DC-ShadowNet: Single-Image Hard and Soft Shadow Removal Using Unsupervised Domain-Classifier Guided Network

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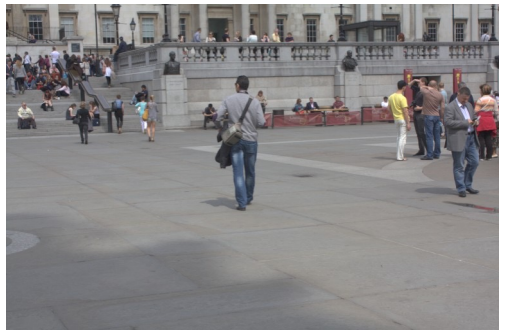
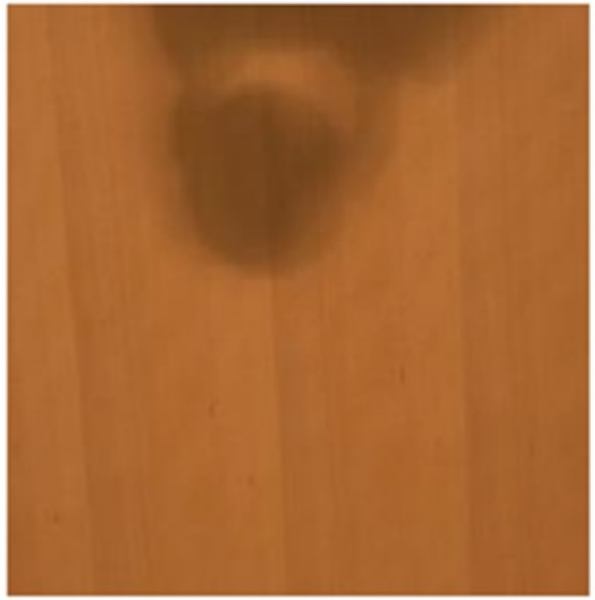
Soft Shadow Problem



(a) Hard Shadow

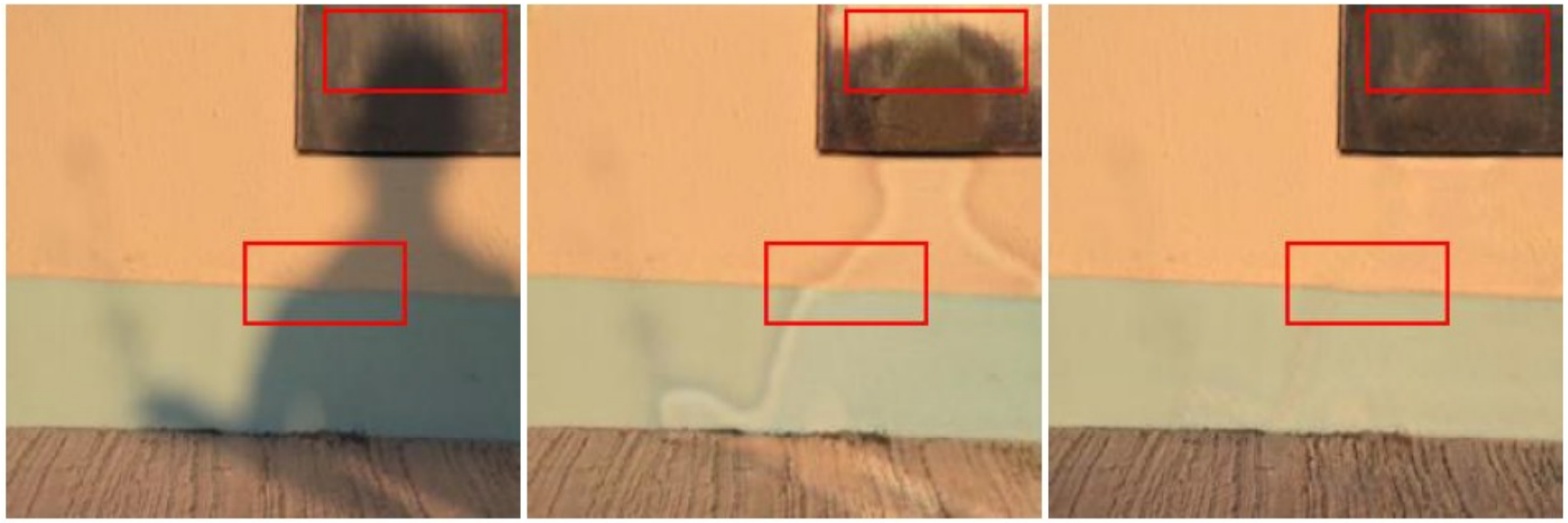

(b) Soft Shadow

[1] Learning to Remove Soft Shadows. ACM TOG 2015

Motivation

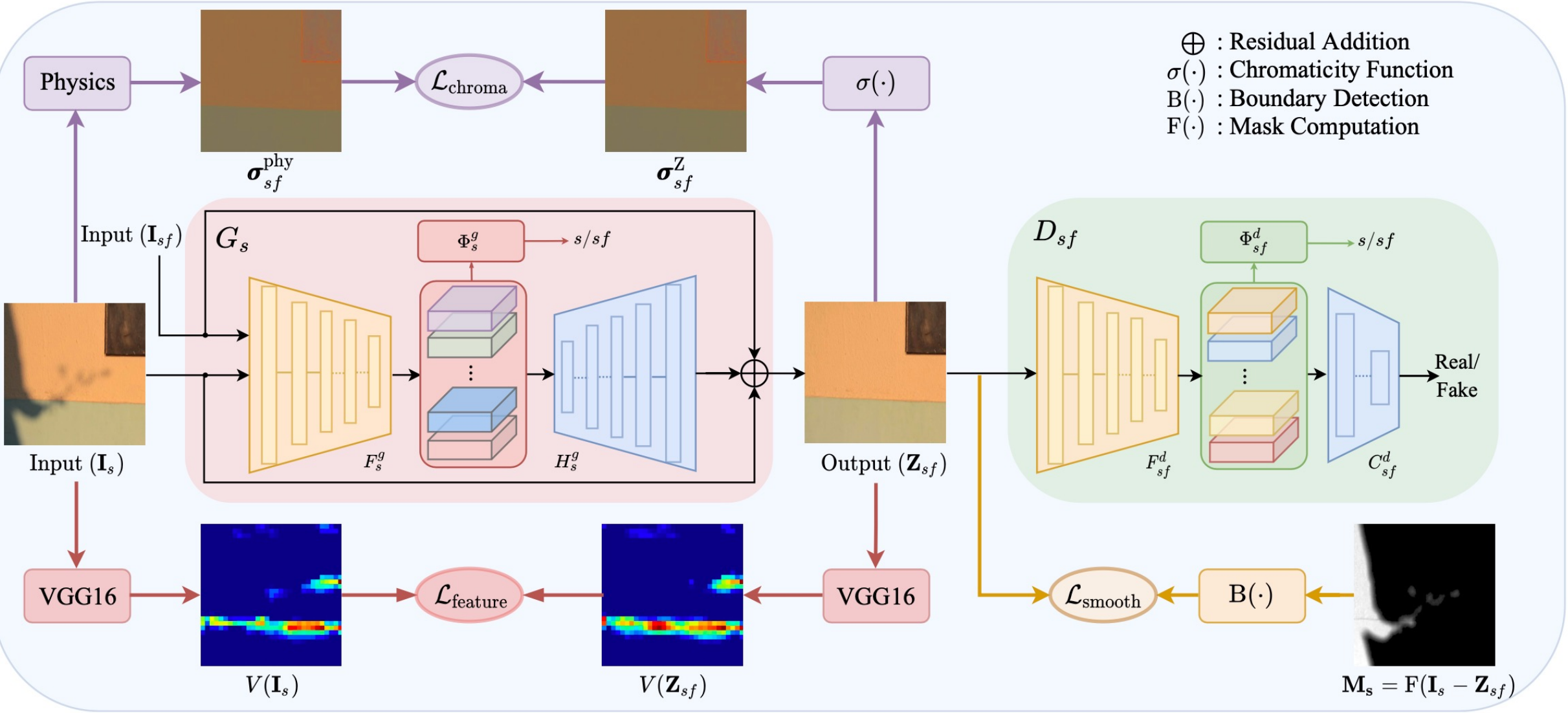
- Physics-based methods fail to handle **soft** shadows and **achromatic** surfaces.
- Supervised learning methods require shadow and non-shadow **pairs**.
- The current unsupervised method fails to remove **soft** shadows.

Main task: remove **hard** and **soft** shadows using an **unsupervised** method.

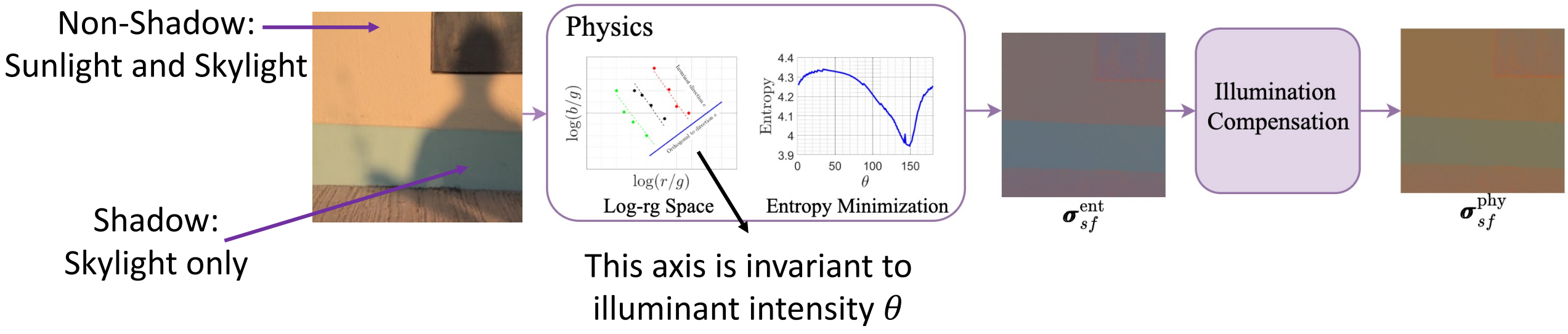


Input Image | Mask-ShadowGAN | DC-ShadowNet

Network Architecture



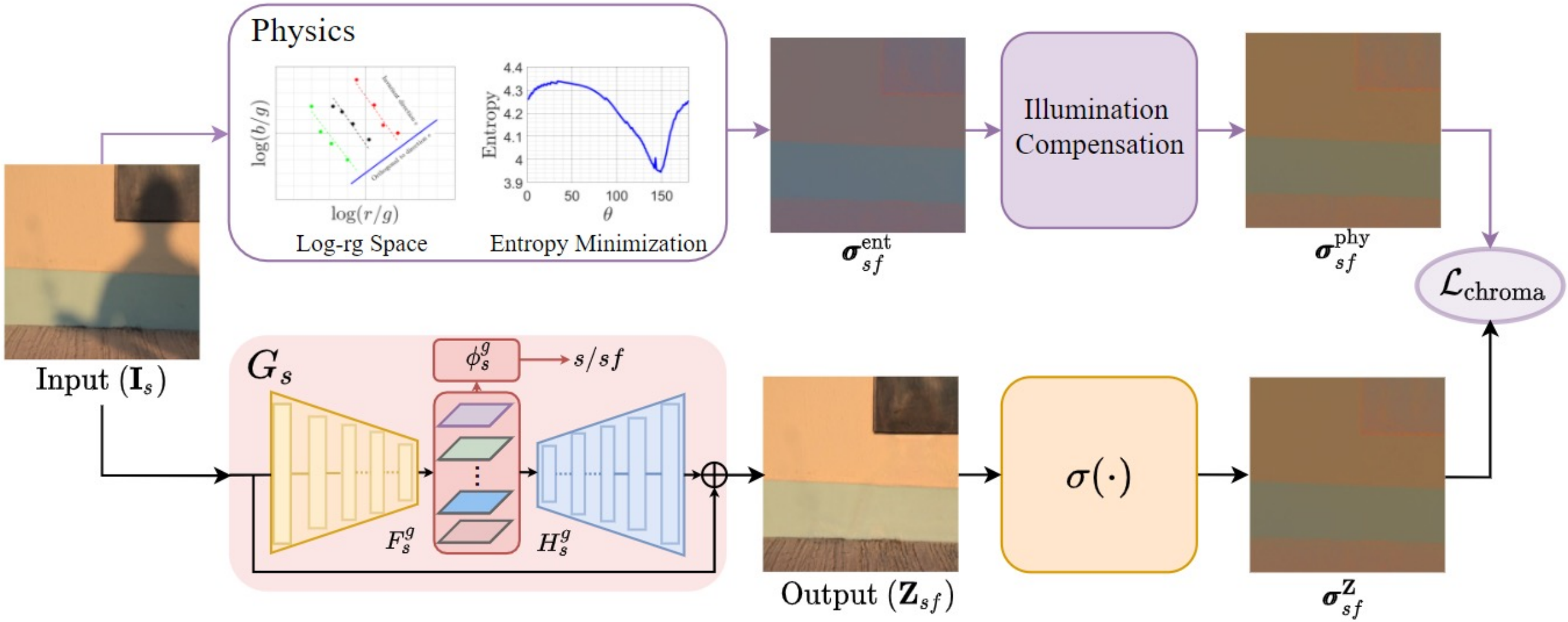
Shadow-Free Chromaticity Loss



This axis is invariant to illuminant intensity θ

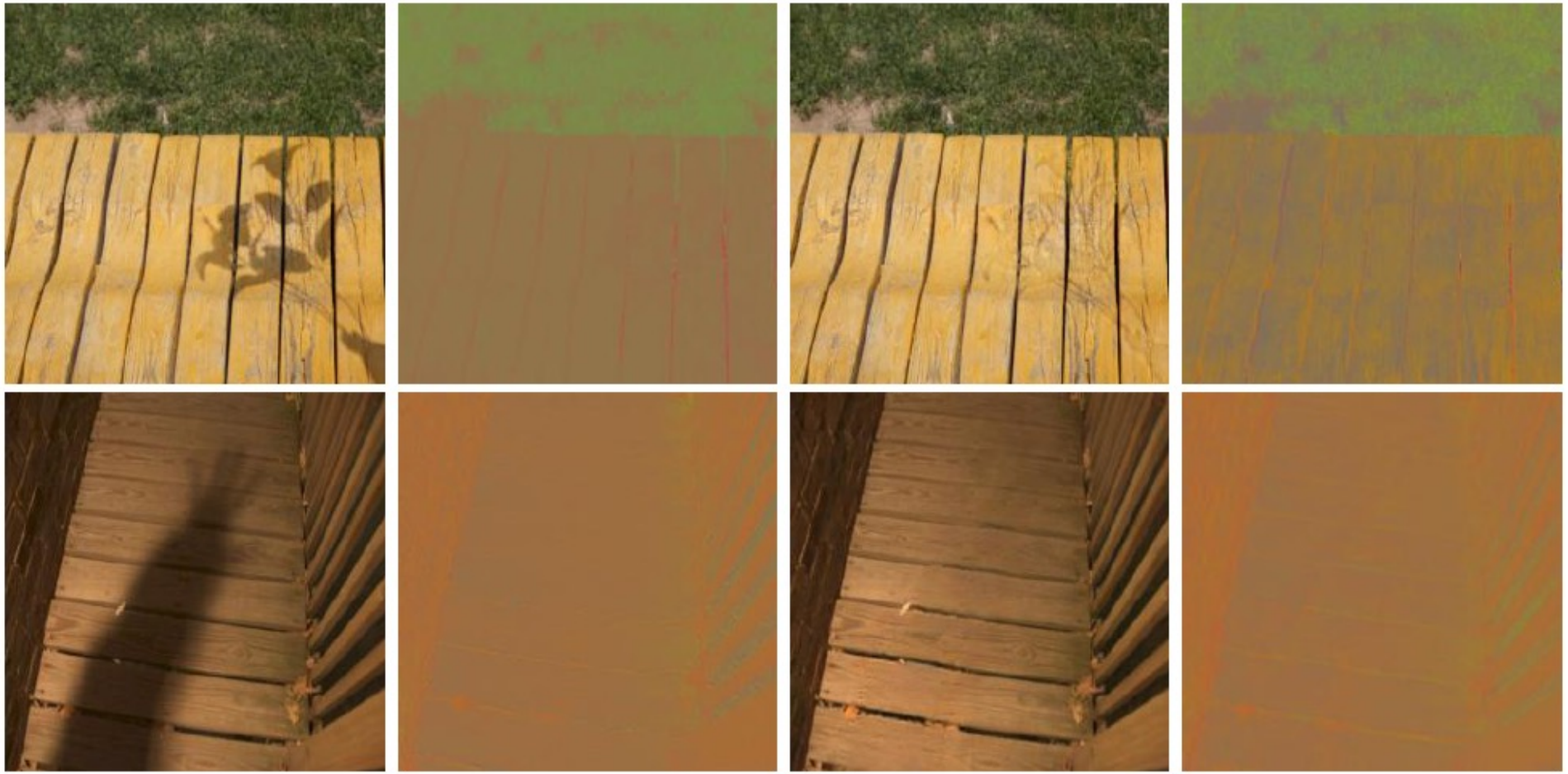
[2] Recovery of chromaticity image free from shadows via illumination invariance. ICCV 2003
[3] On the removal of shadows from images. TPAMI 2005

Shadow-Free Chromaticity Loss



$$\sigma_c = \frac{I_c}{I_r + I_g + I_b}, c \in \{r, g, b\}$$

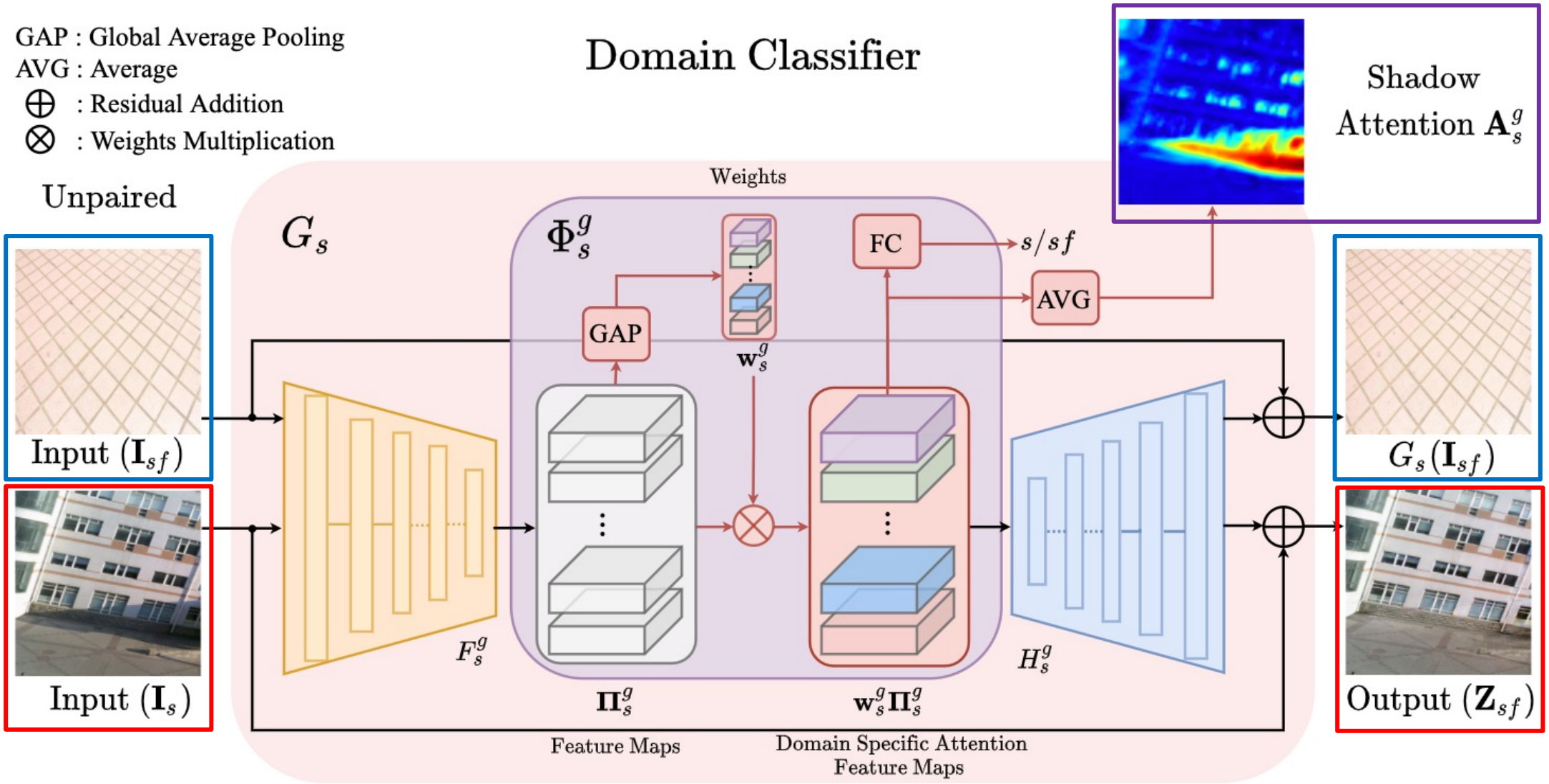
Shadow-Free Chromaticity Loss



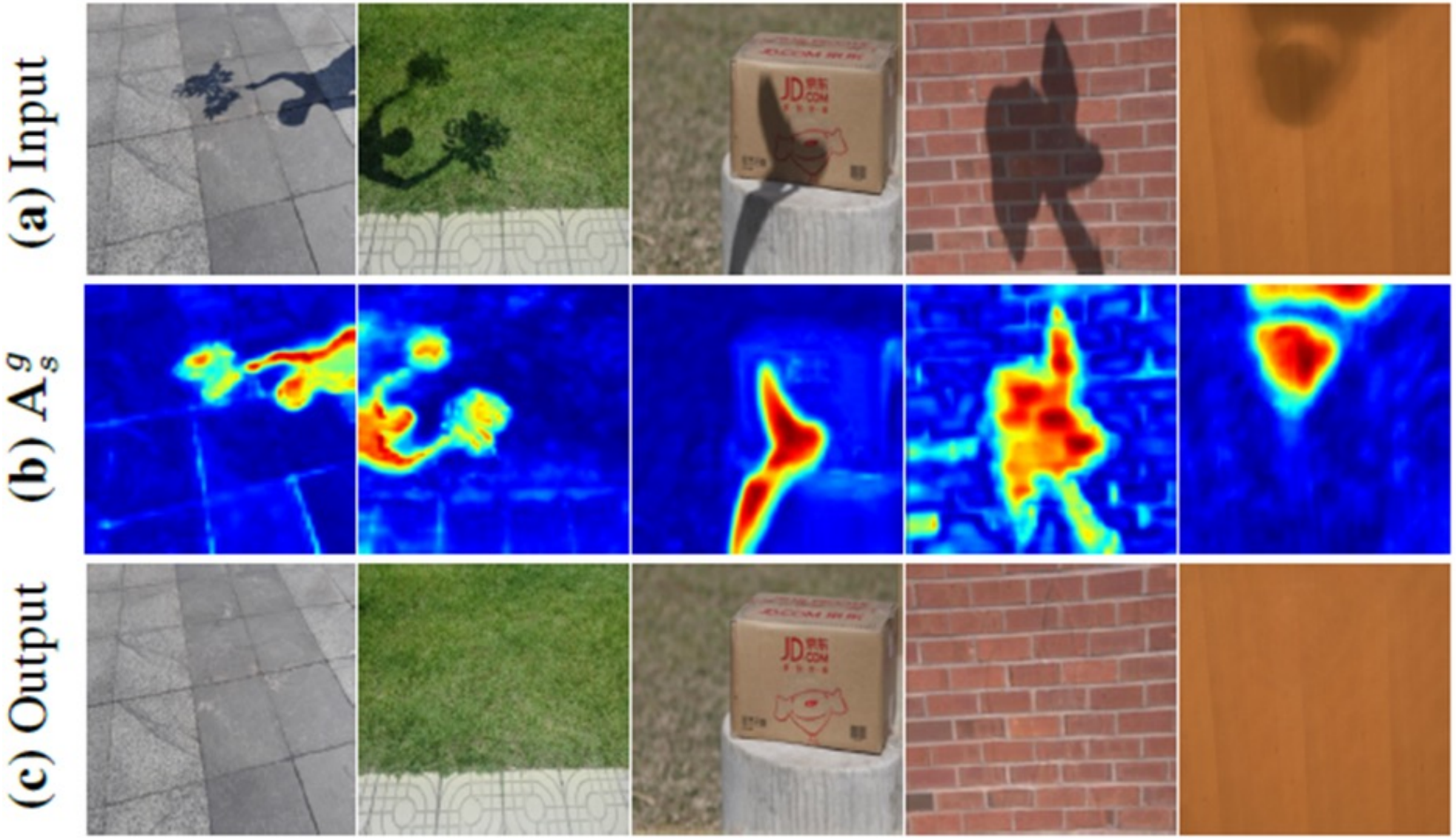
(a) Input Shadow $\mathbf{I}_s$ **(b)** Shadow-Free Chromaticity $\boldsymbol{\sigma}_{sf}^{\text{phy}}$ **(c)** Output Shadow-Free $\mathbf{Z}_{sf}$ **(d)** Chromaticity of the Output $\boldsymbol{\sigma}_{sf}^{\text{Z}}$

$$\mathcal{L}_{\text{chroma}}(G_s) = ||\boldsymbol{\sigma}_{sf}^{\mathbf{Z}} - \boldsymbol{\sigma}_{sf}^{\text{phy}}||_1$$

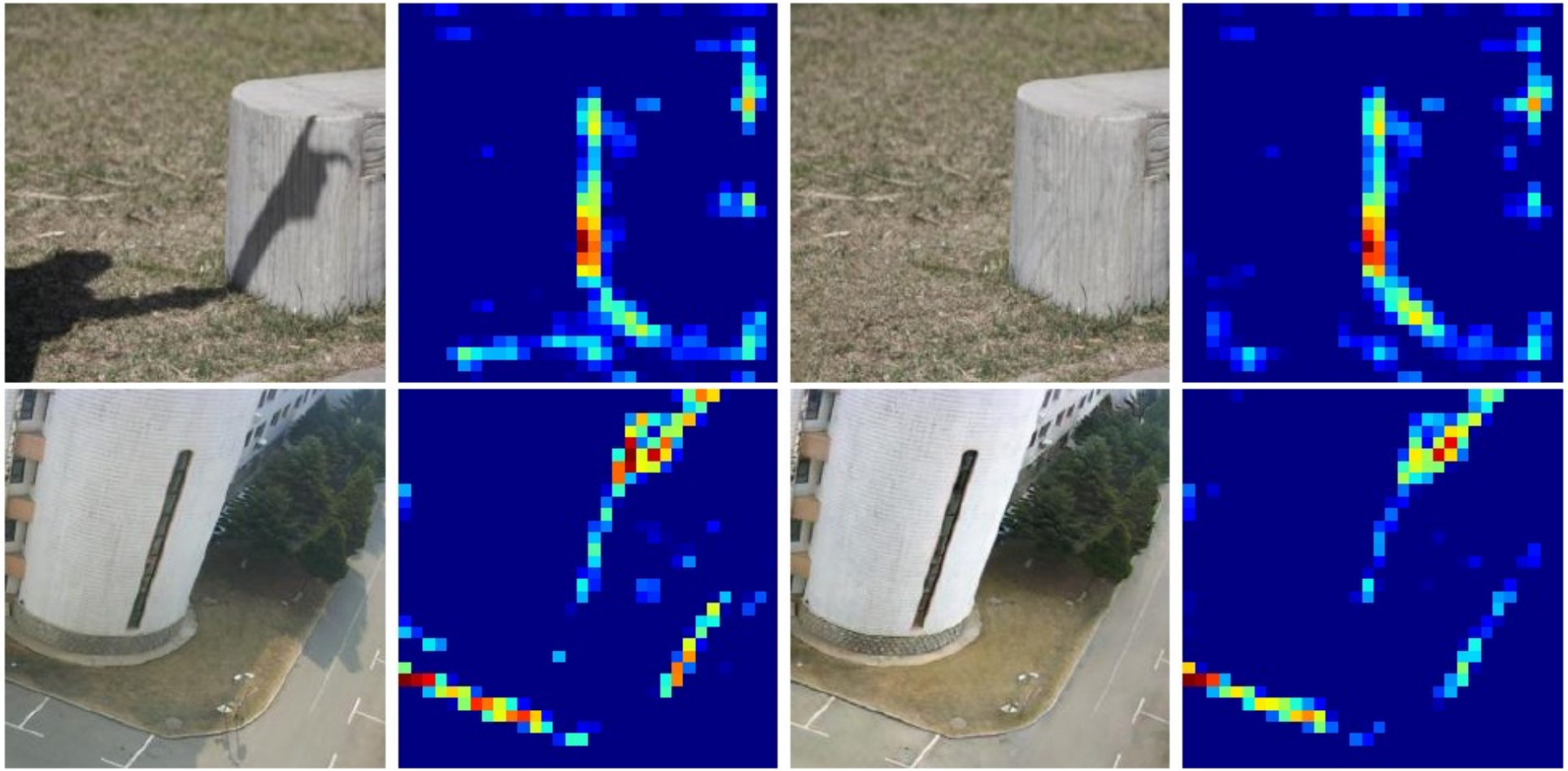
Domain Classifier



Domain Classifier



Shadow-Robust Feature Loss

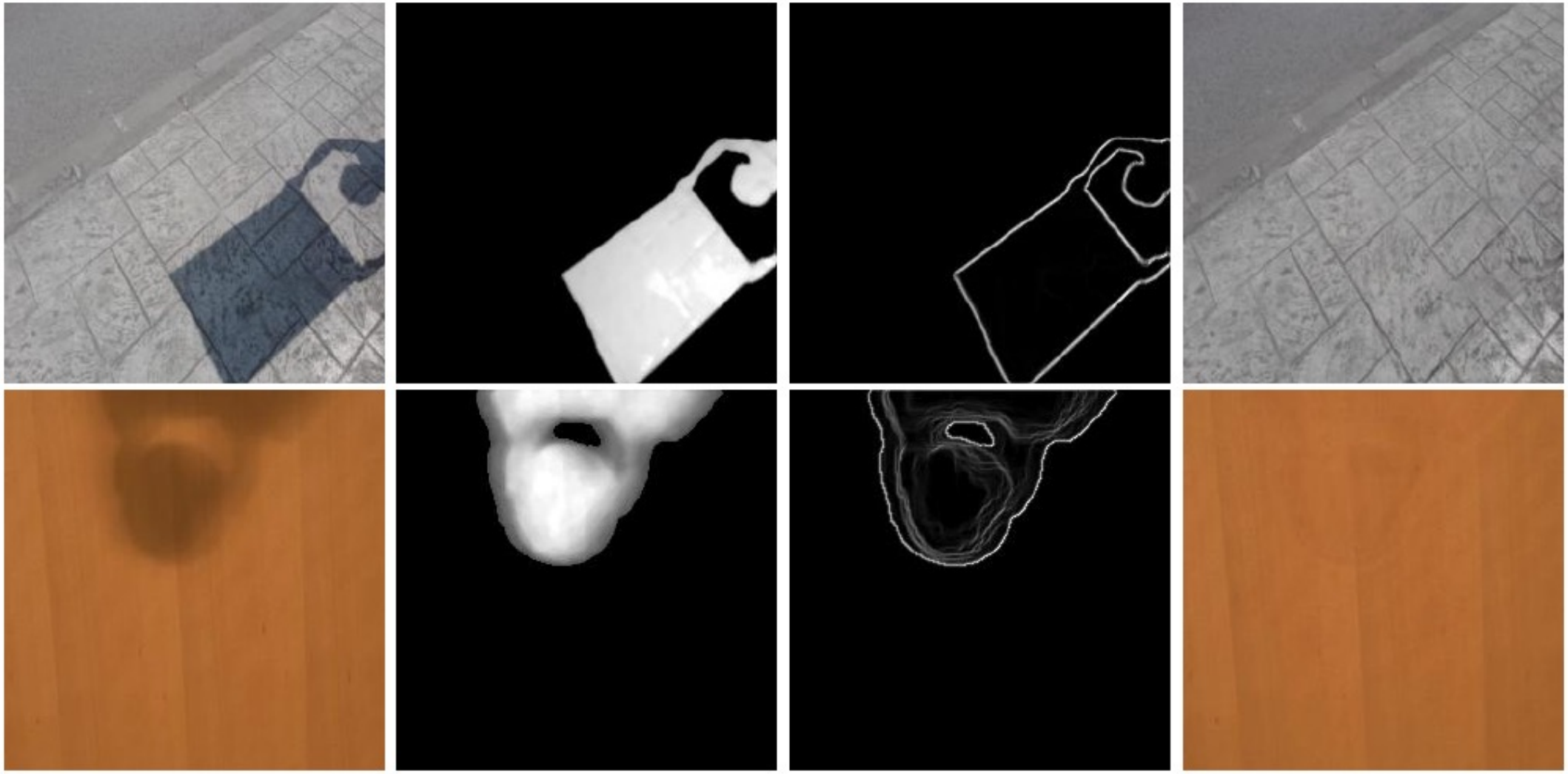


(a) Input Shadow $\mathbf{I}_s$ **(b)** Feature Map of the Input $V(\mathbf{I}_s)$ **(c)** Output Shadow-Free $\mathbf{Z}_{sf}$ **(d)** Feature Map of the Output $V(\mathbf{Z}_{sf})$

$$\mathcal{L}_{\text{feature}}(G_s) = \left\| V(\mathbf{Z}_{sf}) - V(\mathbf{I}_s) \right\|_1,$$

where $V(\mathbf{I}_s)$ and $V(\mathbf{Z}_{sf})$ denote the feature maps extracted from the Conv layer of the pre-trained VGG-16 network.

Boundary Smoothness Loss



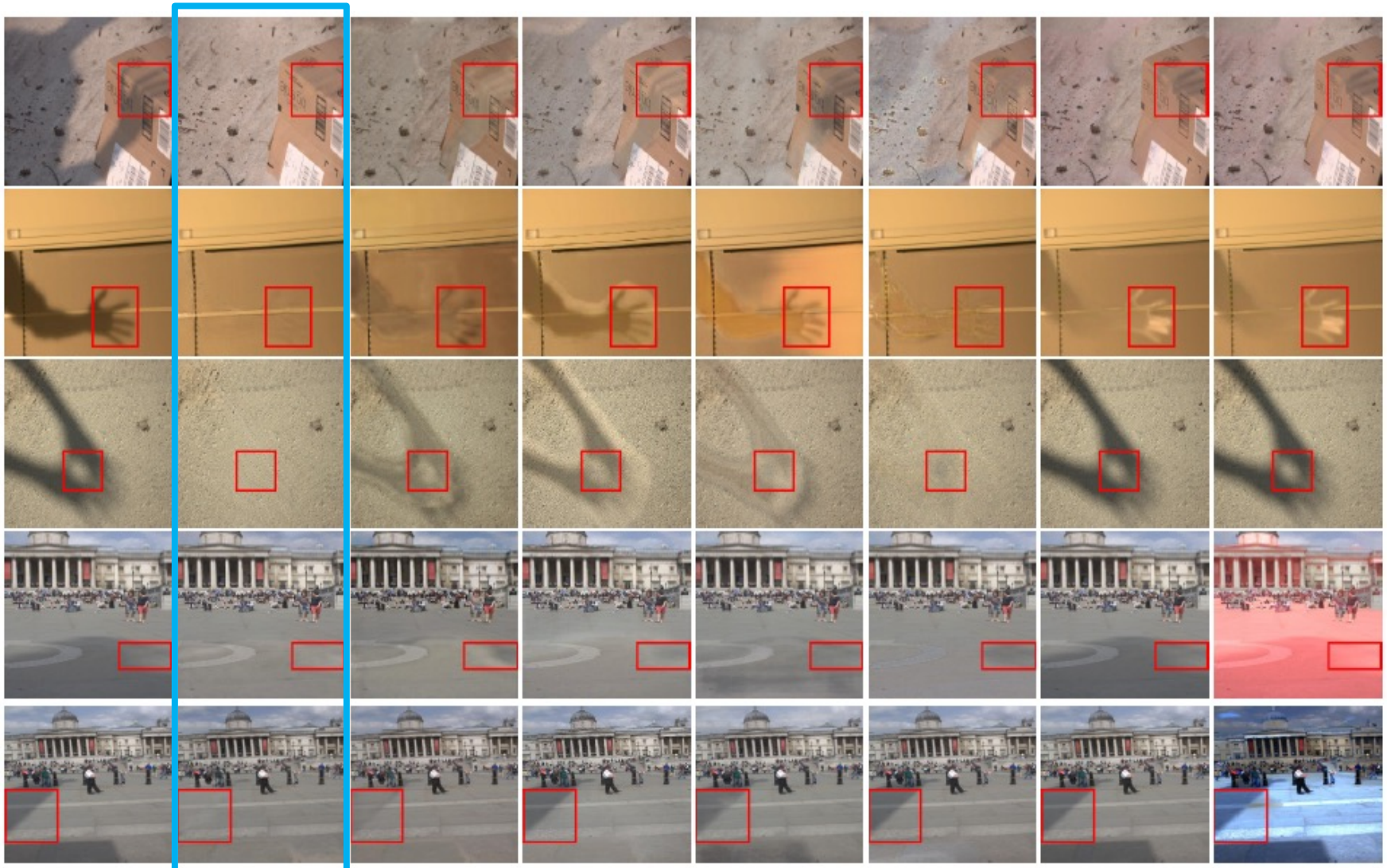
(a) Input Shadow $\mathbf{I}_s$ **(b)** Soft Mask $\mathbf{M}_s$ **(c)** Shadow Boundaries $\mathrm{B}(\mathbf{M}_s)$ **(d)** Output Shadow-Free

Results: Hard Shadows

Results: Hard Shadows

Results: Soft Shadows

Results: Soft Shadows



Quantitative Results

RMSE (lower is better) results on the SRD (left), AISTD (right), LRSS (below) datasets.
All, S and NS represent entire, shadow and non-shadow regions, respectively.

Method	Training	All	S	NS
Our DC-ShadowNet	Unpaired	**4.66**	7.70	3.39
Mask-ShadowGAN [13]	Unpaired	6.40	11.46	4.29
DSC [14]	Paired	4.86	8.81	**3.23**
DeShadowNet [24]	Paired	5.11	**3.57**	8.82
Gong *et al.* [8]	-	12.35	25.43	6.91
Input Image	-	13.77	37.40	3.96

Method	Training	All	S	NS
Our DC-ShadowNet	Unpaired	**4.6**	**10.3**	3.5
Mask-ShadowGAN [13]	Unpaired	5.3	12.5	4.0
DeshadowNet [24]	Paired	7.6	15.9	6.0
ST-CGAN [27]	Paired+M	8.7	13.4	7.7
Gong *et al.* [8]	-	-	13.3	-
Guo *et al.* [10]	Paired+M	6.1	22.0	3.1
Yang *et al.* [32]	-	16.0	24.7	14.4
Input Image	-	8.5	40.2	**2.6**

Method	Input	Guo [11]	Guo [11] (auto)	Gryka [9]	DHAN [1]	SP+M-Net[20]	MaskShadowGAN[13]	**Ours**
RMSE	12.26	6.02	5.87	4.38	7.92	7.48	7.13	**3.48**
PSNR	18.05	27.88	28.02	29.25	25.57	23.93	25.12	**31.01**
Training	-	P+M	P	P+M+S	P+M+S	P+M	UP	UP

[4] Deshadownet: A multi-context embedding deep network for shadow removal. ICCV 2017
[5] Shadow removal via shadow image decomposition. ICCV 2019

Conclusion

• We introduce DC-ShadowNet, a new unsupervised single-image shadow removal network guided by a **domain classifier** to focus on shadow regions.

• We propose novel **unsupervised losses** based on physics, perceptual features, and boundary smoothness losses for robust shadow removal.

• To our knowledge, our method is the **first** unsupervised method to perform shadow removal robustly for both **hard** and **soft** shadow in a single image.

Thank you!

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CODES AND MODEL:

HTTPS://GITHUB.COM/JINYEYING/DC-SHADOWNET-HARD-AND-SOFT-SHADOW-REMOVAL