulating Dual-Pixel Images From Ray Tracing For Depth Estimation

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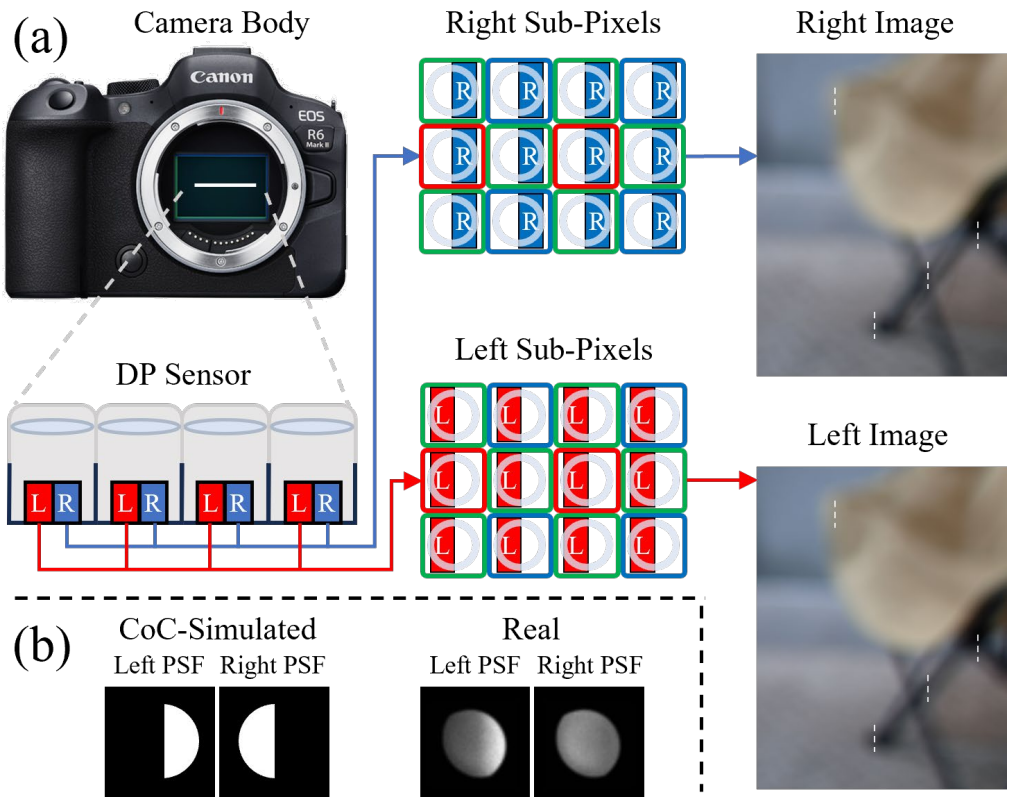
Github Website Wechat

Motivation



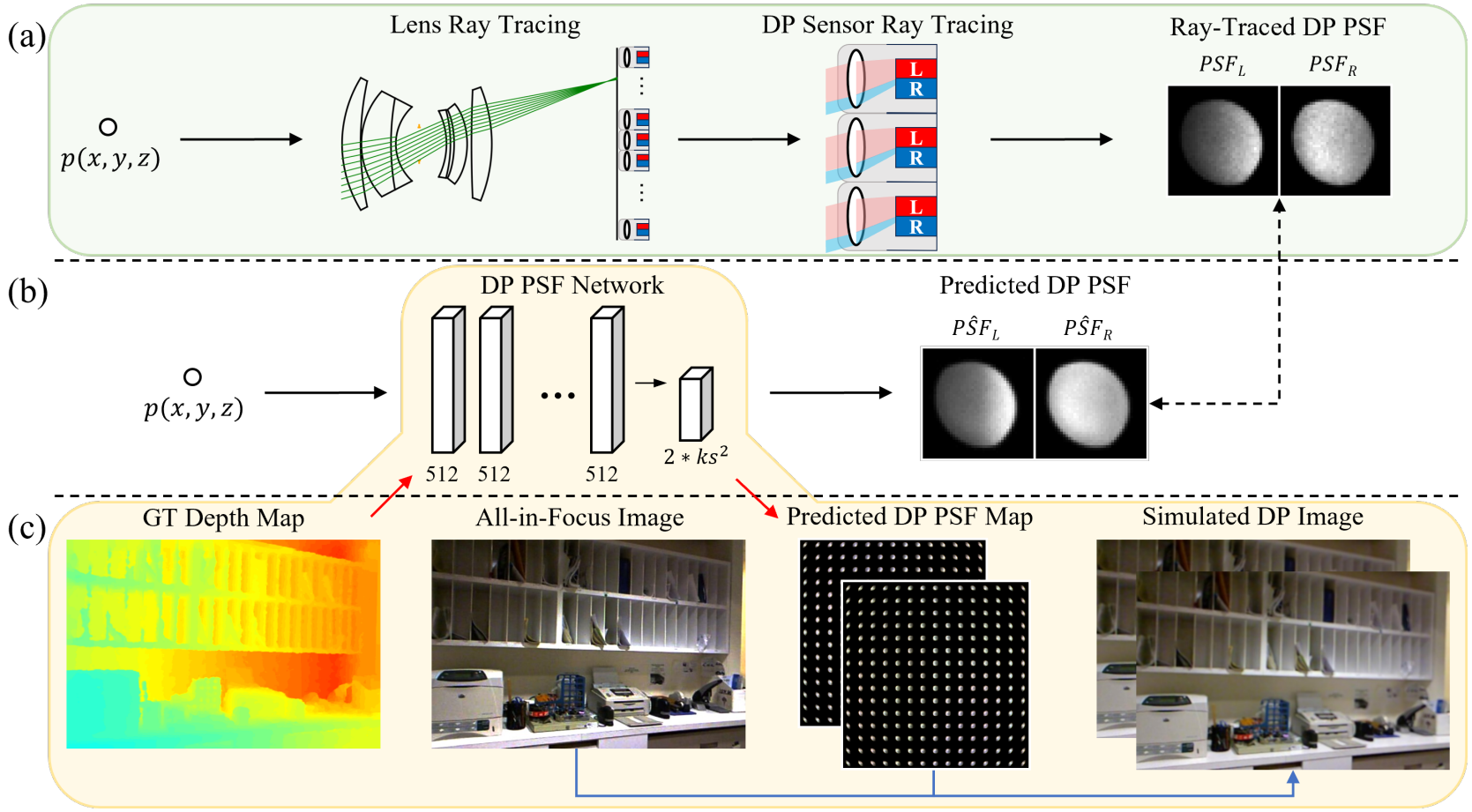
- Dual-Pixel (DP) images are valuable for depth estimation, autofocus, and deblurring (Fig. a).
- However, DP disparity varies across cameras and settings, making real DP-depth paired data difficult to obtain.
- Some methods simulate DP images from RGB-D data to alleviate this, but the results often lack realism (Fig. b).
- **Sdirt** addresses this by using ray tracing to produce realistic DP simulations, significantly reducing the domain gap.

Contributions

Our contributions are fourfold:

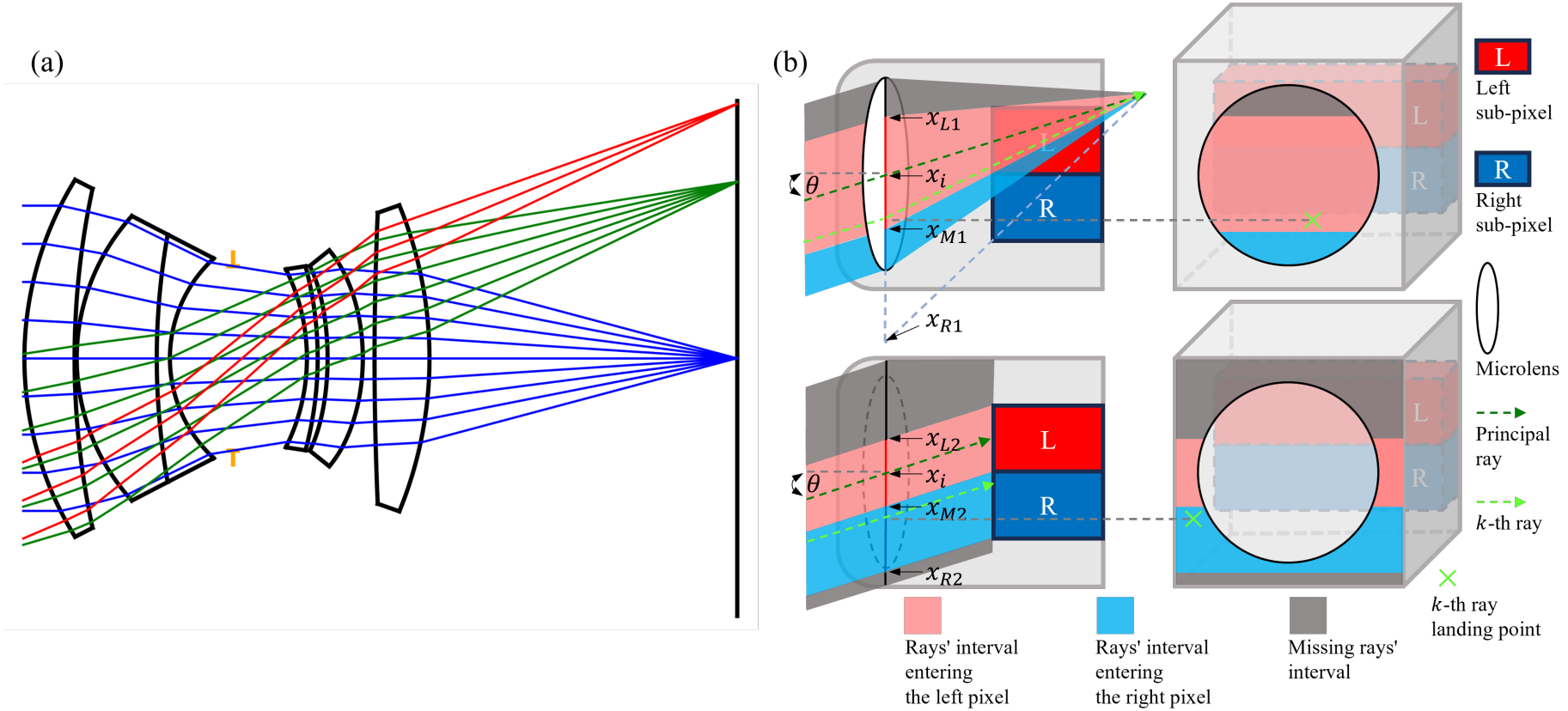
- We propose a ray-traced DP PSF simulator that computes spatially varying DP PSFs, addressing the domain gap between simulated and real DP PSFs caused by lens aberrations and sensor phase splitting.
- We propose a pixel-wise DP image rendering module that uses an MLP to predict the DP PSF for each pixel, narrowing the gap between simulated and real DP images.
- Depth estimation results show that the DfDP model trained on Sdirt generalizes better to real DP images.
- We collected DP119, a real DP-depth paired test set with an open lens structure and fixed focus, featuring diverse real-world scenes.

Method



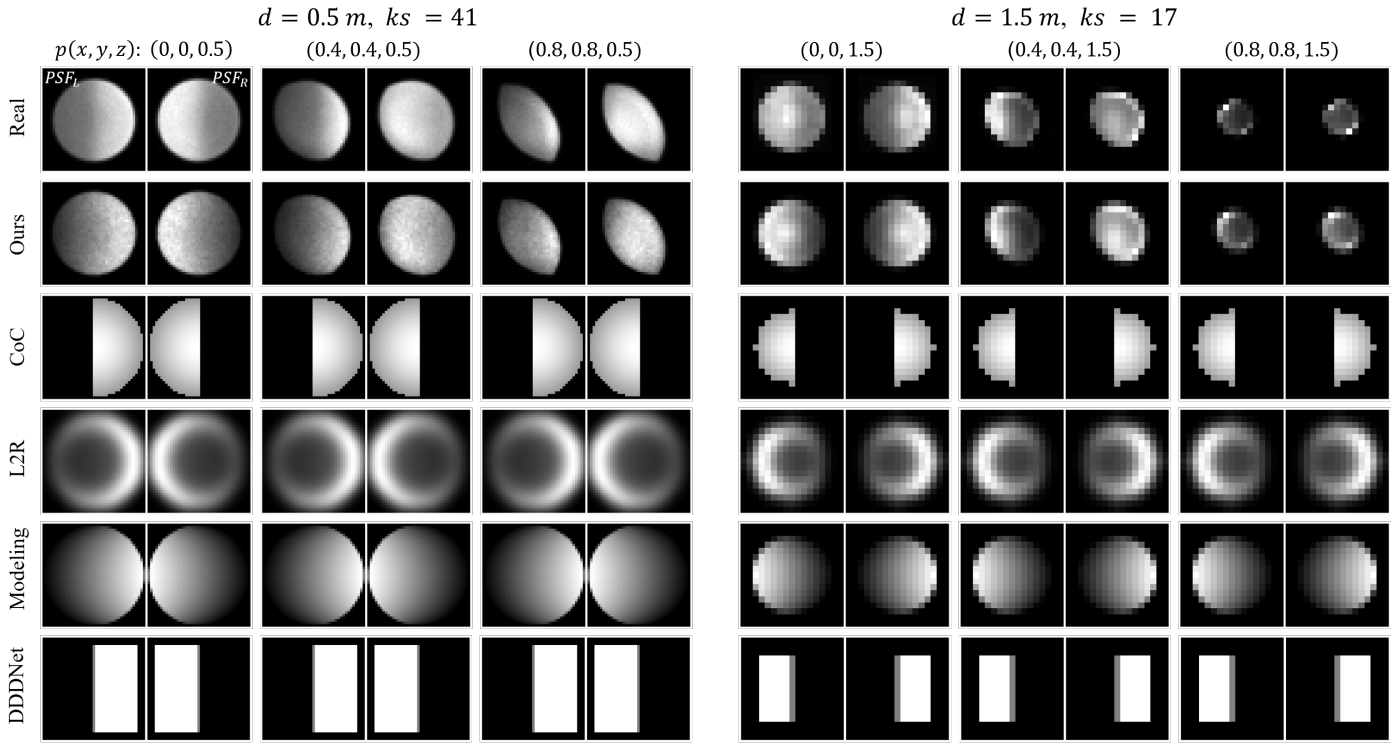
Simulating Dual-Pixel Images from Ray Tracing pipeline. (a) Ray-traced DP PSF simulator. (b) DP PSF prediction network. (c) Pixel-wise DP image rendering module.

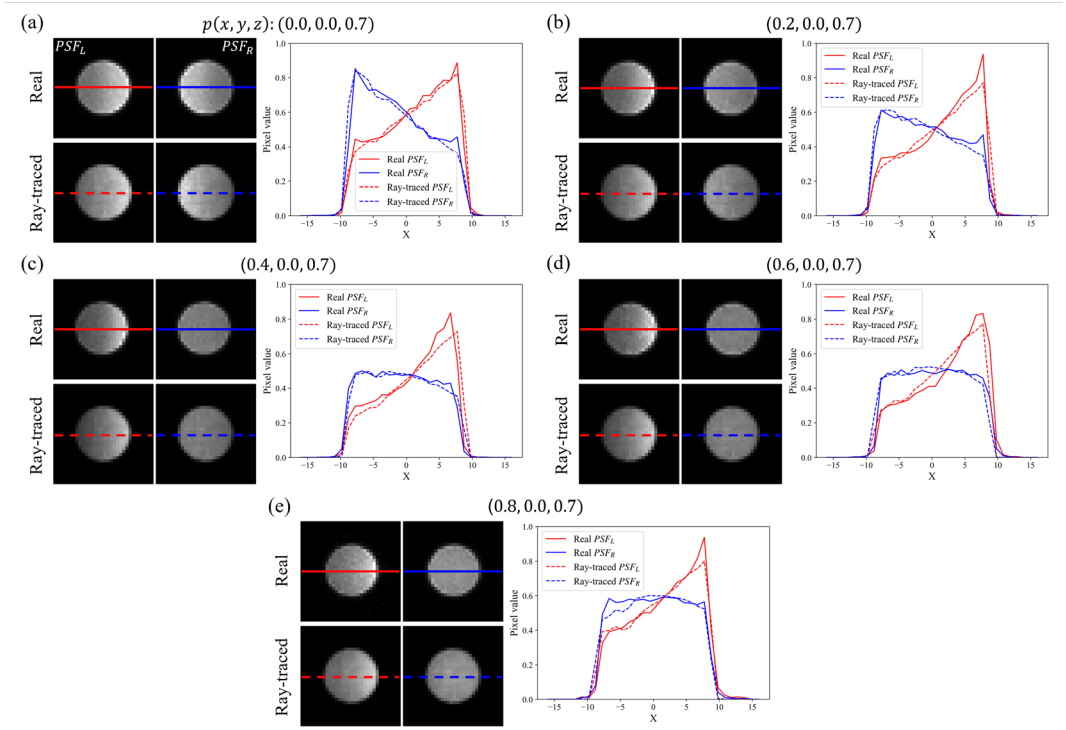
Method



Overview of ray tracing on the lens and DP sensor. (a) Ray tracing on the lens. (b) Ray tracing on the DP sensor.

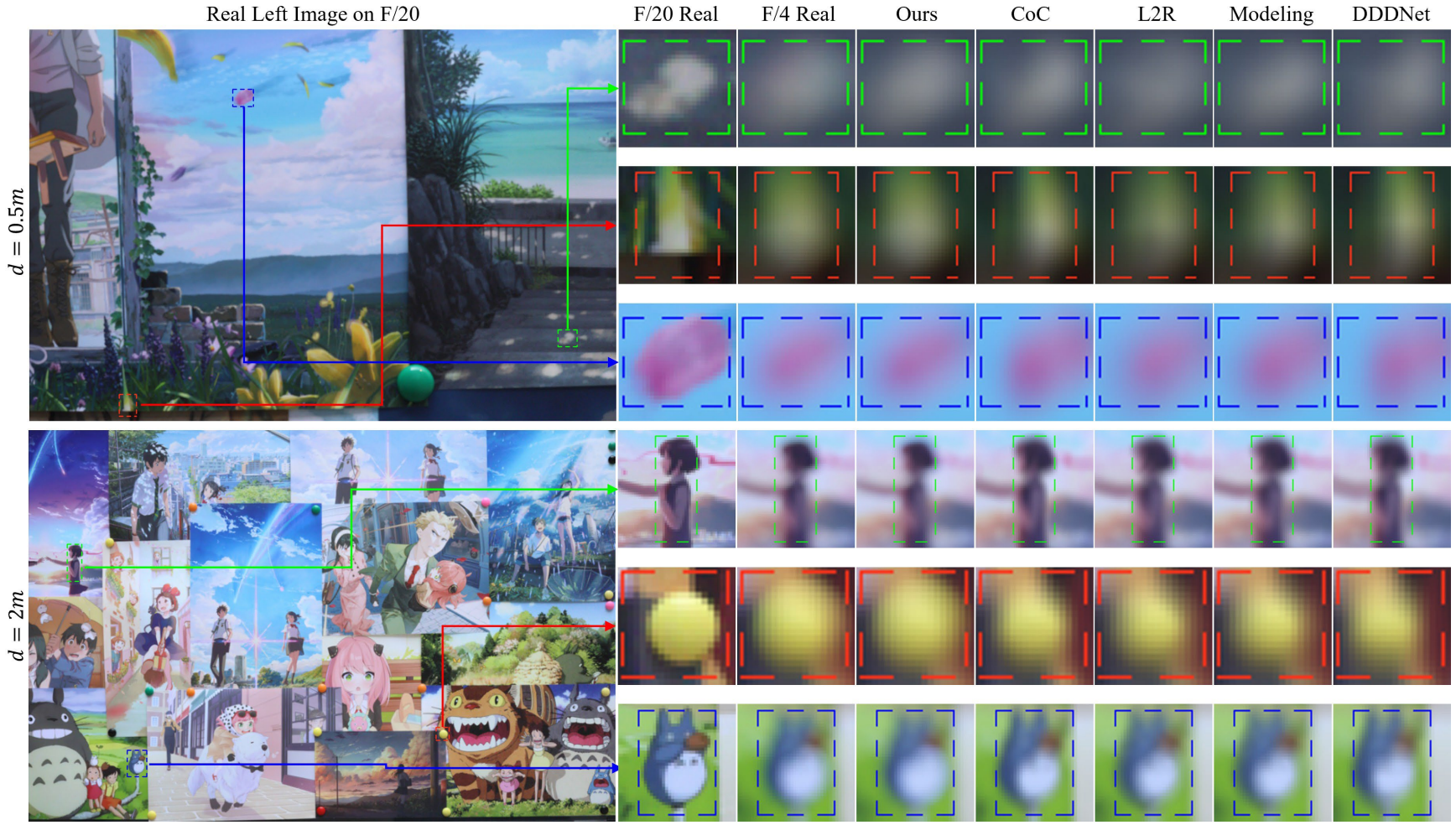
Experiments & Results





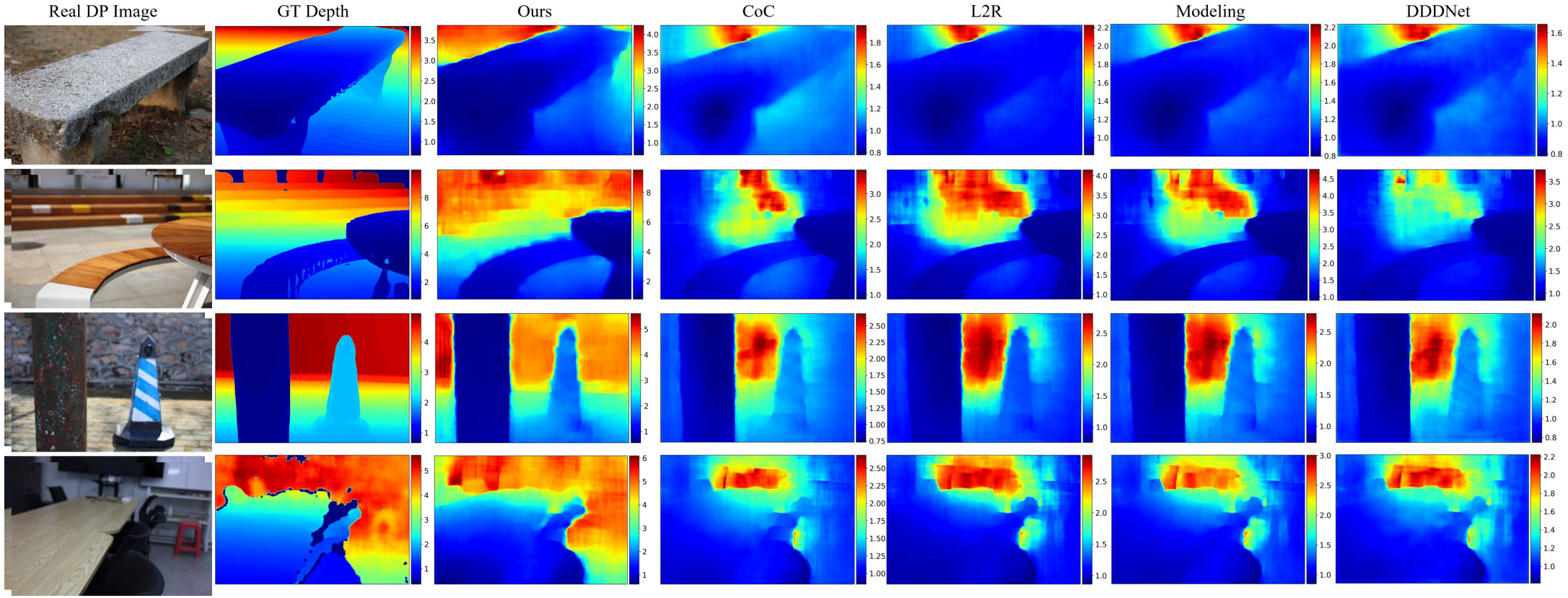
Qualitative results of simulated DP PSFs.

Experiments & Results



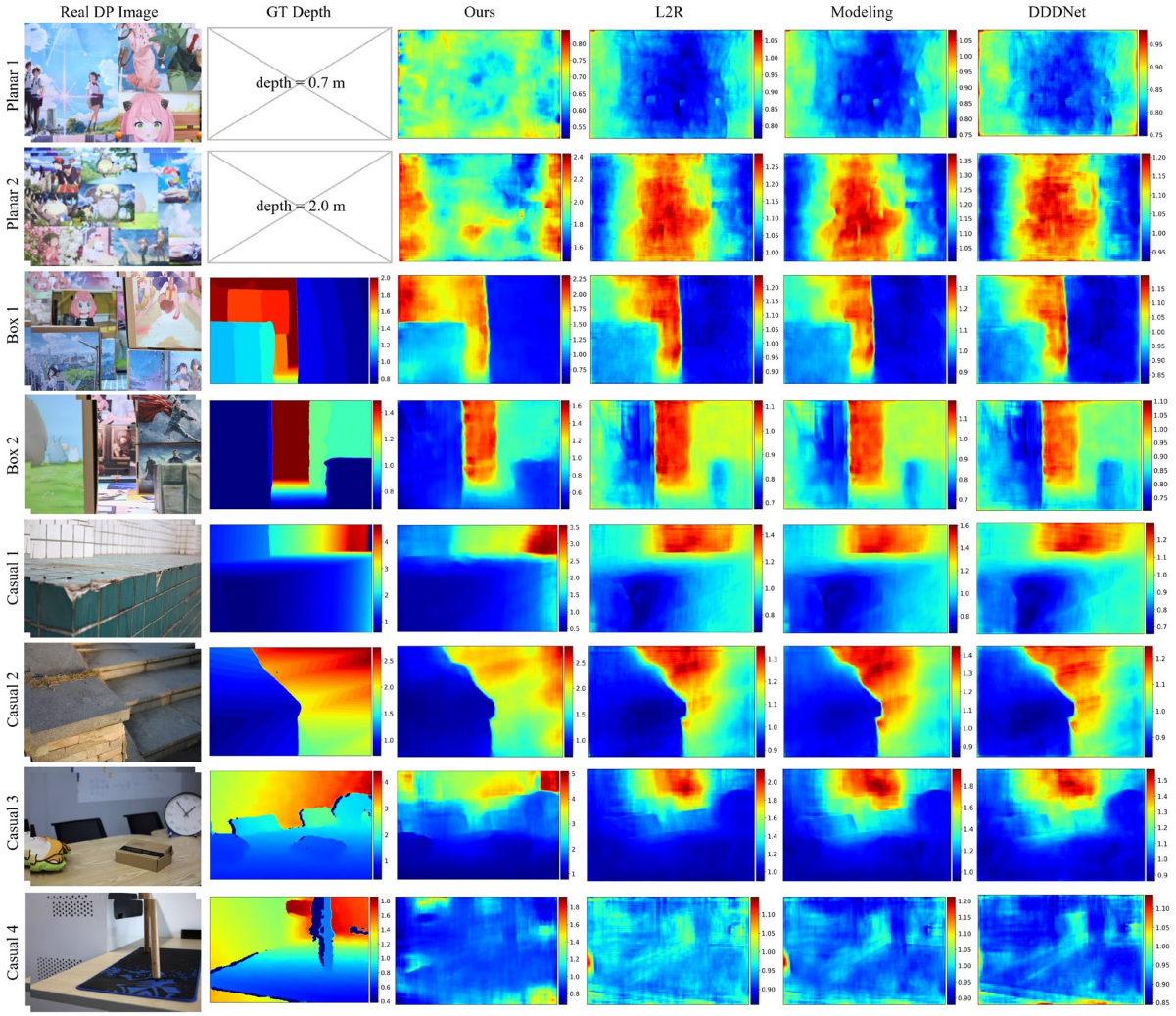
Qualitative results of simulated DP images.

Experiments & Results



Qualitative results of absolute depth estimation.

Experiments & Results



Scene	Method	MAE↓	MSE↓	Abs.r.↓	Sq.r.↓	Acc-1↑	Acc-2↑
Planar	Ours	**0.0845**	**0.0109**	**0.0871**	**0.0095**	**0.9849**	**0.9997**
	CoC	0.2085	0.1001	0.1801	0.0659	0.6670	0.8990
	L2R [2]	0.2418	0.1271	0.2112	0.0841	0.6319	0.8536
	Modeling [26]	0.2284	0.1142	0.2004	0.0766	0.6496	0.8725
	DDDNet [23]	0.2583	0.1485	0.2191	0.0958	0.5648	0.8089
Box	Ours	**0.1197**	**0.0339**	**0.0906**	**0.0231**	**0.9474**	**0.9812**
	CoC	0.3375	0.1804	0.2442	0.1116	0.4412	0.8277
	L2R [2]	0.3866	0.2284	0.2803	0.1412	0.3651	0.7156
	Modeling [26]	0.3655	0.2055	0.2660	0.1278	0.3907	0.7758
	DDDNet [23]	0.4177	0.2676	0.2975	0.1636	0.3456	0.6274
Casual	Ours	**0.2702**	**0.2294**	**0.4632**	0.7241	**0.8236**	**0.9314**
	CoC	0.7925	1.8579	0.5461	0.6821	0.3318	0.6103
	L2R [2]	0.8170	1.7487	0.5597	0.6719	0.2760	0.5315
	Modeling [26]	0.7934	1.7256	0.5510	**0.6655**	0.2978	0.5732
	DDDNet [23]	0.8931	2.0624	0.5752	0.7135	0.2481	0.4685

Qualitative & quantitative results of absolute depth estimation.

Conclusion

Simulated DP images help address the scarcity of DP-depth paired data but face a domain gap between simulated and real DP data.

In this work, we propose a novel simulation framework called Sdirt to bridge this gap.

Specifically, we calculate the DP PSF for points in object space using ray tracing, and employ a network to predict them.

Then, we render DP images based on the predicted DP PSFs.

Experimental results show that the proposed Sdirt can simulate more realistic DP data.

Moreover, depth estimation models trained based on Sdirt generalize better to real DP images.

Contact

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- BibTeX:

QR code :
Github/Website

```
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   title={Simulating Dual-Pixel Images From Ray Tracing For Depth Estimation},
   author={He, Fengchen and Zhao, Dayang and Xu, Hao and Quan, Tingwei and Zeng, Shaoqun},
   journal={arXiv preprint arXiv:2503.11213},
   year={2025}
}
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