Reflection Removal Using a Dual-Pixel Sensor

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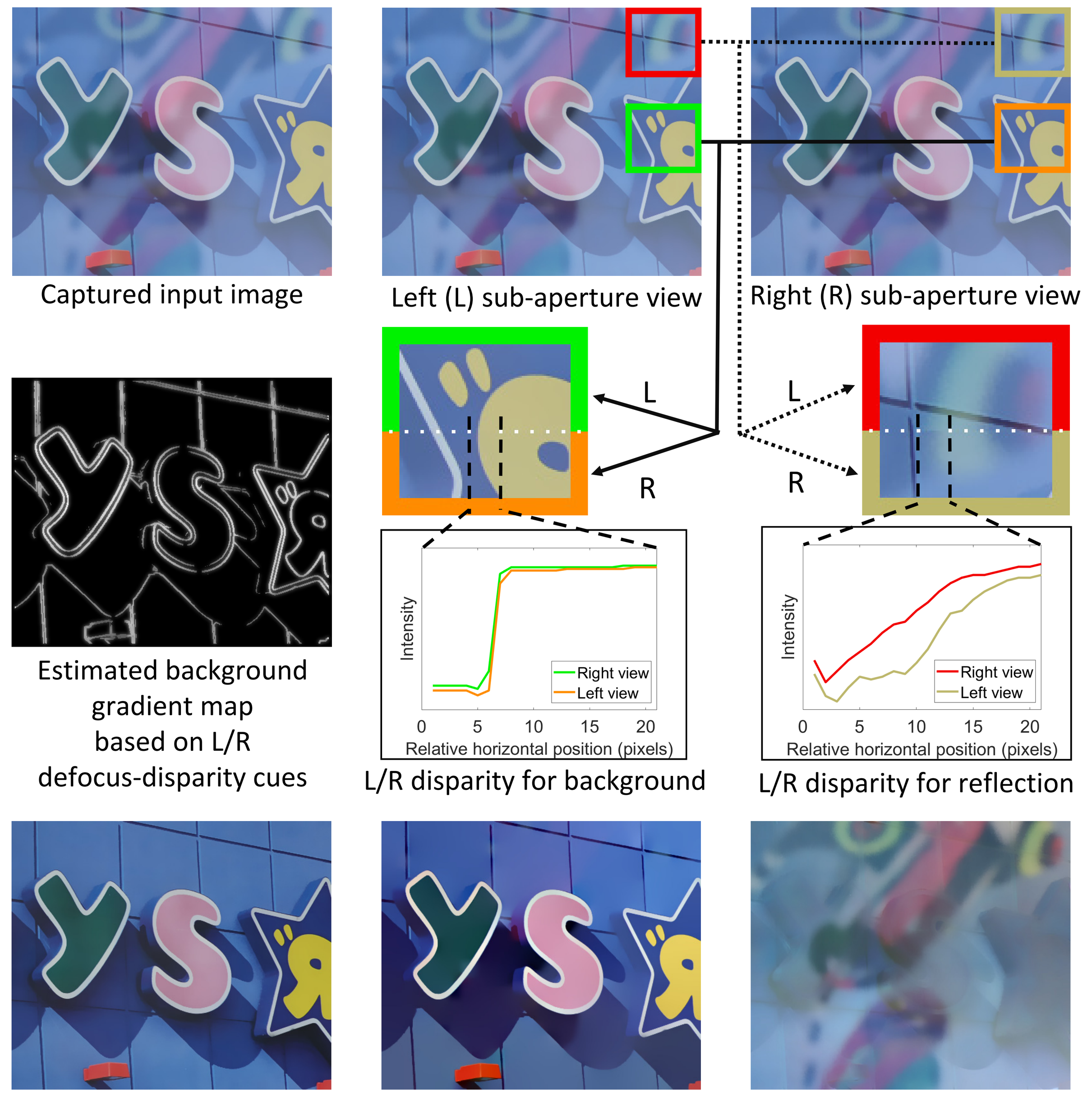
Our reflection removal method using a dual-pixel sensor

We show that the dual-pixel (DP) sensor, present on most modern cameras, can greatly simplify the task of reflection removal.

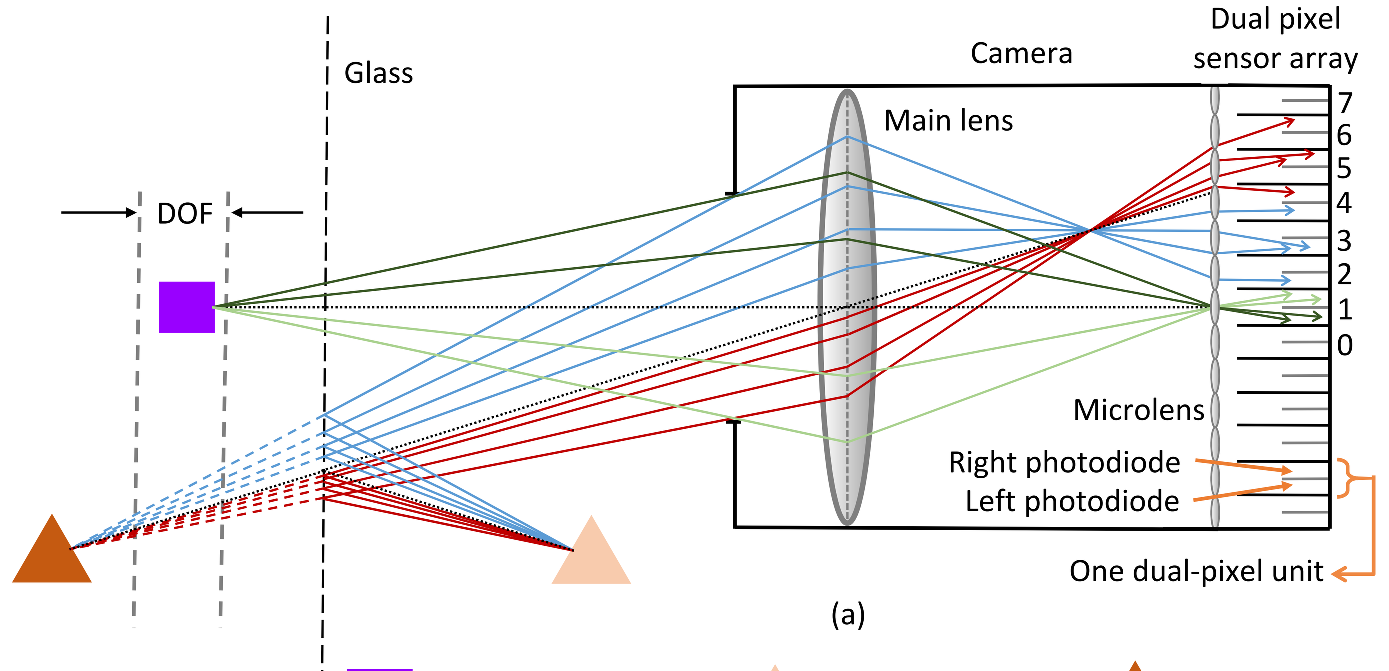
The DP sensor furnishes *two* sub-aperture views of the scene from a *single* captured image.

Our method exploits "defocus-disparity" cues in these two sub-aperture views to detect gradients corresponding to the in-focus background and incorporate them into an optimization framework to recover the desired background layer.

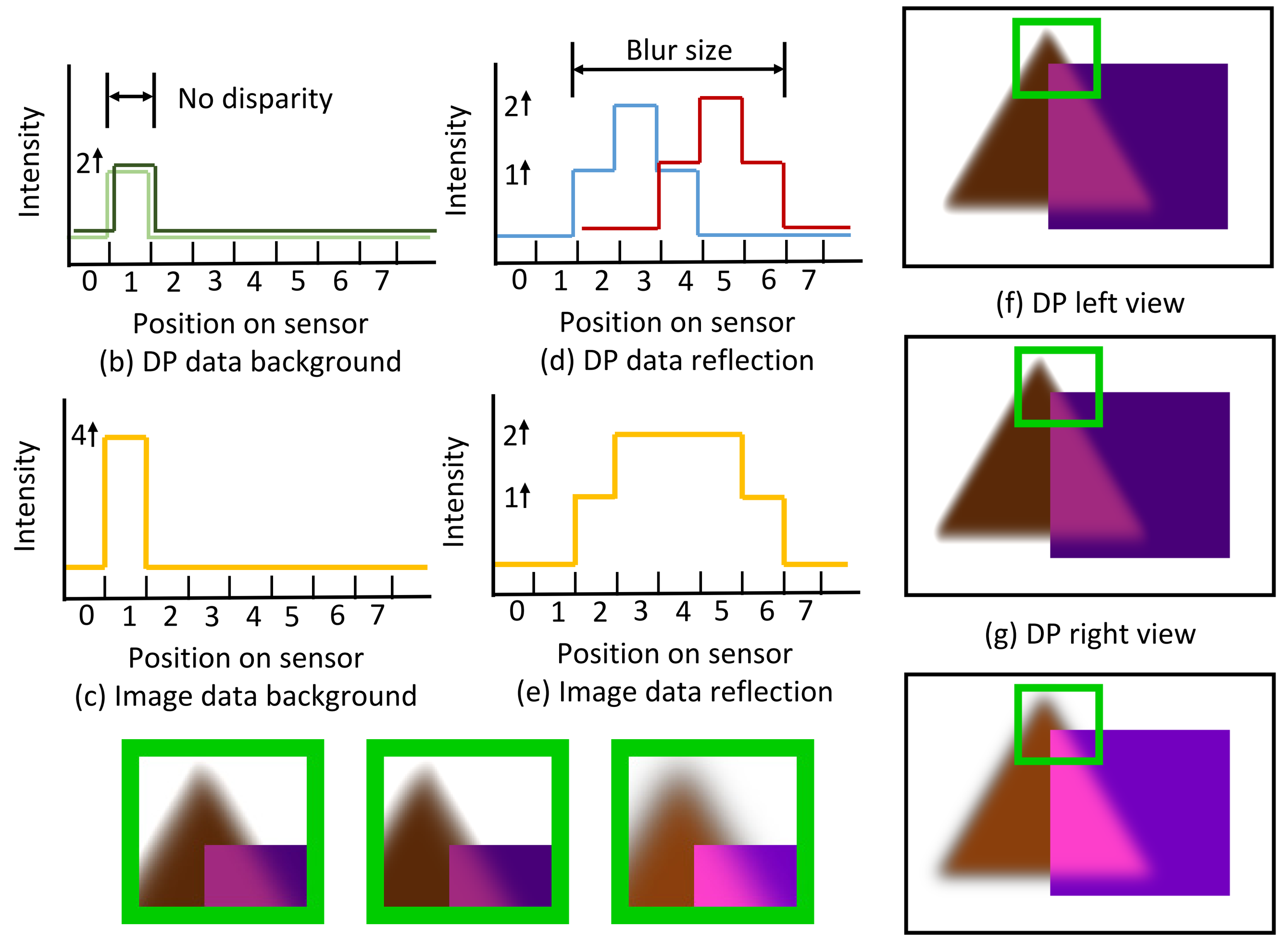


Captured input image
Left (L) sub-aperture view
Right (R) sub-aperture view
Estimated background gradient map based on L/R defocus-disparity cues
L/R disparity for background
L/R disparity for reflection
Ground truth background layer
Our estimated background layer
Our estimated reflection layer

Image formation model with dual-pixel sensor



(a)



(b) DP data background
(c) Image data background
(d) DP data reflection
(e) Image data reflection
(f) DP left view
(g) DP right view
(h) Observed image
(f+)
(g+)
(h+)

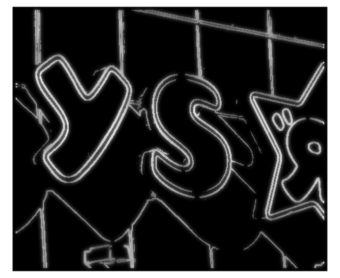
Sub-pixel disparity is estimated based on a quadratic fit to SSD values computed from the gradients of the two sub-aperture views [WG18].

Cost function

Hyper-Laplacian Gaussian

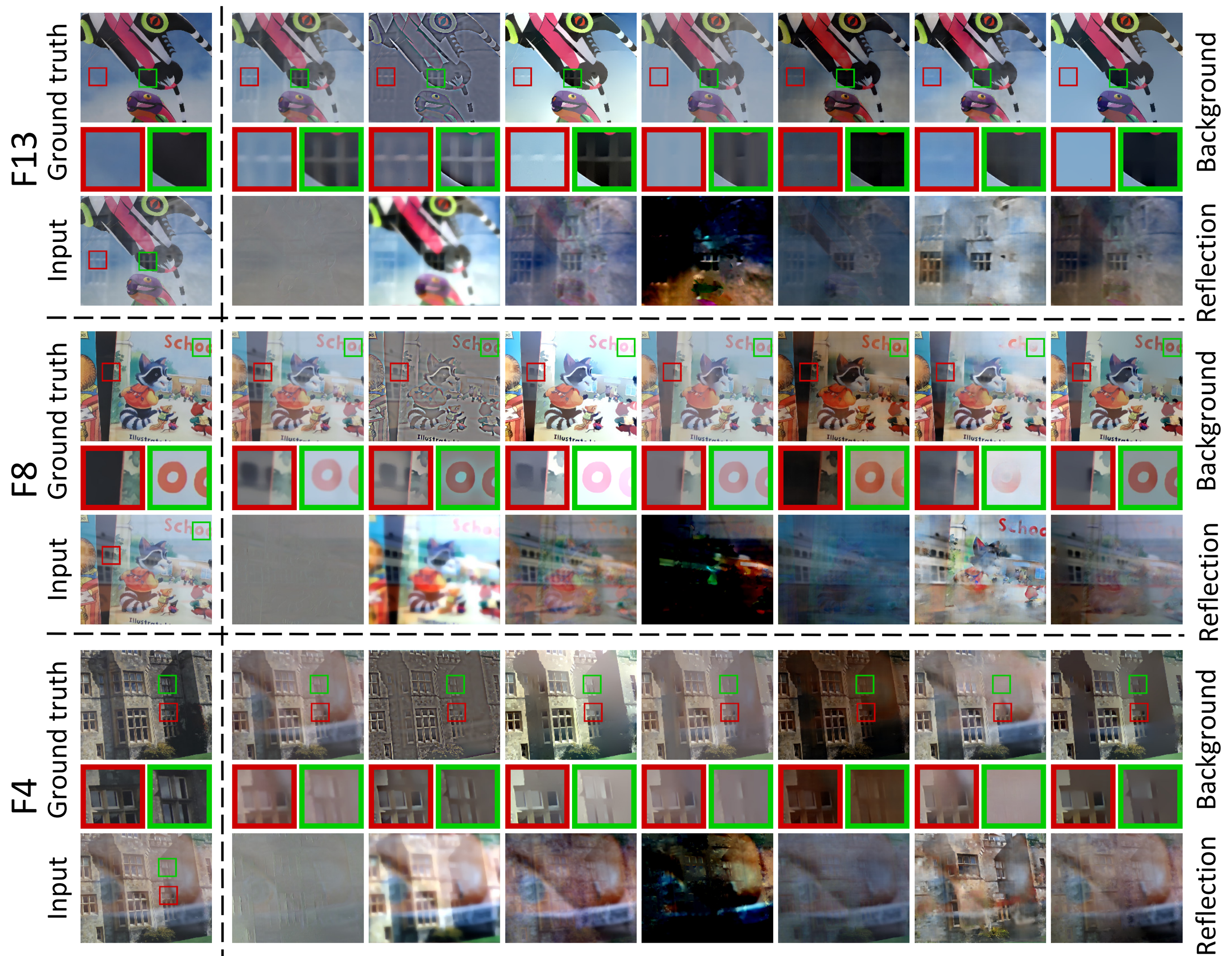
$$\arg\min_{\mathbf{b},\mathbf{r}} \left\{ ||\mathbf{Db}||_p^p + \lambda ||\mathbf{Dr}||_2^2 \right\}$$

$$\arg\min_{\mathbf{b}} \left\{ ||\mathbf{Db}||_p^p + \lambda ||\mathbf{CD}(\mathbf{g}-\mathbf{b})||_2^2 \right\}$$



Controlled dataset

6 backgrounds × 5 reflections × 5 aperture values = **150** images

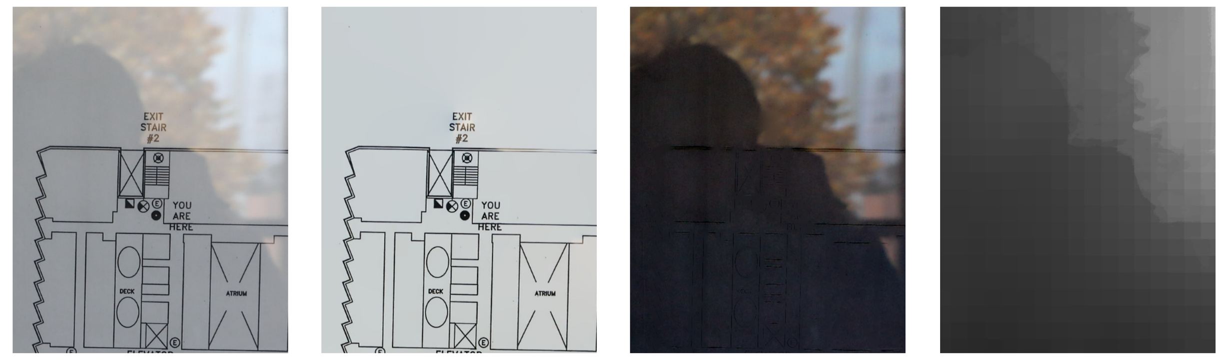


Method	PSNR (dB)	SSIM	sLMSE	NCC	SI
LB13	16.12	0.689	0.870	0.966	0.758
GC14	16.02	0.798	0.888	0.945	0.496
LB14	14.20	0.842	0.797	0.981	0.840
WS16	16.62	0.836	0.884	0.975	0.837
ZN18	15.57	0.797	0.867	0.979	0.818
YG18	16.49	0.832	0.871	0.978	0.847
Ours	**19.45**	**0.883**	**0.946**	**0.982**	**0.870**

Dataset and code

In-the-wild dataset

Extended capabilities: Depth map



Input image
Background
Reflection
Depth map of reflection layer

References

[WG18] Wadhwa et al., "Synthetic depth-of-field with a single-camera mobile phone", SIGGRAPH 2018.
[LB13] Y. Li and M. S. Brown, "Exploiting reflection change for automatic reflection removal", ICCV 2013.
[GC14] X. Guo et al., "Robust separation of reflection from multiple images", CVPR 2014.
[LB14] Y. Li and M. S. Brown, "Single image layer separation using relative smoothness", CVPR 2014.
[WS16] R. Wan et al., "Depth of field guided reflection removal", ICIP 2016.
[ZN18] X. Zhang et al., "Single image reflection separation with perceptual losses", CVPR 2018.
[YG18] J. Yang et al., "Seeing deeply and bidirectionally: A deep learning approach for single image reflection removal", ECCV 2018.