Single Image Reflection Removal with Absorption Effect

Qian Zheng[1], Boxin Shi[2,3], Jinnan Chen[1], Xudong Jiang[1], Ling-Yu Duan[2,3], Alex C. Kot[1]

[1]Nanyang Technological University, [2]Peking University, [3]Peng Cheng Laboratory

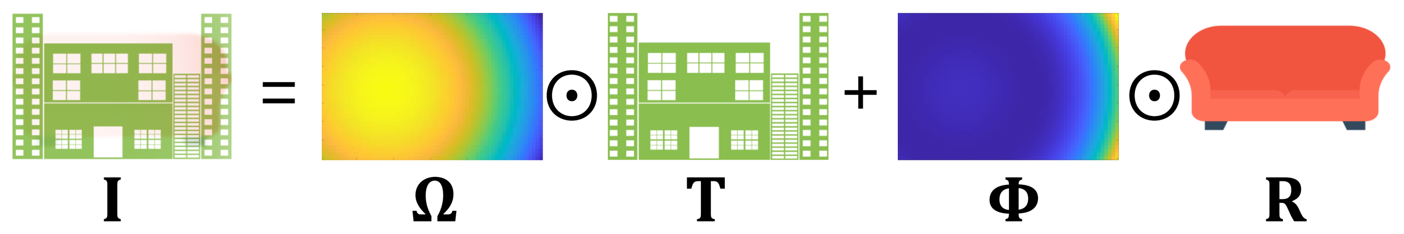
MOTIVATION

- Absorption effect **varies** with different colors, thicknesses, and orientations of glass in the real-world.
- Absorption effect **darkens** the transmission image.
- Existing single reflection removal methods assume the image formation model **without** absorption effect.

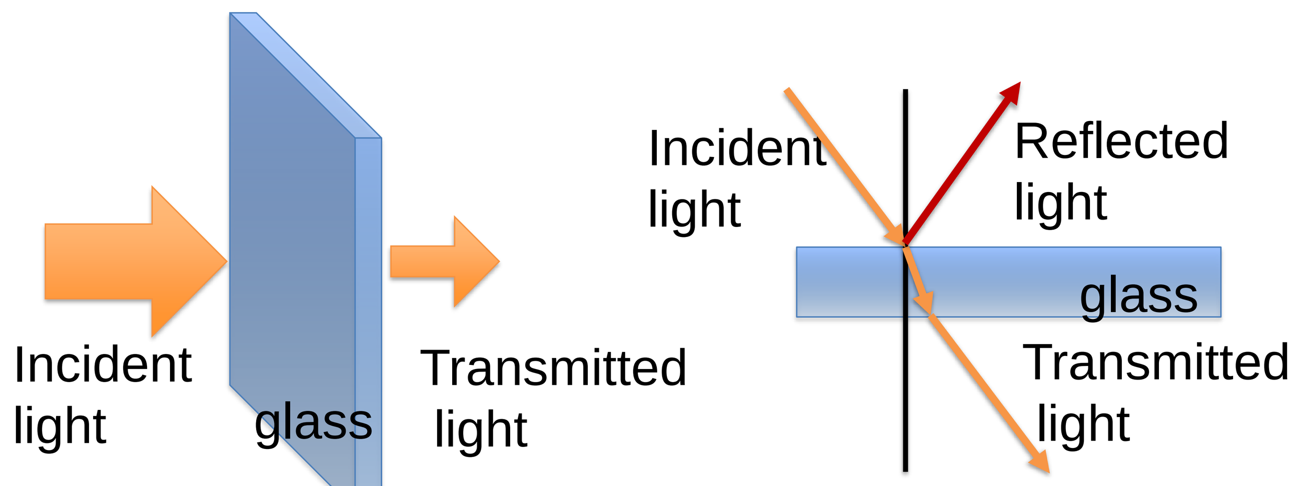
Explicitly considering the absorption effect helps recovery transmission image with more accurate overall intensity.

ABSORPTION EFFECT MODELING

- Image formation model



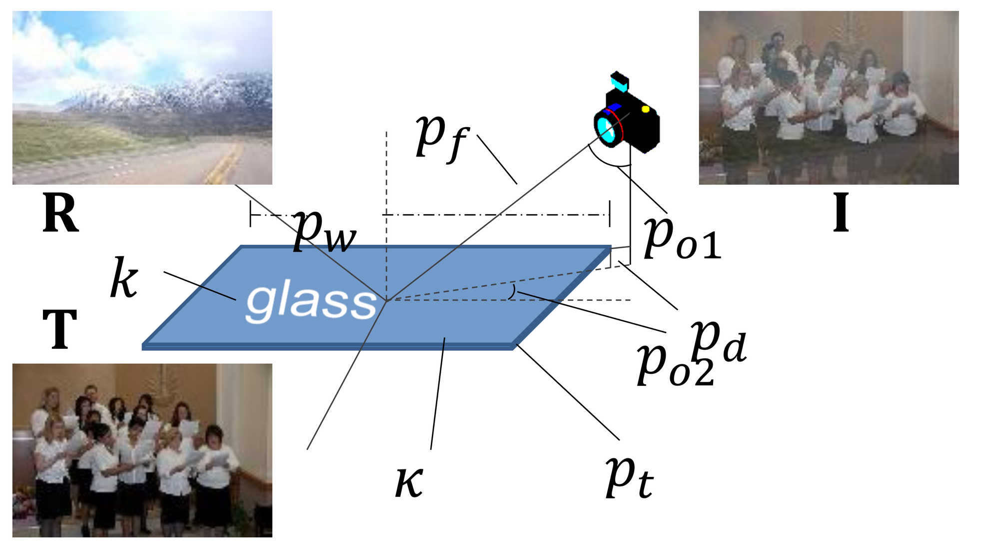
- Formulating Ω and Φ based on **Beer-Lambert law** and **Fresnel's equation**, *i.e.*, $\Omega + \Phi \neq 1$

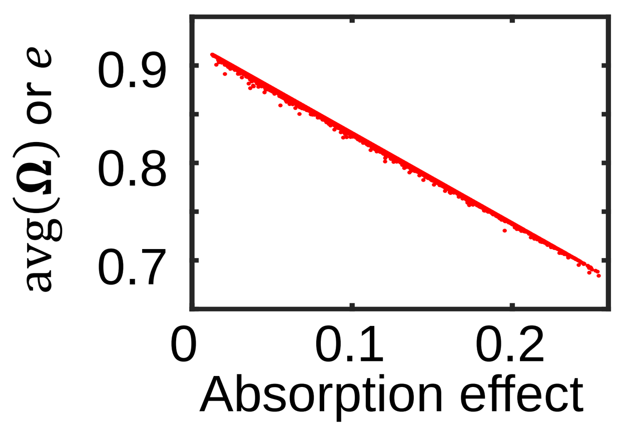


Datasets	ZN18	WS19	WT19	WY19	KH20	LY20
SIR^2-Thick	11.0	5.20	63.0	13.8	9.08	13.8
ZC20-Orien	1.97	28.2	24.7	7.20	16.9	7.02
LY20-Data	6.13	2.77	65.4	58.4	5.60	/
SIR^2	22.9	-12.4	58.7	-6.02	4.26	11.8
ZN18-Data	/	-13.3	38.7	/	20.0	10.1

NUMERICAL APPROXIMATION

- Monte Carlos simulation





The mean value of Ω can be used to numerically approximate the absorption effect e.

- Two-Step solution

$$g: \mathbf{I} \rightarrow e, \qquad h: (\mathbf{I}, e) \rightarrow \mathbf{T}$$

ESTIMATING e

- Two-branch network g with sharing weights
  - ReLU6: cut off large values produced by **strong reflection** which is **sparse**.
  - Zero-Center: subtract the uniform impact caused by the **weak reflection** which is **dense**.

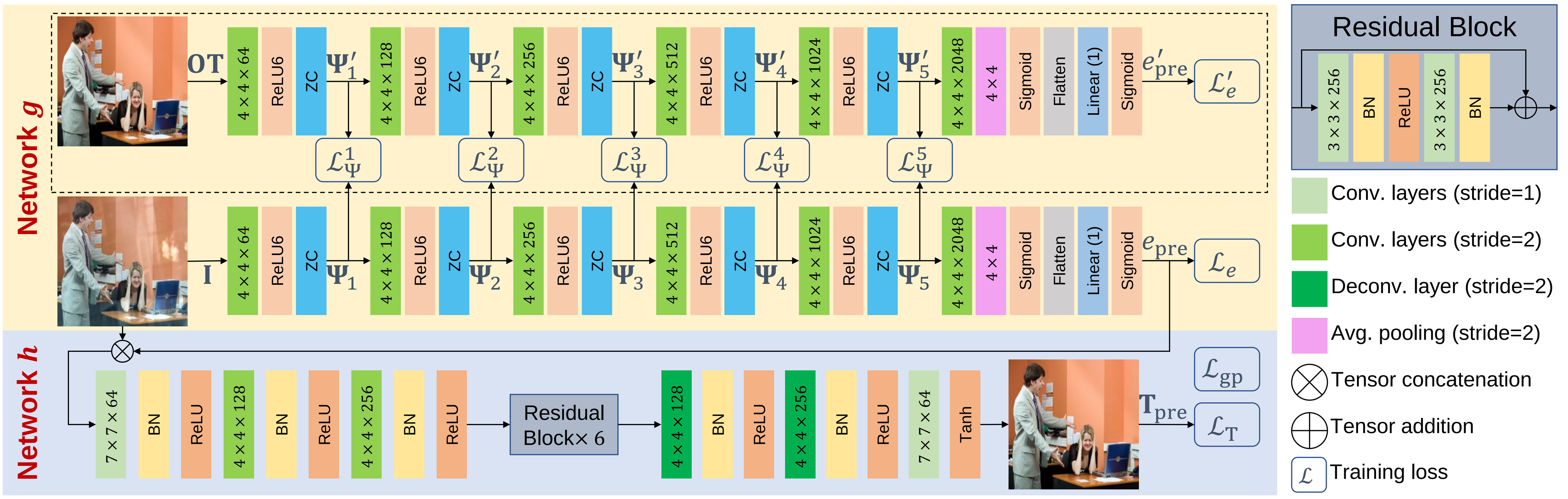
ReLU6 and zero-center help propagate e through layers.

RECOVERING T

- Gradient penalized network h guided by e
  - Considering e as a variable and reformulate the optimization with the form of **Partial Differential Equations**.
  - Constructing **an initial value problem** and constraining it to have a **unique solution** with the Lipschitz constraint.

Lipschitz constraint reliefs the impact of the perturbation of e when recovering the transmission T.

FRAMEWORK



EXPERIMENTAL RESULTS

Dataset(size)	Metric	Ours	One-branch	*w/o*-Con	ZN18[21]	YM19[17]	WS19[23]	WT19[7]	WY19[4]	KH20[25]	LY20[26]
SIR^2-Thick (120)[31]	SSIM	**0.8965**	0.8877	**0.8940**	0.8494	0.8598	0.8751	0.8687	0.8864	0.8869	0.8641
	IS	**0.9773**	0.9711	**0.9752**	0.9275	0.9520	0.9532	0.9630	0.9646	0.9696	0.9598
	PSNR	**24.05**	22.85	**23.59**	18.91	21.85	20.63	22.03	23.00	23.46	22.02
ZC20-Orien (160)[50]	SSIM	**0.8790**	0.8638	0.8663	0.8673	0.8660	0.8244	0.8644	0.8616	**0.8757**	0.8743
	IS	**0.9722**	0.9598	**0.9720**	0.9670	0.9660	0.9142	0.9594	0.9646	0.9712	0.9681
	PSNR	**23.93**	20.42	**23.69**	22.61	23.68	19.26	21.40	23.84	23.48	23.56
LY20-Data (220)[26]	SSIM	**0.8732**	0.8568	**0.8673**	0.8354	0.8531	0.8420	0.8244	0.8254	0.8480	0.8568
	IS	**0.9552**	0.9428	**0.9503**	0.9410	0.9458	0.9401	0.9368	0.9499	0.9490	0.9414
	PSNR	**23.97**	22.23	**23.72**	23.13	21.93	21.35	20.73	22.41	22.85	23.61
SIR^2 (454)[31]	SSIM	**0.9003**	0.8906	0.8934	0.8703	0.8680	**0.8961**	0.8746	0.8906	0.8916	0.8945
	IS	**0.9756**	0.9688	**0.9733**	0.9267	0.9503	0.9500	0.9594	0.9593	0.9666	0.9589
	PSNR	**24.34**	23.06	**23.90**	19.24	22.20	20.93	22.05	23.35	23.64	22.76
ZN18-Data (109)[21]	SSIM	**0.7783**	0.7653	0.7669	0.7671	0.7395	0.7663	0.6844	0.7668	0.7507	**0.7691**
	IS	**0.8970**	0.8846	**0.8966**	0.8843	0.8703	0.8956	0.8678	0.8727	0.8808	0.8773
	PSNR	**19.63**	18.32	**19.60**	18.44	18.69	19.04	17.01	19.22	18.84	19.05

CONTRIBUTIONS

- The **first formulation** to consider the absorption effect in the context of reflection removal and show that the absorption effect can be **numerically approximated** by the average of refractive amplitude.
- **A two-step solution**, with a two-branch training strategy and the constraint of Lipschitz condition, to solve the problem of single image reflection removal with the **consideration of absorption effect**.

Codes Available!