Anti-Glare: Tightly Constrained Optimization for Eyeglass Reflection Removal

Tushar Sandhan & Jin Young Choi

Seoul National University, South Korea

Introduction

Absence of a clear eye visibility not only degrades the aesthetic value of an entire face image but also creates difficulties in many computer vision tasks. So we try to increase the eye visibility from a single image in the presence of eyeglass reflections.

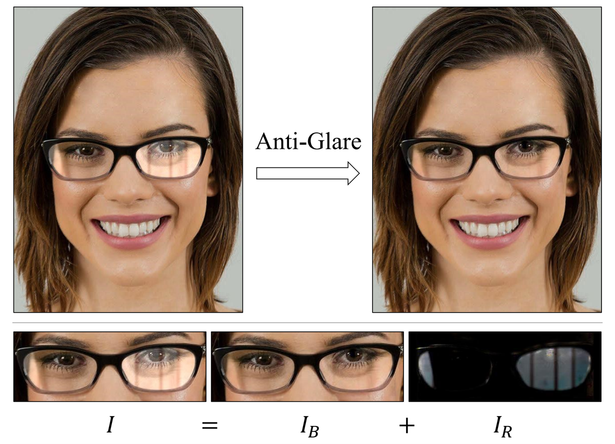
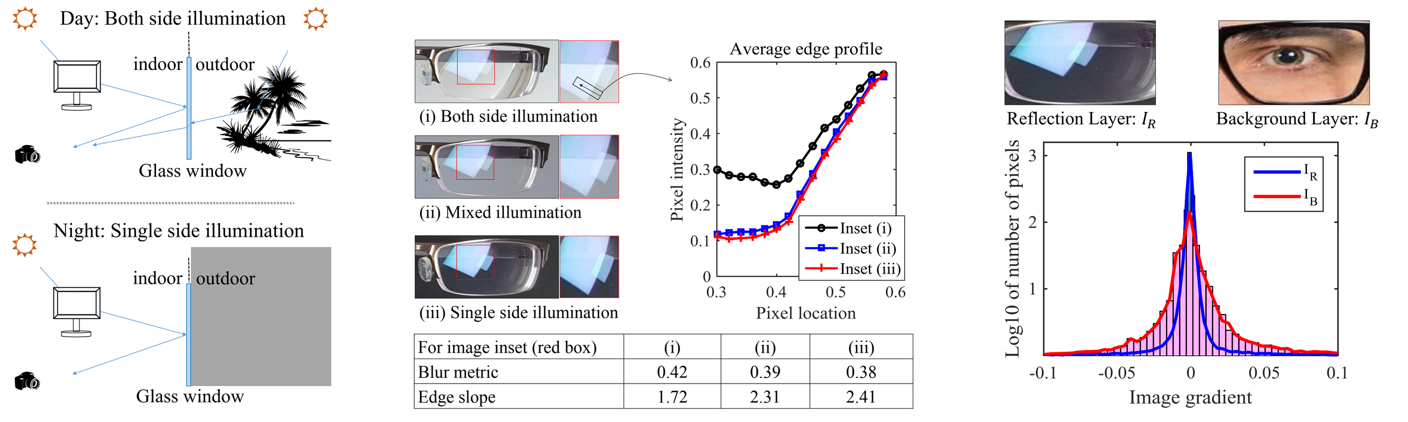


Figure 1: An input from [4] having synthetic reflections and our result

Contributions

1. Inspected the salient properties of eyeglass materials.
2. Derived the priors using following cues:
   - Single side illumination on eyeglasses ⇒ reflections with sharp & sparse gradients.
   - Residual reflections: eyeglass attenuates each light λ differently ⇒ color tint & piecewise constancy
   - Bilateral symmetry: $\diamond \lfloor \diamond$
3. Prior (residual map) is used to gradually tighten the constraints in an optimization problem at each iteration.
4. Eyes with Eyeglasses (EwE): a synthetic dataset is created & evaluated for iris detection.
   (dataset will be available at `http://pil.snu.ac.kr`)

Eyeglass Reflections



For image inset (red box)	(i)	(ii)	(iii)
Blur metric	0.42	0.39	0.38
Edge slope	1.72	2.31	2.41

Illumination type — Reflection sharpness — Gradient distribution

Single side illumination gives rise to very sharp reflections. Eyeglasses always have single side illumination.

In case of eyeglasses, different wavelengths are attenuated differently (Fig. 2), so the reflection layer shows a specific color or a hue like green, blue, violet etc.

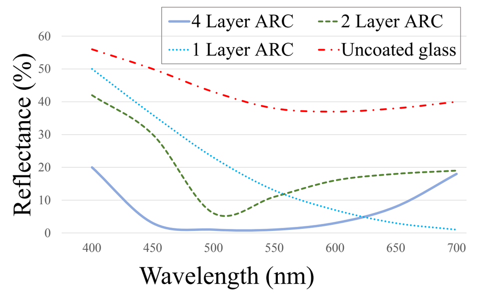


Figure 2: Reflectance Vs λ for an eyeglass [1, 5]

Facial Symmetry Prior

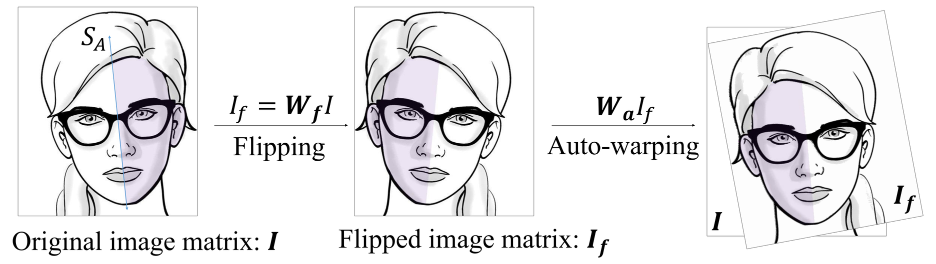


Figure 3: Auto-flip-warping: Note how the in-plane rotation of a face can easily be handled by $\mathbf{W}_a$. Assumption: Eyeglass reflections are not bilaterally symmetric.

$$\frac{\gamma}{2}\left\|\widetilde{\mathbf{W}}_{af} I_R - \widetilde{\mathbf{W}}_{af} I\right\|^2. \quad (1)$$

Tight constraints

Residual reflection property ⇒ look for distinctive hue regions. Constructing the hue map M_{H_t} as

$$M_{H_t} = \exp\left(-\eta_1 \|H_I - \bar{\mu}(H_{R_t})\|^2\right). \quad (2)$$

Filter it via guiding through hue & saturation to obtain,

$$M_{R_t}[i] = \frac{1}{w}\sum_{k\in\mathbb{N}_i} W[k]\exp\left(-\eta_2\|i-k\|^2\right)\frac{M_{H_t}[k]}{\max(M_{H_t})},$$
$$W[k] = \exp\left(-\eta_3\left\|\Delta_{i,k}H_I\right\|^2 - \eta_4\left\|\Delta_{i,k}S_I\right\|^2\right), \quad (3)$$

Tight the lower bound by spreading color tint (prior) over the residual map as,

$$\Gamma_t = \bar{\mu}(I_{R_t})M_{R_t}. \quad (4)$$

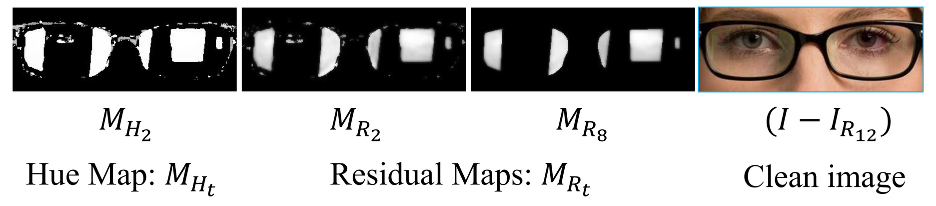


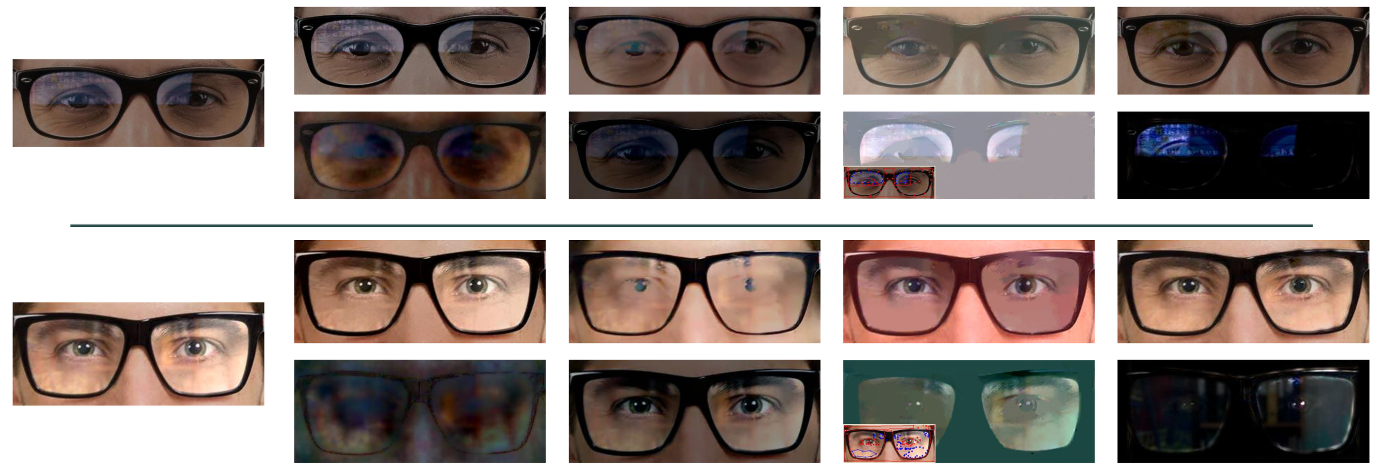
Figure 4: Hue and residual map at different iterations of the optimization scheme.

Optimization

$$\min_{I_R}\sum_i\left\{\sum_{j\in\mathbb{J}_R}|D_i^j I_R|^\alpha + \sum_{j\in\mathbb{J}_B}\frac{\lambda}{2}\left\|D_i^j I_R - D_i^j I\right\|^2\right\} + \frac{\gamma}{2}\left\|\widetilde{\mathbf{W}}_{af} I_R - \widetilde{\mathbf{W}}_{af} I\right\|^2, \quad \text{s.t.} \quad \kappa\Gamma_t[i] \le I_R[i] \le I[i], \quad (5)$$

	Input	Sparsity	Symmetry	Tight constr.	G.Truth
PSNR	21.92 dB	21.93 dB	28.92 dB	35.80 dB	-
SSIM	0.8913	0.8915	0.9689	0.9880	-
		(γ=0, κ=0 in (5))	($\gamma \neq 0$, κ=0 in (5))	($\gamma \neq 0$, $\kappa \neq 0$ in (5))	

Results



Time →	0.6 sec.	1208.5 sec.	42.0 sec.	11.1 sec.
Input ↑	[3]	[6]	[2]	**Ours**

Iris detection is the precursors for iris recognition systems. On EwE dataset: ROC curve in Fig. 5 ⇒ the greater the eye visibility, the better the iris detection accuracy.

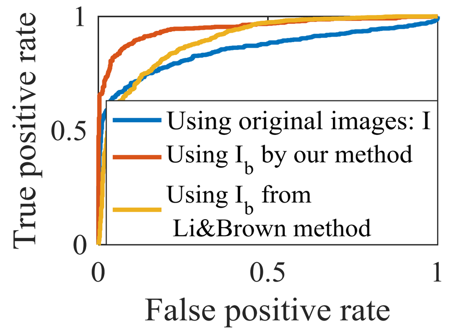


Figure 5: ROC Iris det.

Conclusion

This method removes eyeglass reflections from a single frontal face image. What if reflections turn out to be perfectly symmetric? What about specular reflections? What if face is out-of-plane rotated?

References

[1] Dinguo Chen. Anti-reflection (ar) coatings made by sol-gel processes: A review. *Solar Energy Mat. & Solar Cells*, 2001.
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[5] Hemant Kumar Raut, V. Anand Ganesh, A. Sreekumaran Nair, and Seeram Ramakrishna. Anti-reflective coatings: A critical, in-depth review. *Energy Environ. Sci.*, 2011.
[6] YiChang Shih, D. Krishnan, F. Durand, and W. T. Freeman. Reflection removal using ghosting cues. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2015.