Reflection Separation using a Pair of Unpolarized and Polarized Images

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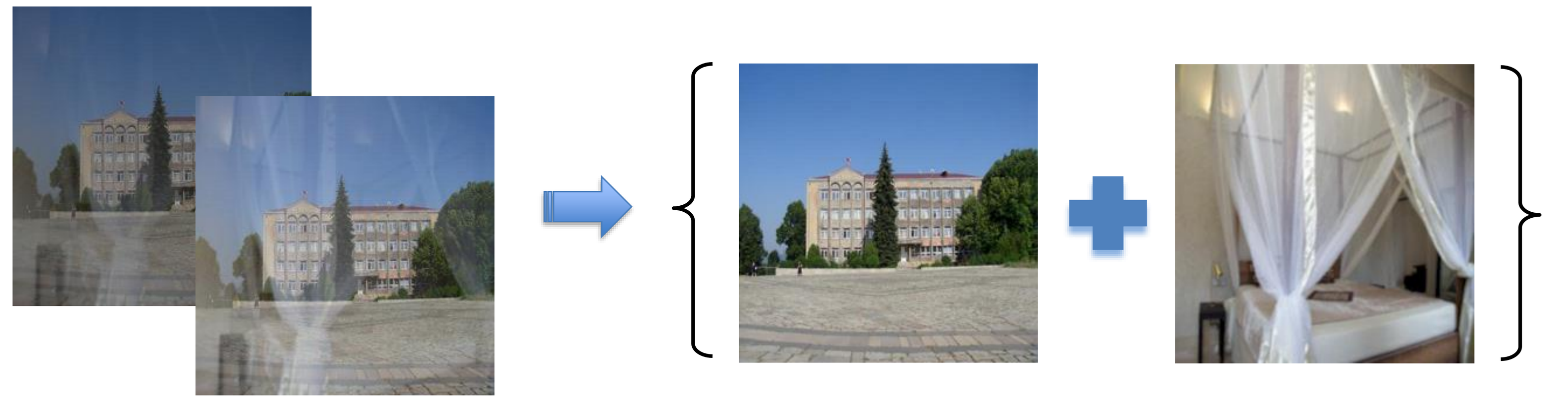
Goal & Contributions

Goal: To separate the reflection and transmission layers using polarization information.

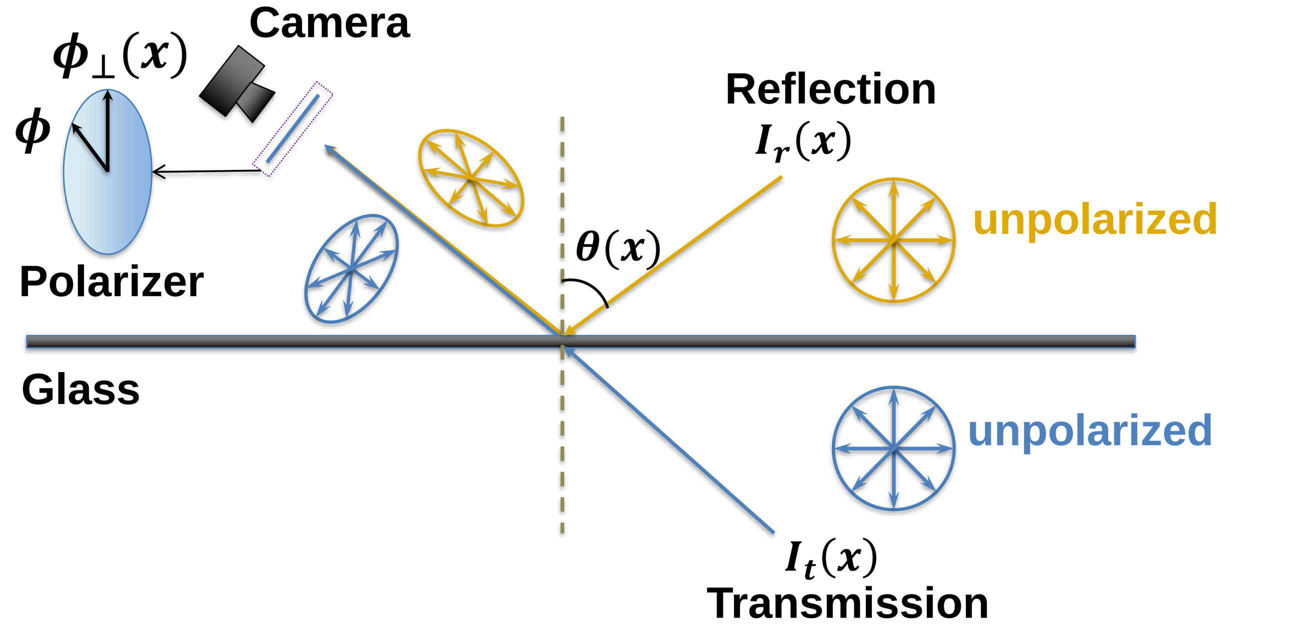


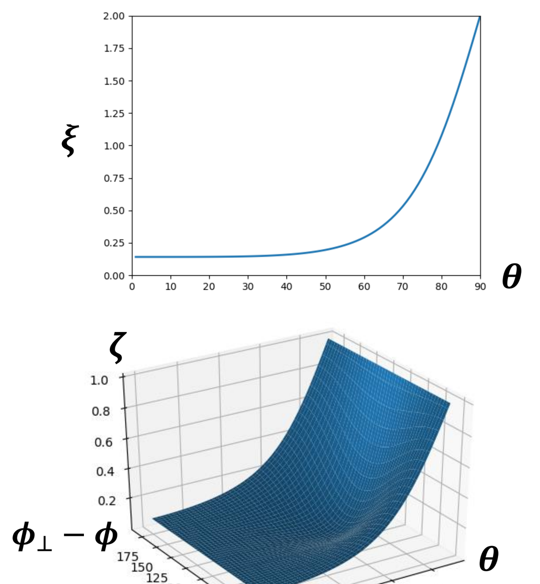
Contributions:

- A simpler and light-efficient setup for reflection separation using a pair of unpolarized and polarized images.
- A new formulation based on semi-reflector orientation estimation, which induces a well-posed physical image formation model to be reliably learned for layer separation.
- An end-to-end deep neural network with gradient loss to solve the separation problem.

Our Setup

- Images with & without polarizer in front of the camera





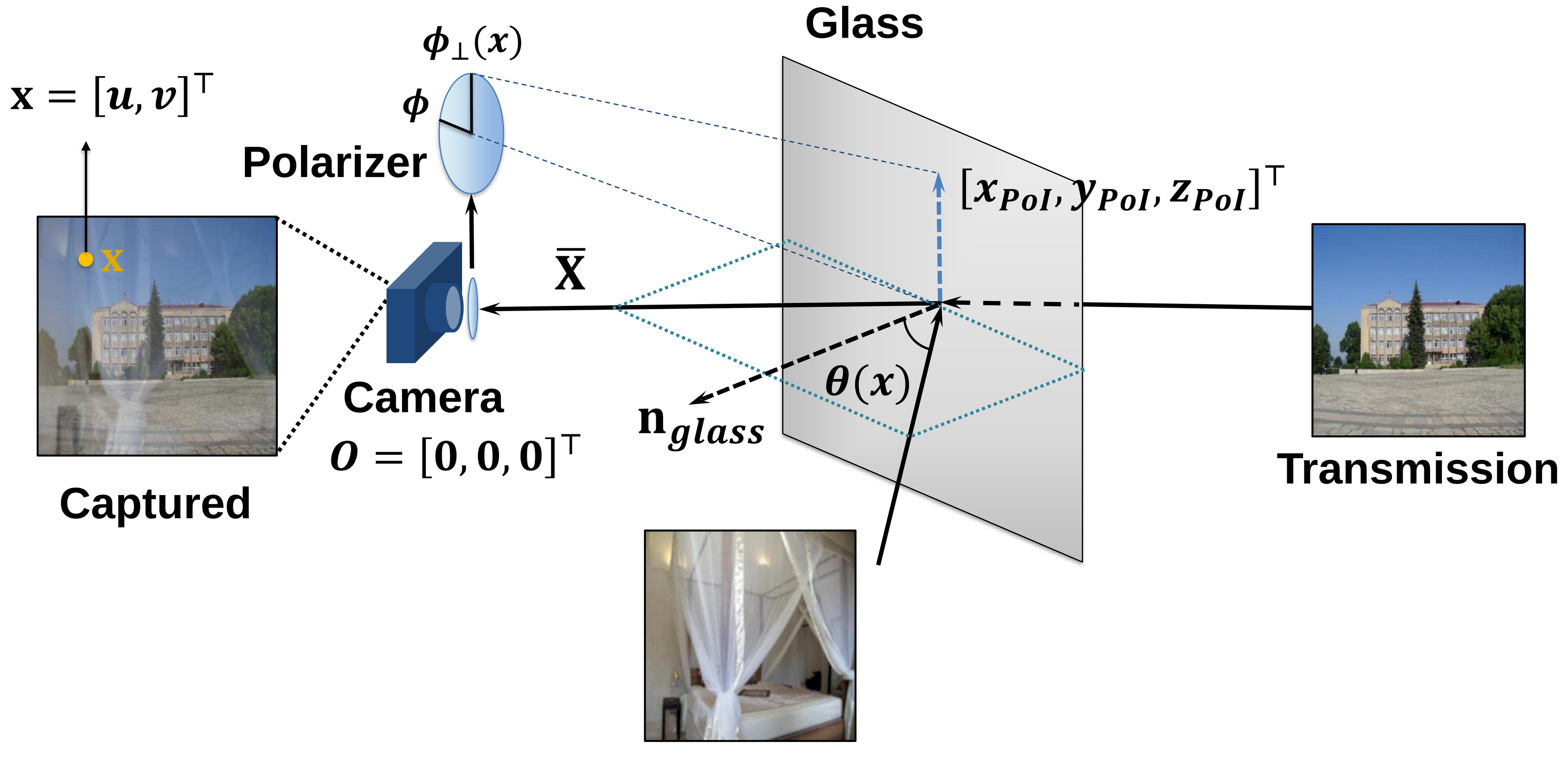
$$I_{unpol}(x) = I_r(x)\cdot\frac{\xi(x)}{2} + I_t(x)\cdot\frac{2-\xi(x)}{2},\quad I_{pol}(x) = I_r(x)\cdot\frac{\zeta(x)}{2} + I_t(x)\cdot\frac{1-\zeta(x)}{2},$$

$$\xi(x) = R_\perp(\theta(x)) + R_\parallel(\theta(x)),$$

$$\zeta(x) = R_\perp(\theta(x))\cos^2(\phi-\phi_\perp(x)) + R_\parallel(\theta(x))\sin^2(\phi-\phi_\perp(x)),$$

where $\theta(x)$ is the angle of incidence, $\phi_\perp(x)$ is the orientation of the polarizer for the best transmission of the component perpendicular to the Pol, $R_\perp$ and $R_\parallel$ are the relative strength of light components.

Physical Image Formation Model



Normal of glass: $\mathbf{n}_{glass} = [\tan\alpha \quad -\sin\beta \quad \cos\beta]^\top$,
where α and β are the rotation angles around y-axis and x-axis respectively.

Ray direction for an image pixel $\mathbf{x} = [u, v]^\top$:

$$\mathbf{X} = \lambda[u-p_x \quad v-p_y \quad f]^\top, \qquad \bar{\mathbf{X}} = \mathbf{X}/\|\mathbf{X}\|$$

$$\begin{cases} \theta(x) = \arccos(|\mathbf{n}_{glass}\cdot\bar{\mathbf{X}}|) \\ \phi_\perp(x) = \arctan\frac{y_{Pol}}{x_{Pol}}, \text{ where } [x_{Pol}, y_{Pol}, z_{Pol}]^\top = \mathbf{n}_{glass}\times\bar{\mathbf{X}} \end{cases}$$

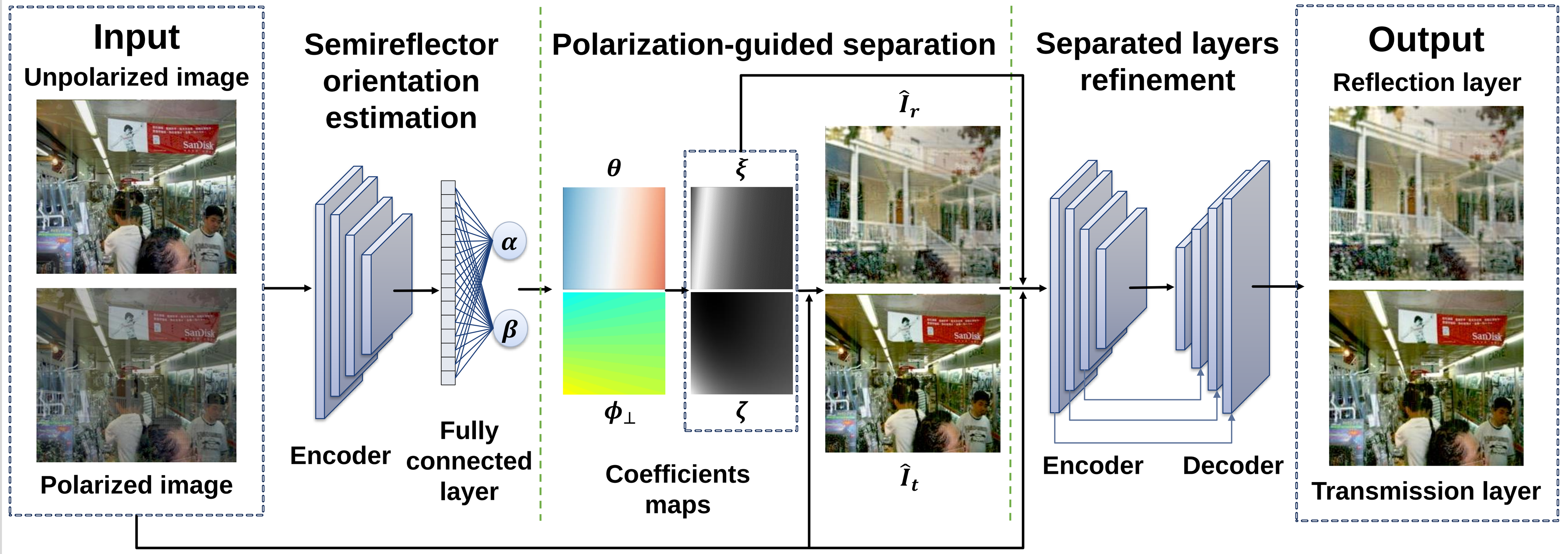
Quantitative Results

		Ours	Ours-Initial	ReflectNet-Finetuned	Ours-2% noise	Ours-8% noise	Ours-16% noise
Transmission	SSIM	**0.9708**	0.8324	0.9627	0.9691	0.9668	0.9619
	PSNR	**28.23**	21.61	27.52	28.08	27.31	27.17
Reflection	SSIM	**0.8953**	0.6253	0.8303	0.8785	0.8418	0.8022
	PSNR	**20.92**	13.90	18.50	20.53	19.18	18.26

References

[1] Wieschollek et al. Separating reflection and transmission images in the wild. In Proc. ECCV, 2018.
[2] Wan et al. CRRN: Multi-scale guided concurrent reflection removal network. In Proc. CVPR, 2018.
[3] Zhang et al. Single image reflection separation with perceptual losses. In Proc. CVPR, 2018.

Reflection Separation Network



Qualitative Results