Reflection scene separation from a single image

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RISE
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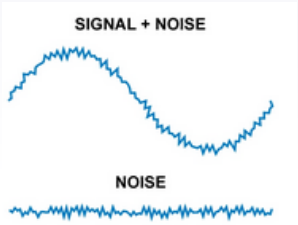
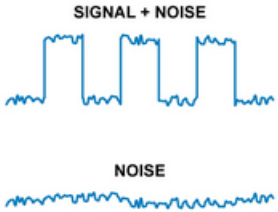
博 云 搜 索 实 验 室

What is noise?

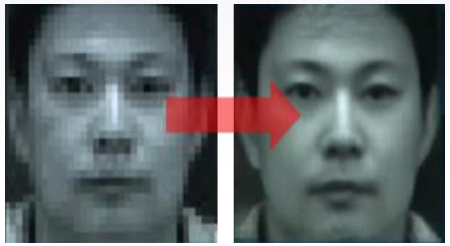
- Noise is an unwanted disturbance in an electrical signal



Analog signal



Digital signal



Super-resolution

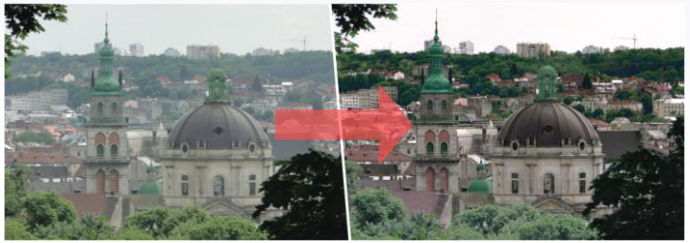
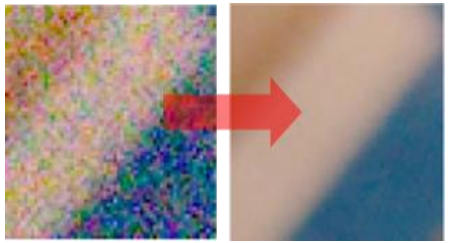


Image dehazing

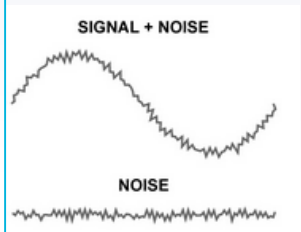


Denoising

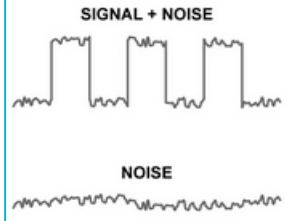
Reflection removal

What is noise?

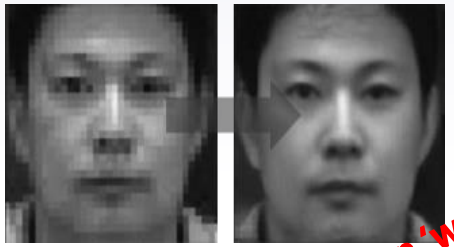
- Noise is an unwanted disturbance in an electrical signal



Analog signal



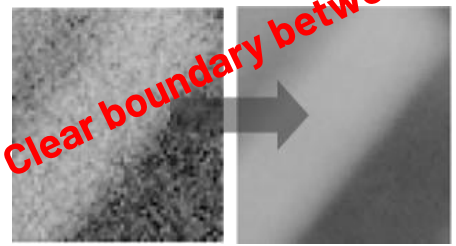
Digital signal



Super-resolution

Image dehazing

Clear boundary between 'wanted' and 'unwanted'

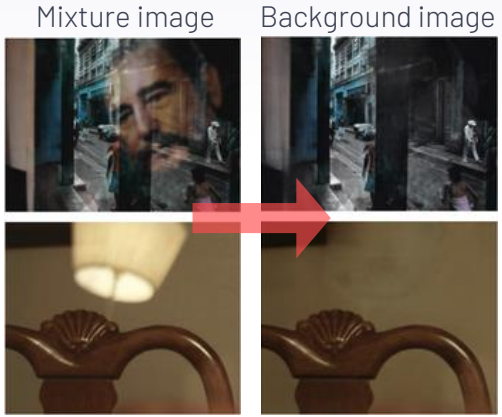


Denoising

Reflection removal

Is the reflection noise?

- The fuzzy boundary between “wanted” and “unwanted” for reflection



The reflection is the unwanted signal

Is the reflection noise?

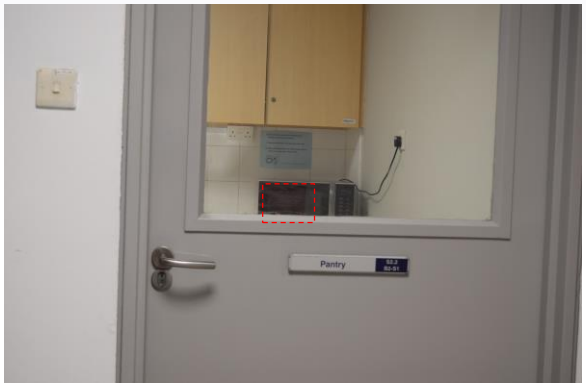
- The fuzzy boundary between “wanted” and “unwanted” for reflection

The reflection is the unwanted signal

Is the reflection noise?

- The fuzzy boundary between “wanted” and “unwanted” for reflection
  - Glass is not only a noise-generator but also a semi-reflector to record the surrounding world.

The reflection is the unwanted signal



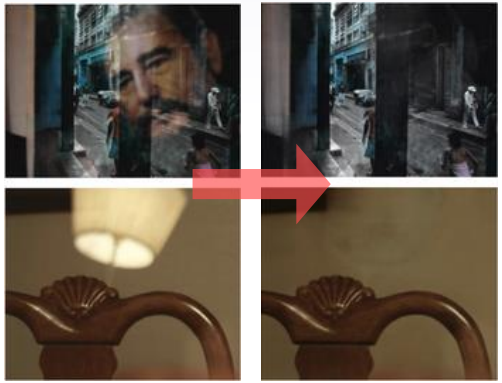
The reflection is the wanted signal

Is the reflection noise?

- The fuzzy boundary between “wanted” and “unwanted” for reflection
  - Glass is not only a noise-generator but also a semi-reflector to record the surrounding world.

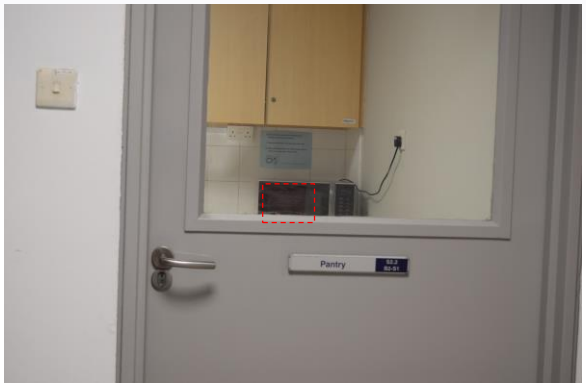
Reflection removal

Mixture image Background image



The reflection is the unwanted signal

Reflection scene separation

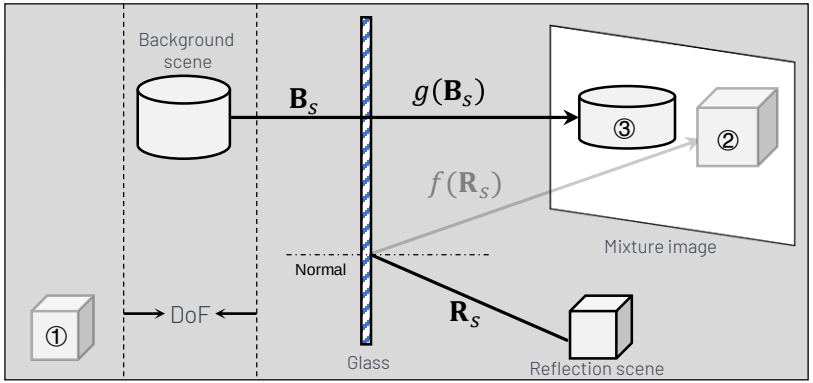


The reflection is the wanted signal

Reflection scene separation

- Physical formulation

Physical model for the reflection scene separation problem



① Virtue image of reflected scene ② Reflection component ③ Background component

Mixture image

Background scene image

Reflection component image

Reflection scene image

$$\mathbf{I} = g(\mathbf{B}_s) + f(\mathbf{R}_s)$$

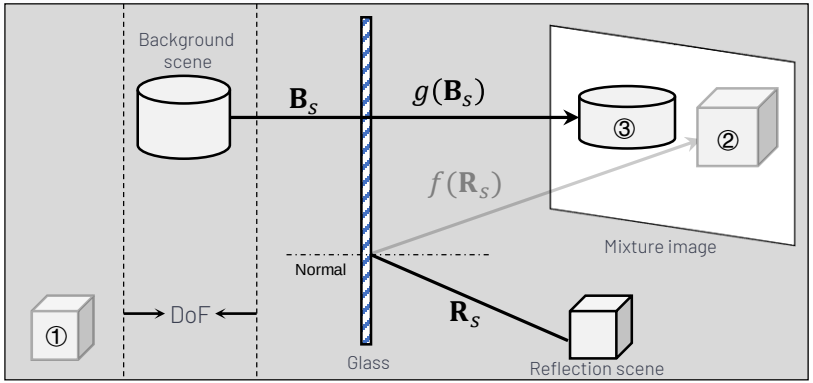
Background scene: $\mathbf{B}_s \approx g(\mathbf{B}_s)$

Reflection scene: $\mathbf{R}_s > f(\mathbf{R}_s)$

Reflection scene separation

- Objective
  - Obtain a clear reflection scene image from the mixture image

Physical model for the reflection scene separation problem



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Mixture image

Background scene image

Reflection component image

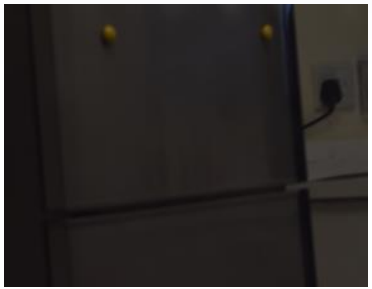
Reflection scene image

Reflection scene separation

- Related work
  - Previous reflection removal methods regard the reflection component image as the by-product.

Mixture image

Reflection component image

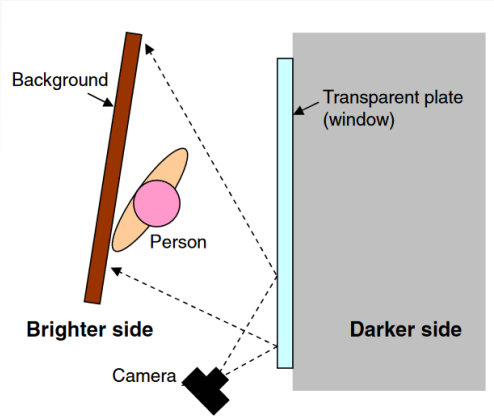


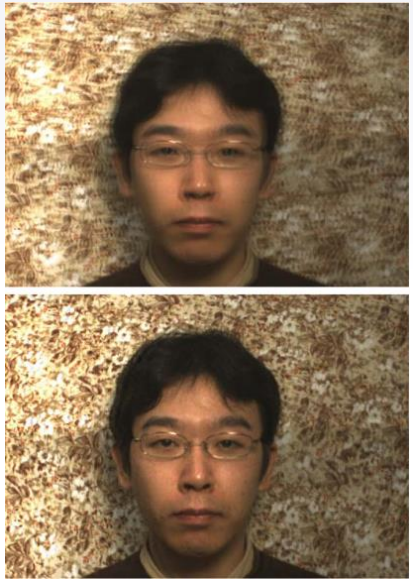
Mixture image

Reflection component image

Reflection scene separation

- Related work



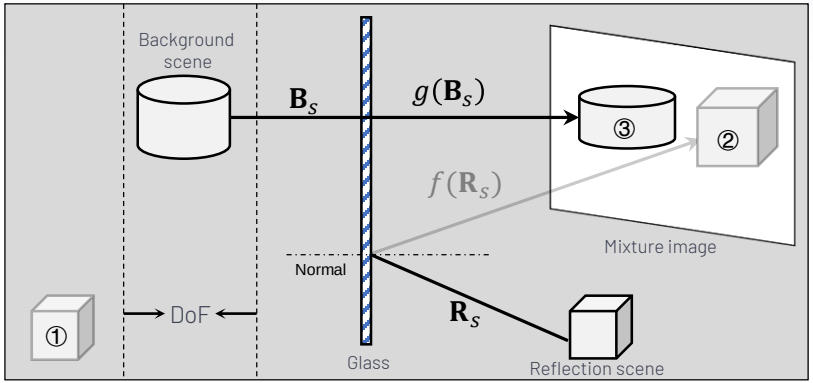


Yano, T., Shimizu, M., & Okutomi, M.. Image restoration and disparity estimation from an uncalibrated multi-layered image. In 2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (pp. 247-254). IEEE.

Reflection scene separation

- Solution

Physical model for the reflection scene separation problem



① Virtue image of reflected scene ② Reflection component ③ Background component

Mixture image

Background scene image

Reflection component image

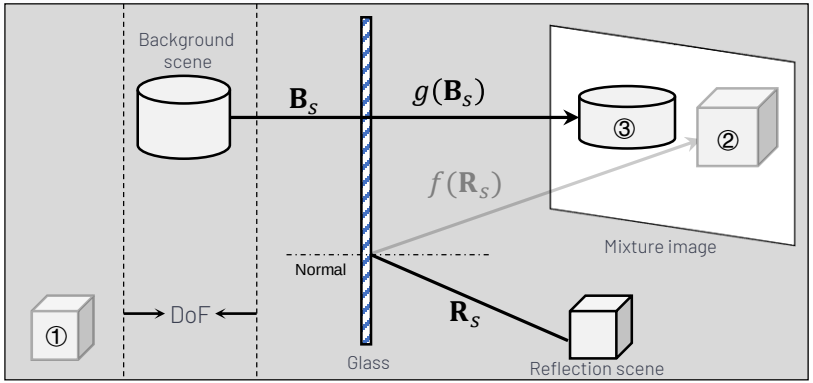
Reflection scene image

$$\mathbf{I} = g(\mathbf{B}_s) + f(\mathbf{R}_s)$$

Reflection scene separation

- Solution

Physical model for the reflection scene separation problem



① Virtue image of reflected scene ② Reflection component ③ Background component

Mixture image

Background scene image

Reflection component image

Reflection scene image

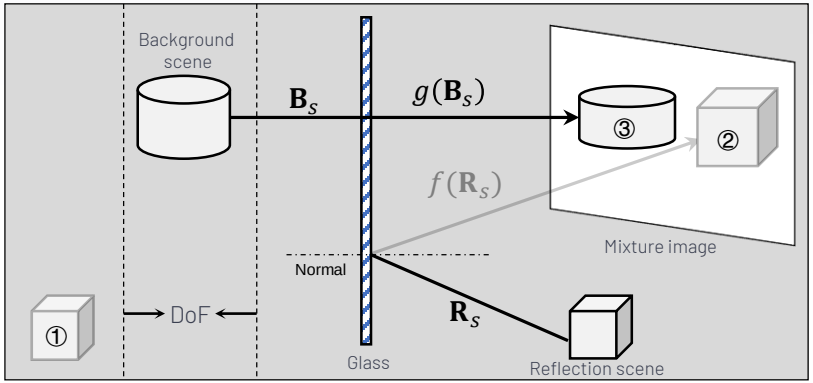
$$\mathbf{I} = g(\mathbf{B}_s) + f(\mathbf{R}_s)$$

First stage: Reflection separation: $\mathbf{I} \rightarrow f(\mathbf{R}_s)$

Reflection scene separation

- Solution

Physical model for the reflection scene separation problem



① Virtue image of reflected scene ② Reflection component ③ Background component

Mixture image

Background scene image

Reflection component image

Reflection scene image

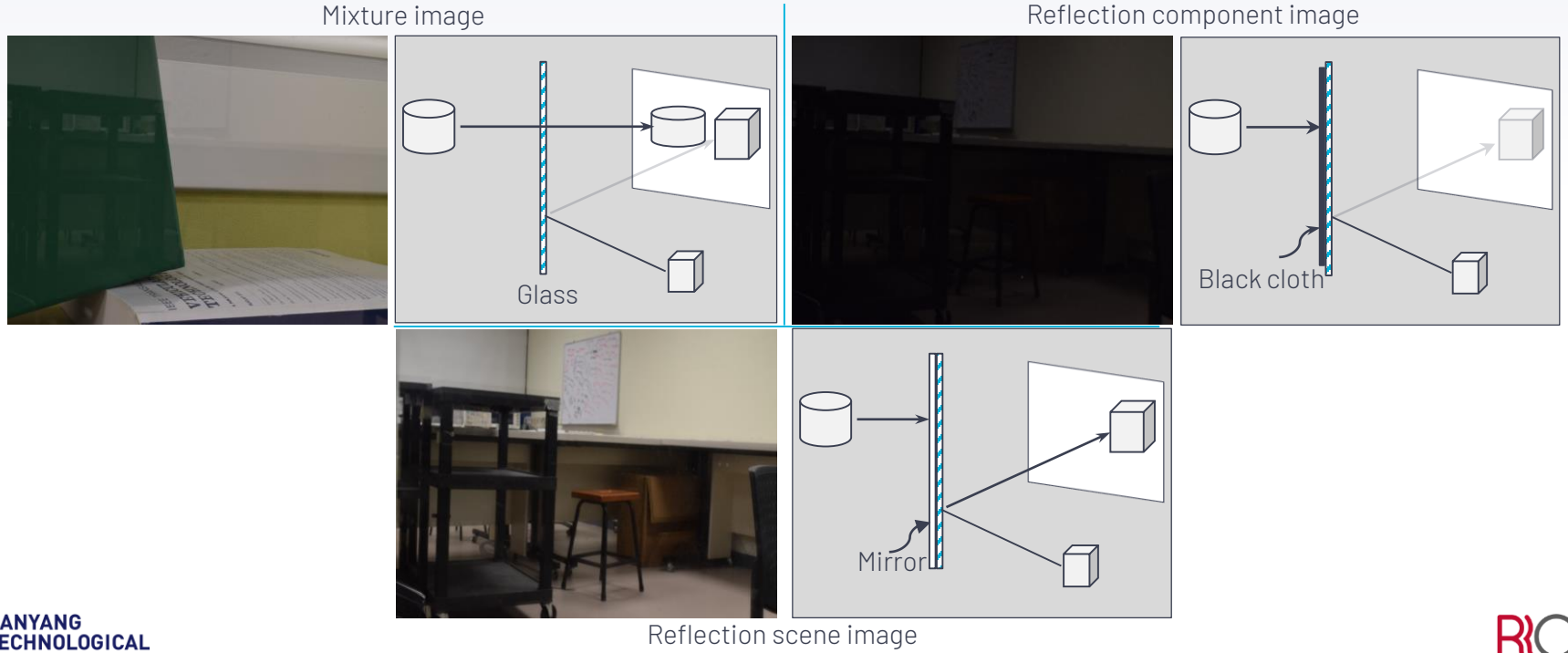
$$\mathbf{I} = g(\mathbf{B}_s) + f(\mathbf{R}_s)$$

First stage: Reflection separation: $\mathbf{I} \rightarrow f(\mathbf{R}_s)$

Second stage: Reflection scene enhancement: $f(\mathbf{R}_s) \rightarrow \mathbf{R}_s$

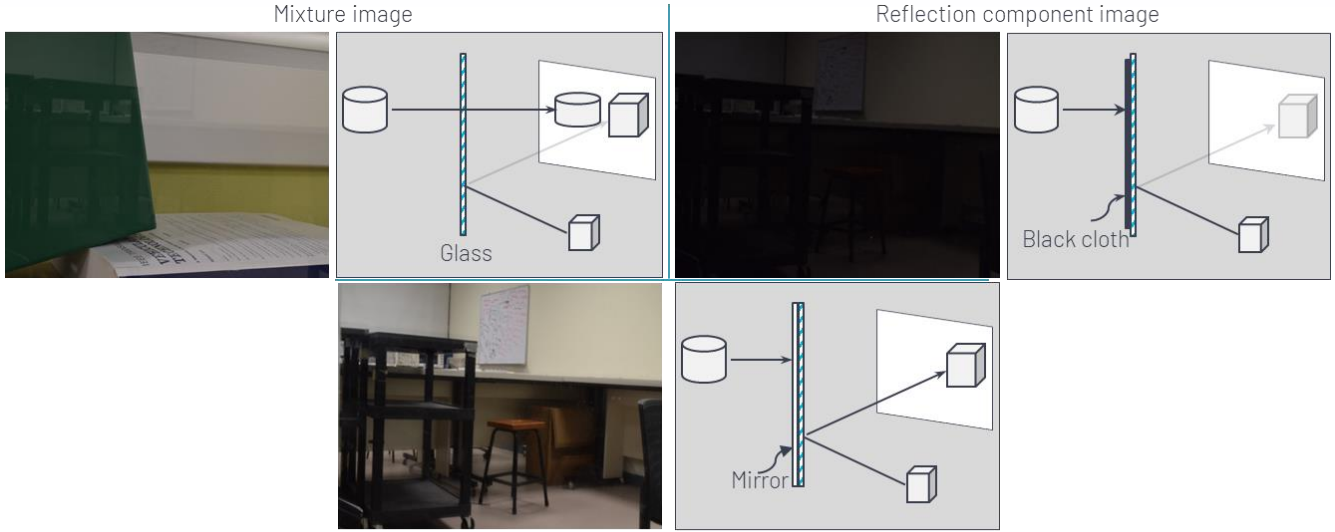
Reflection scene separation

- Dataset collection



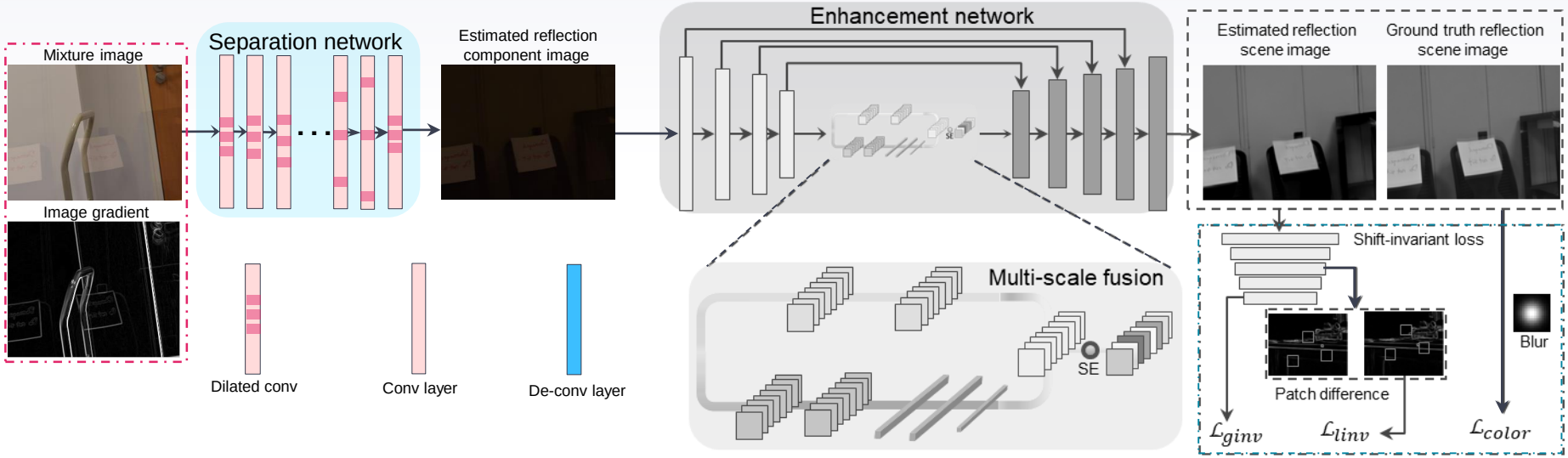
Reflection scene separation

- Dataset collection
  - Training dataset with 50 image triplets, where each image is cropped into 40 smaller images.
  - Evaluation dataset with 30 image triplets.
  - A problem: The mirror behind the glass may introduce the spatial shifts between the mixture image, reflection component image, and the ground truth reflection scene image.



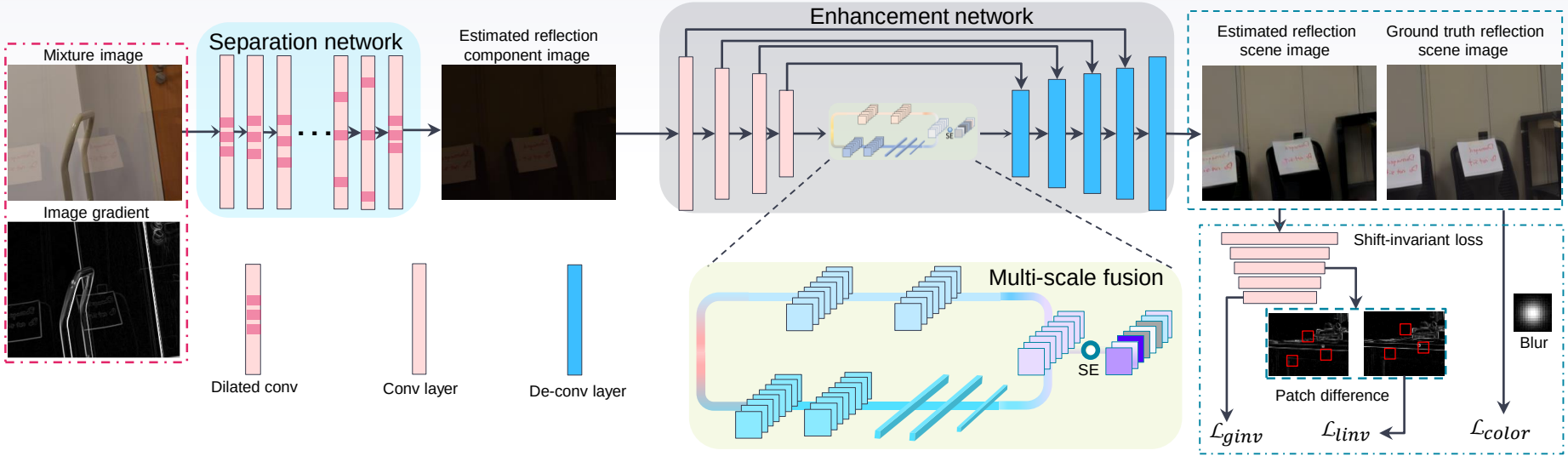
Reflection scene separation

- Solution First stage: Reflection separation



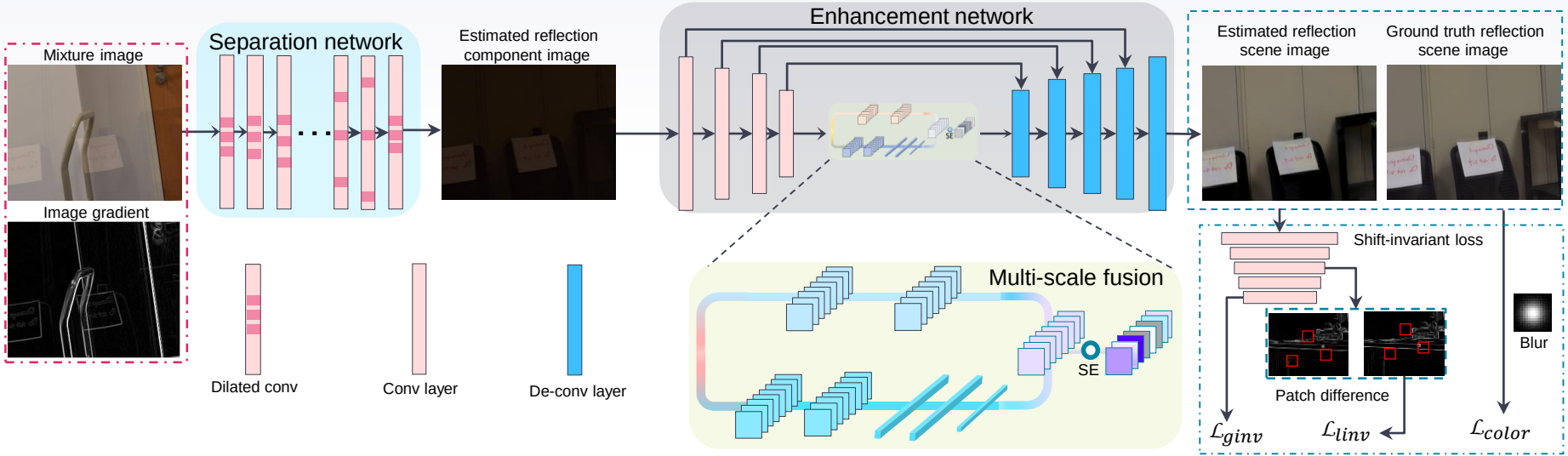
Reflection scene separation

- Solution Second stage: Reflection scene enhancement



Reflection scene separation

- Solution Second stage: Reflection scene enhancement



$$\mathcal{L}_{color} = 1 - \mathbf{mean}\left(\frac{z_b \cdot z_b^*}{\max(\|z_b\|_2 \cdot \|z_b^*\|_2, \epsilon)}\right)$$

Reflection scene separation

- Solution Second stage: Reflection scene enhancement
  - Shift-invariant loss---Local invariant loss

$$\mathcal{L}_{linv} = \sum_{i=1}^{m} \left\| \Psi_i(\Phi(z)) - \Psi_{NN(i)}(\Phi(z^*)) \right\|_1$$

$\Psi_i(\Phi(z))$: a patch from $\Phi(z)$

$\Psi_{NN(i)}(\Phi(z^*))$: the similar patch of $\Psi_i(\Phi(z))$ from $\Phi(z^*)$

$NN(i)$: the surrounding regions around pixel i

$$NN(i) = \text{argmax}_{j=1,\ldots,m_s}(\mathbb{D}_f(p_i, q_j) + \omega_s \mathbb{D}(p_i, q_j))$$

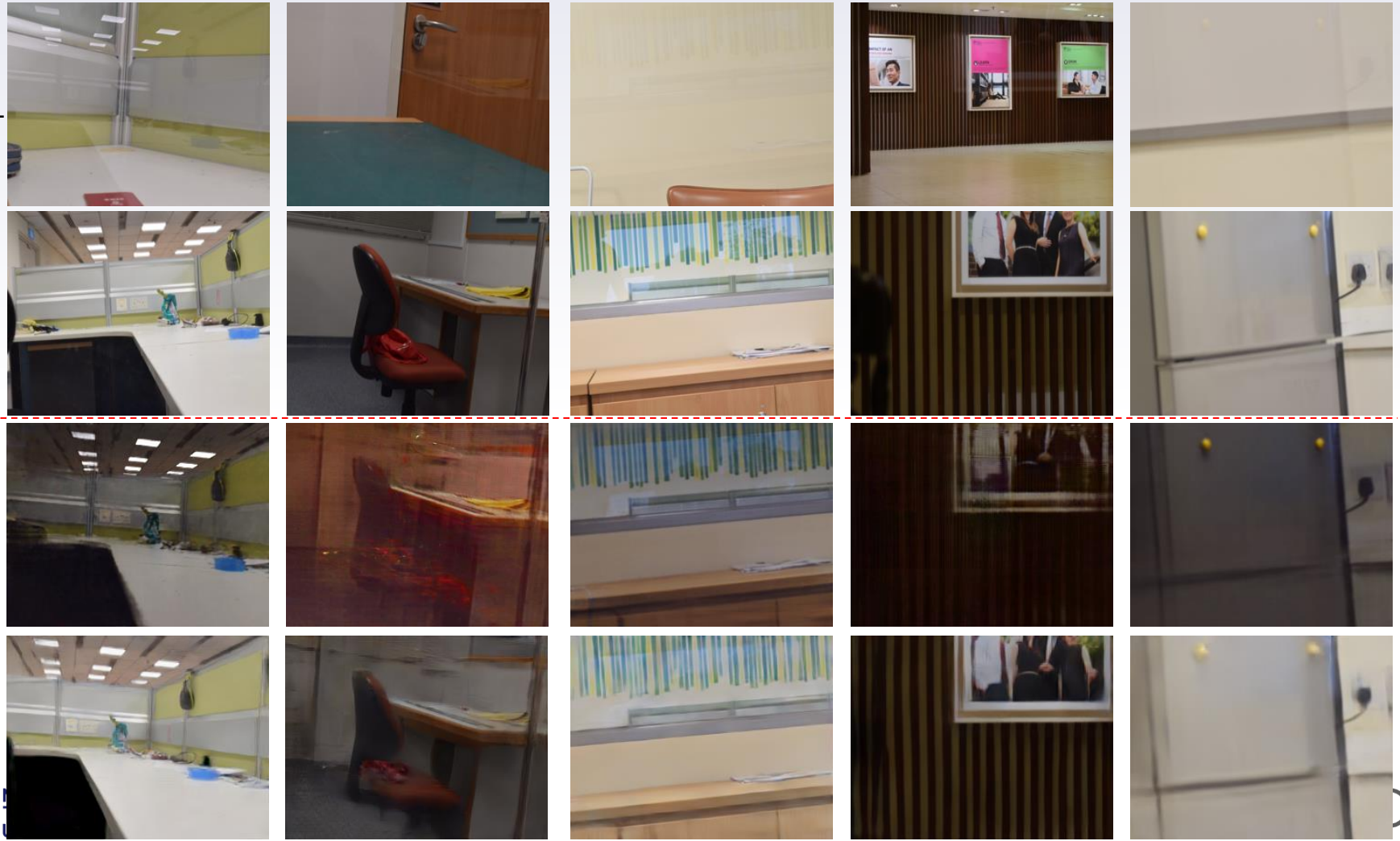
Result

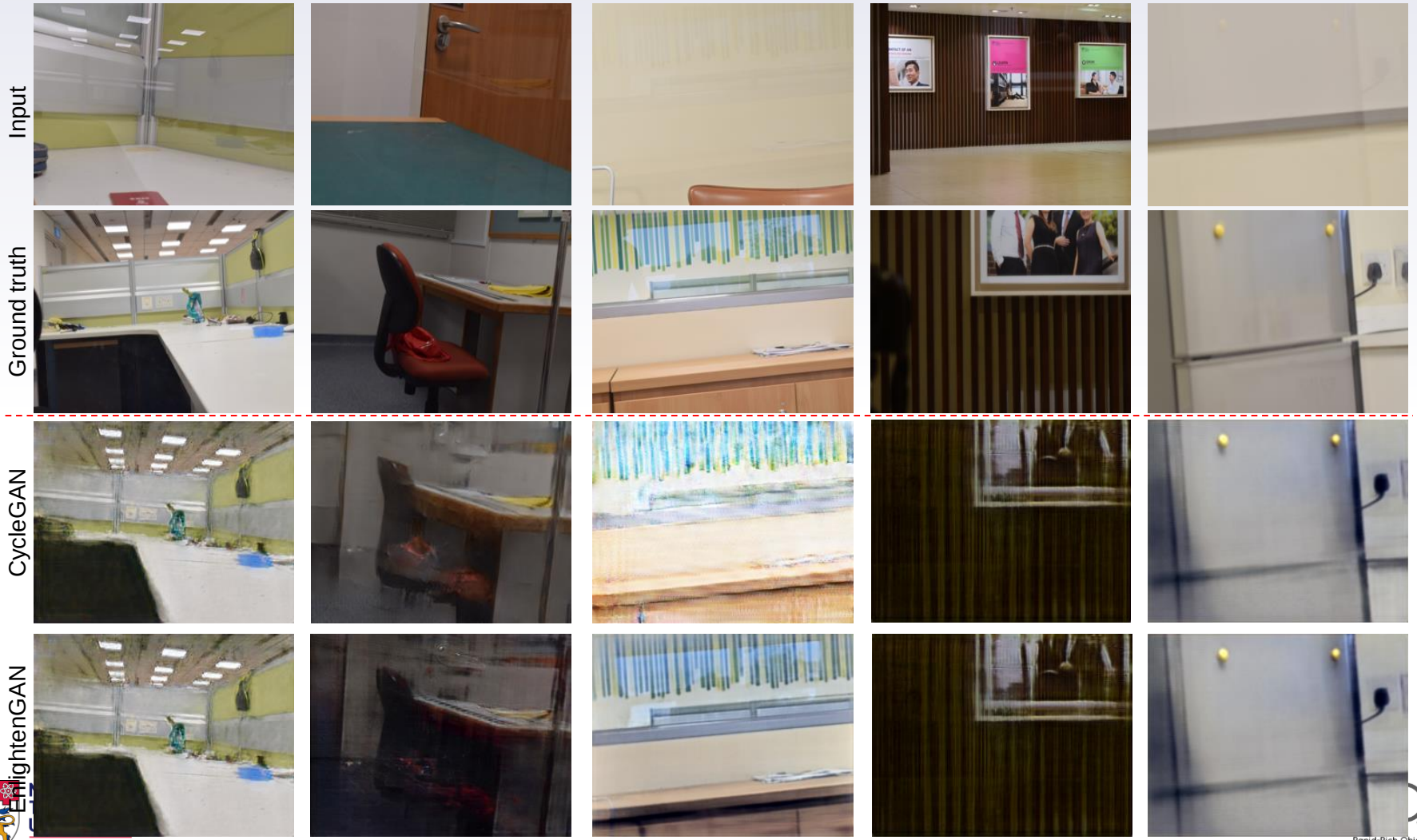
- We compare with CycleGAN [1], EnlightenGAN [2], and DPE [3] to evaluate the performances of the reflection scene enhancement results.
- Tested on the collected evaluation dataset.
- Evaluated by SSIM, LPIPS, and PSNR.

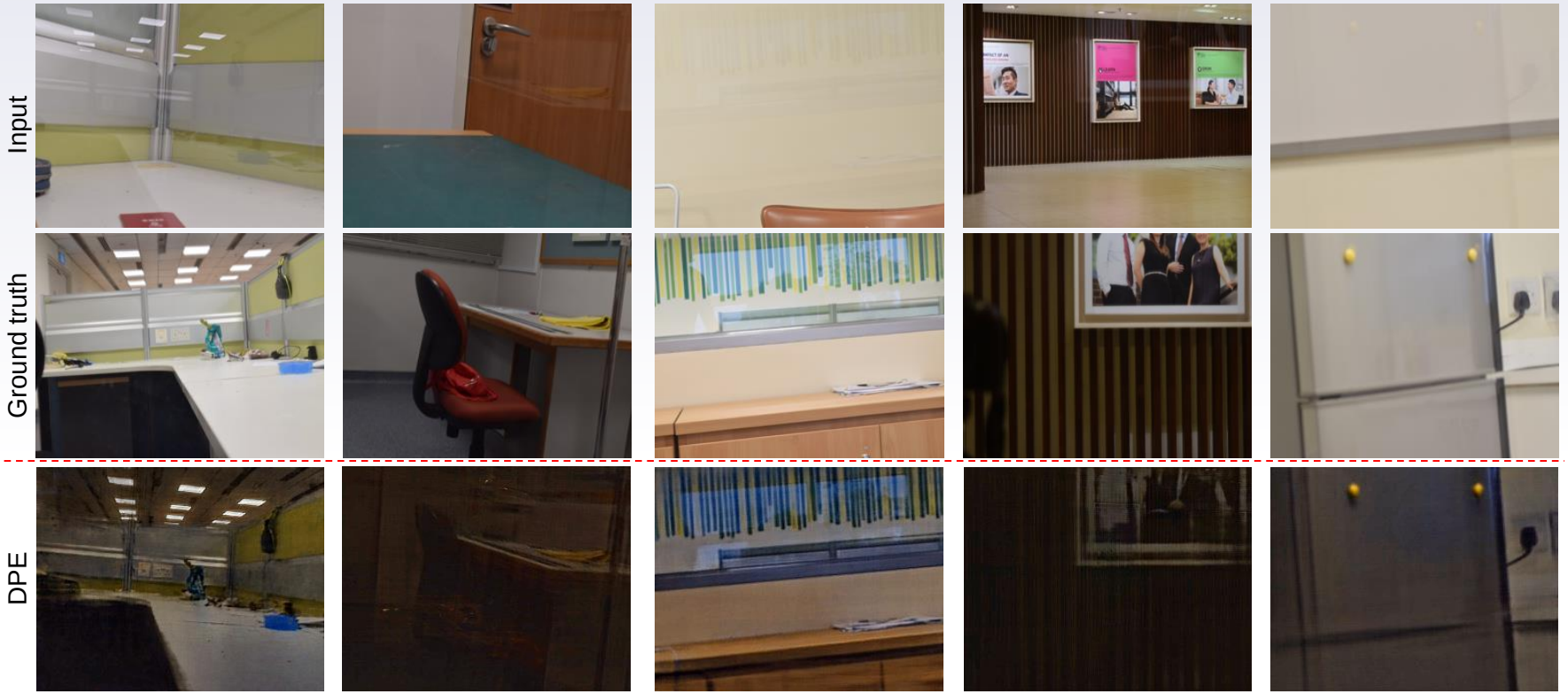
[1] Zhu, J. Y., Park, T., Isola, P., & Efros, A. A. (2017). Unpaired image-to-image translation using cycle-consistent adversarial networks. In Proceedings of the IEEE international conference on computer vision (pp. 2223-2232).

[2] Jiang, Y., Gong, X., Liu, D., Cheng, Y., Fang, C., Shen, X., & Wang, Z. (2019). EnlightenGAN: Deep light enhancement without paired supervision. arXiv preprint arXiv:1906.06972.

[3] Chen, Y. S., Wang, Y. C., Kao, M. H., & Chuang, Y. Y. (2018). Deep photo enhancer: Unpaired learning for image enhancement from photographs with GANs. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (pp. 6306-6314).


Input
Ground truth
RCI
Our result


Input
Ground truth
CycleGAN
EnlightenGAN


Input
Ground truth
DPE

Result

	LPIPS	SSIM	PSNR
Ours	**0.151**	**0.716**	**16.886**
CycleGAN [31]	0.202	0.583	15.581
EnlightenGAN [11]	0.315	0.595	12.956
DPE [4]	0.331	0.479	10.998

Limitations

- The reflection separation performance
- The generalization ability
- The size of the dataset
- The suppression of the artifacts

Thank you

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