Scene Understanding — Lighting

Dr Fangcheng Zhong

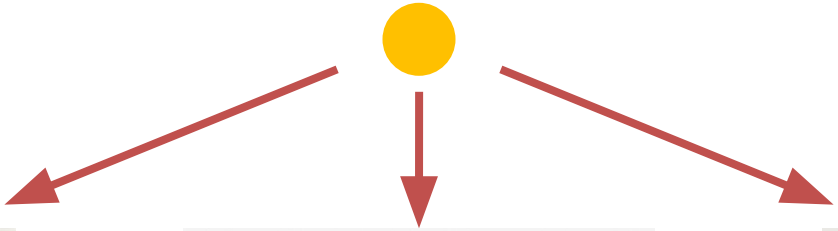
light estimation

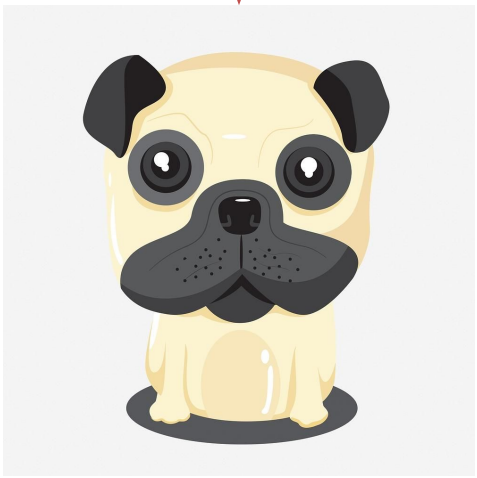
relighting (shading + shadow)

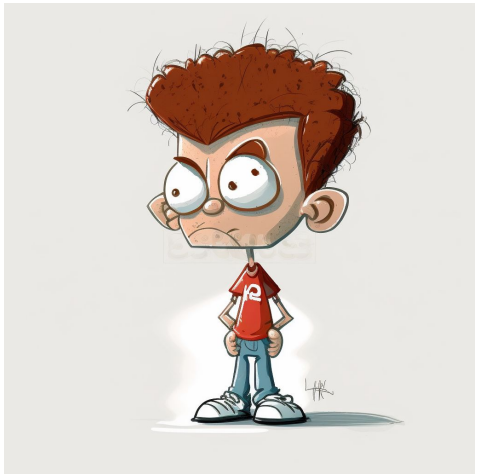
Outline

- Models of light
  - Point light
  - Directional light
  - Environment light
    - lightmap images, spherical harmonics
- Lighting estimation
  - HDR light probes
- Relighting
  - Shadow map

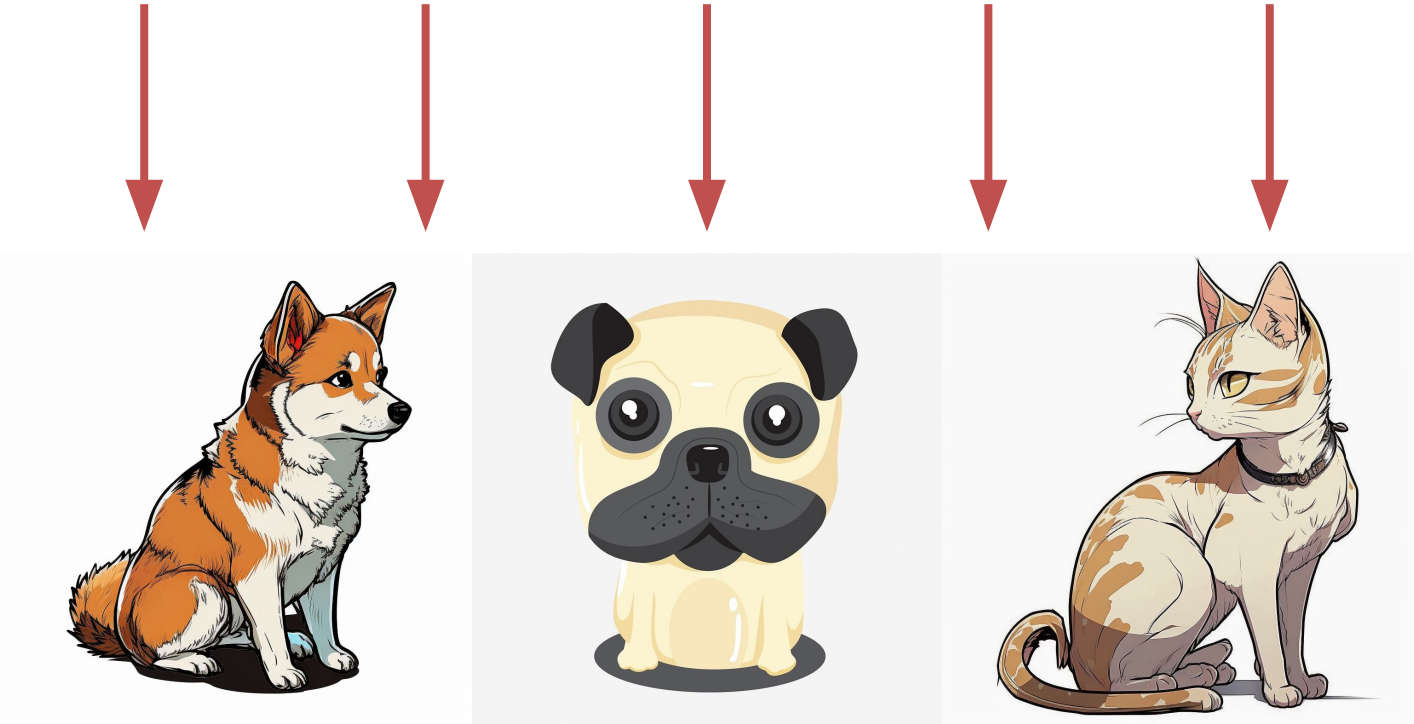
Point Light





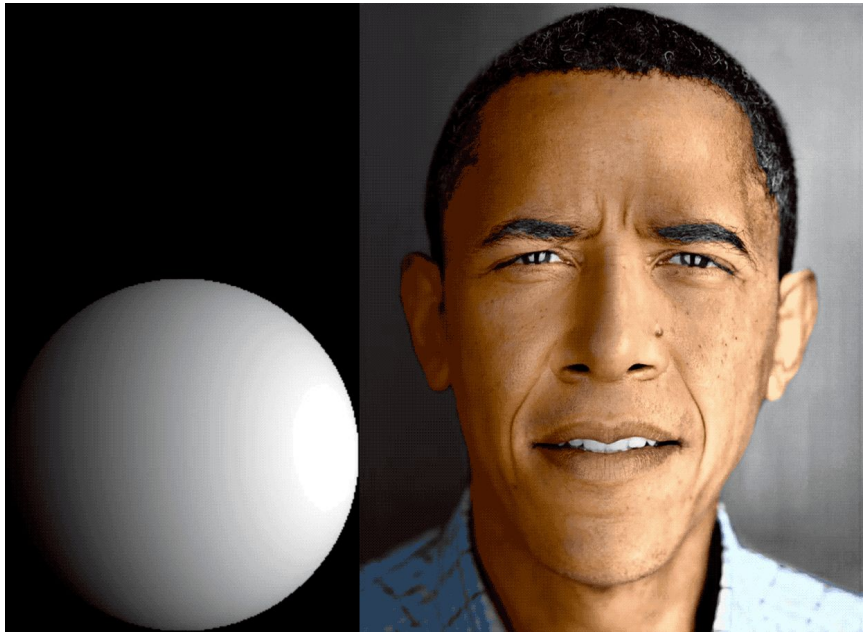


Directional Light



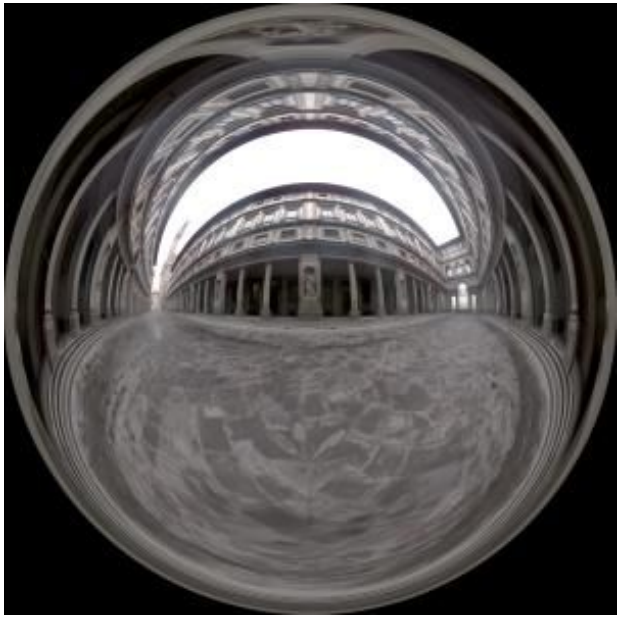
Environment Light

- A mapping representing distant lighting from all directions



$$f(\mathbf{x}, \theta, \varphi)$$
$$= \text{light intensity}$$

Lightmap Images



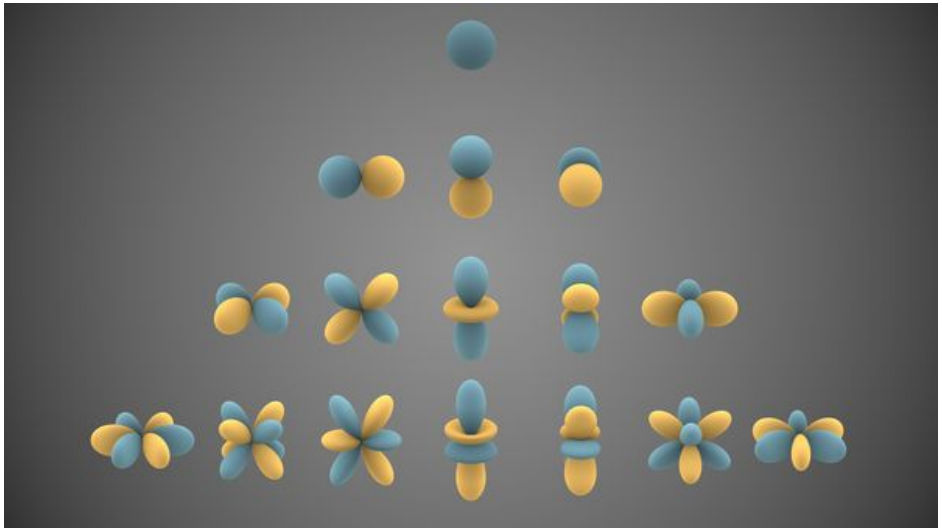
spherical map

Lightmap Images

cube map

Spherical Harmonics

- A set of basis functions to represent functions defined on the surface of a sphere



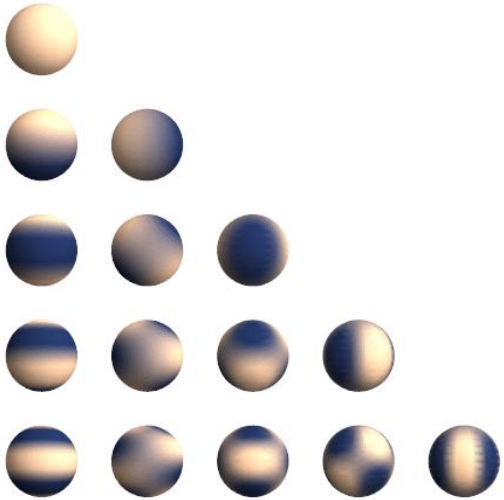
Spherical Harmonics

$$Y_l^m(\theta, \varphi) = N e^{im\varphi} P_l^m(\cos\theta)$$

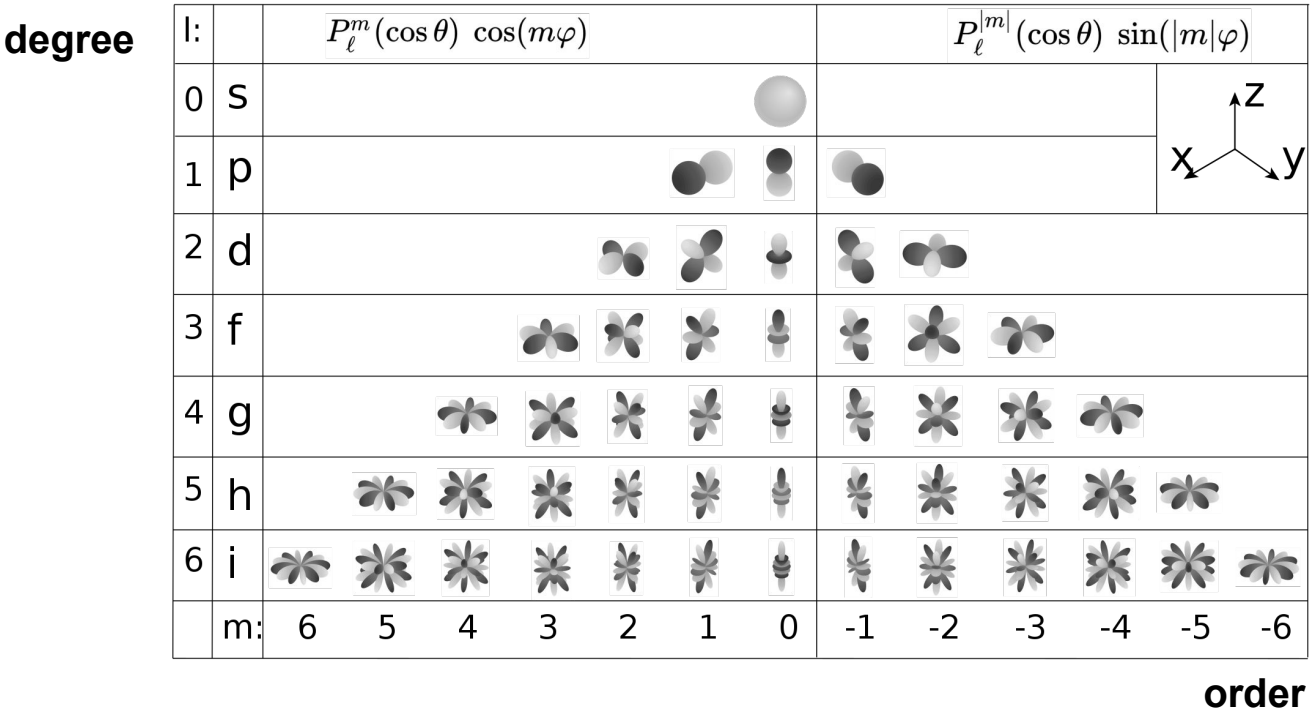
Y_ℓ^m — **spherical harmonic function** of degree $\ell \in \{ 0, 1, 2, \ldots\}$ and order $m \in [-\ell, \ell]$

P_ℓ^m — associated Legendre polynomial

N — normalising constant



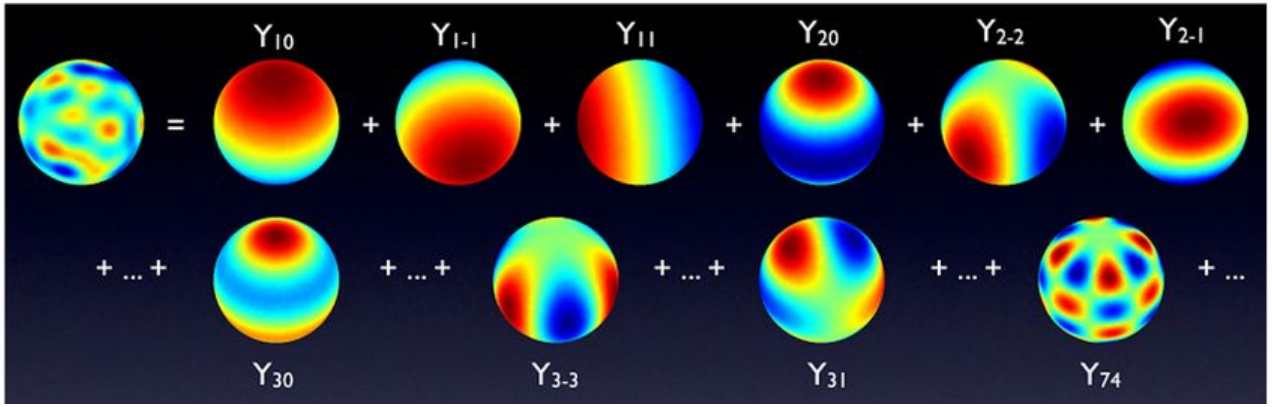
Spherical Harmonics



Spherical Harmonics

- Use the coefficients of the spherical harmonic functions to represent illumination

$$f(\theta,\varphi)=\sum_{l=0}^{\infty}\sum_{m=-l}^{l}a_l^m Y_l^m(\theta,\varphi)$$

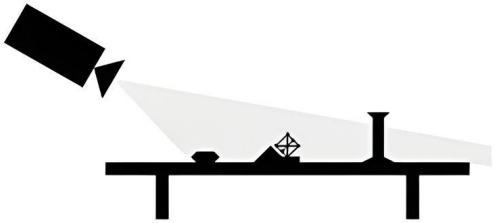


	Spherical harmonics	Lightmap images
Storage	compact	memory intensive
Computation	expensive	fast
Accuracy	limited	high
Editability	difficult	controllable
Generalisability	yes	no

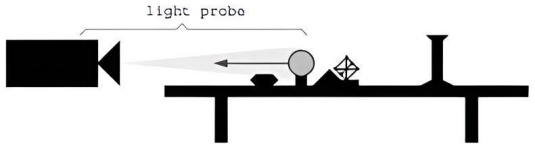
Light Estimation

light probe images

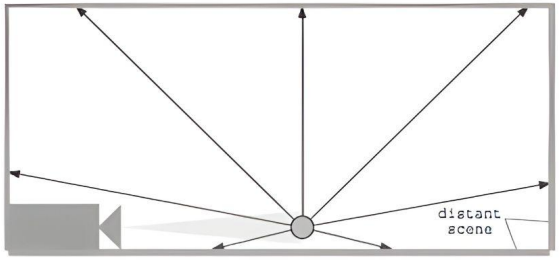
Light Probes



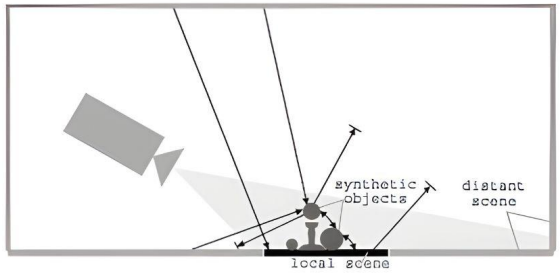
(a) Acquiring the background photograph



(b) Using the light probe



(c) Constructing the light-based model



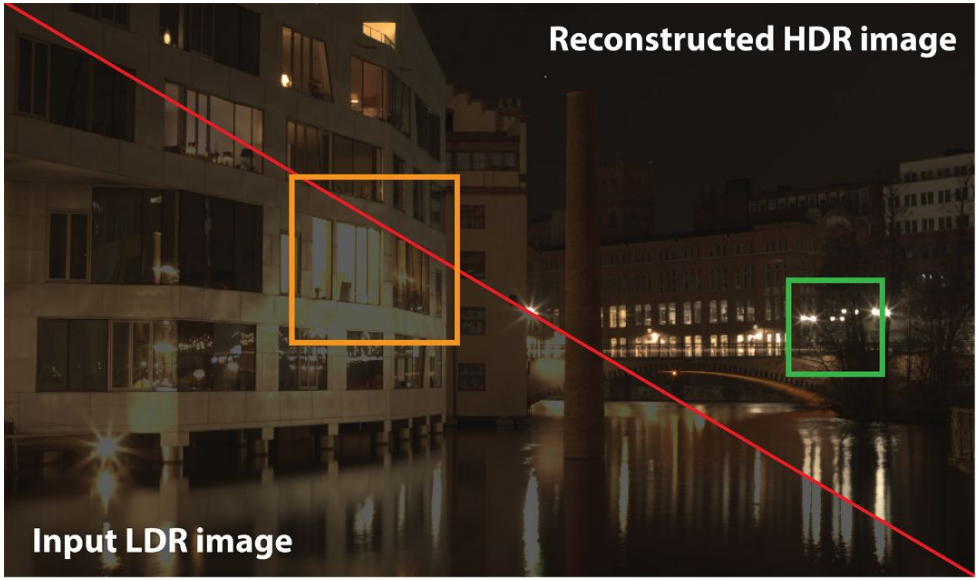
(d) Computing the global illumination solution

P. Debevec, “Rendering synthetic objects into real scenes: bridging traditional and image-based graphics with global illumination and high dynamic range photography,” in ACM SIGGRAPH 2008 classes, Los Angeles, California, Aug. 2008

Omnidirectional Light Estimation

LeGendre, Chloe, et al. "Deeplight: Learning illumination for unconstrained mobile mixed reality." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2019.

HDR Estimation

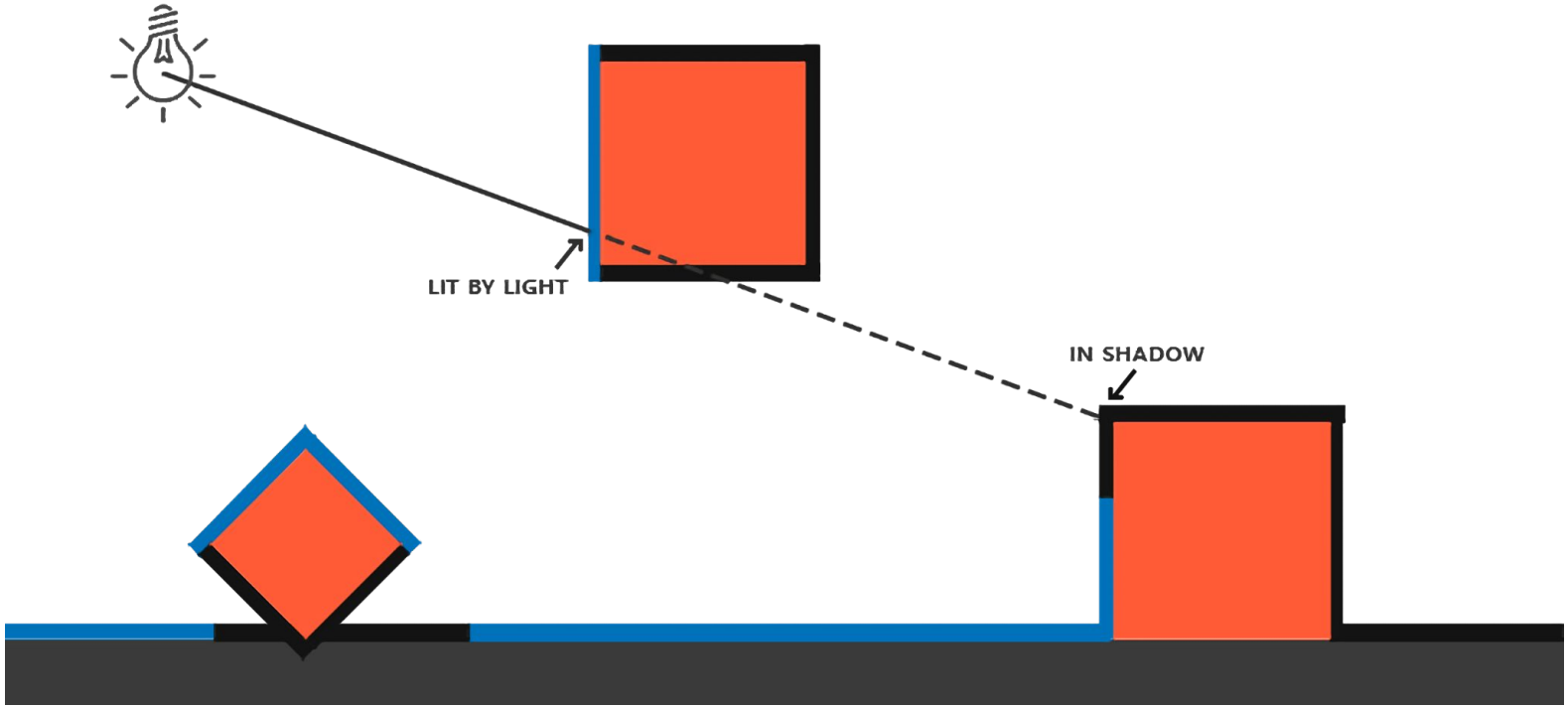


Gabriel Eilertsen, Joel Kronander, Gyorgy Denes, Rafał K. Mantiuk, Jonas Unger. HDR image reconstruction from a single exposure using deep CNNs. In: ACM Transactions on Graphics (Proc. of SIGGRAPH Asia 2017), 36(6), Article 178, 2017.

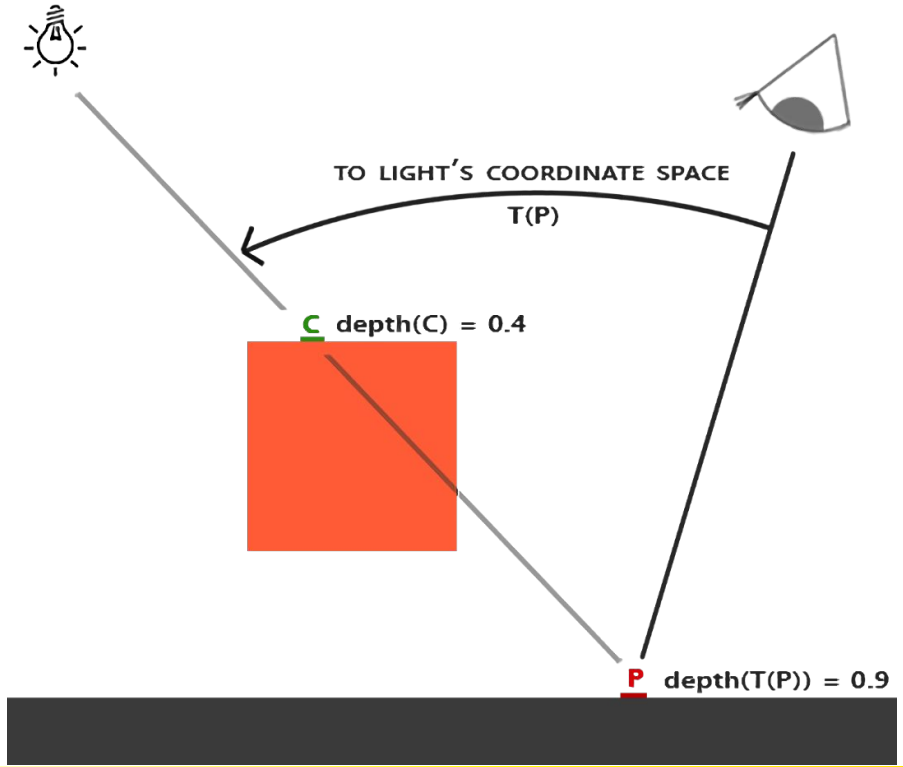
Relighting

relighting = shading + shadow

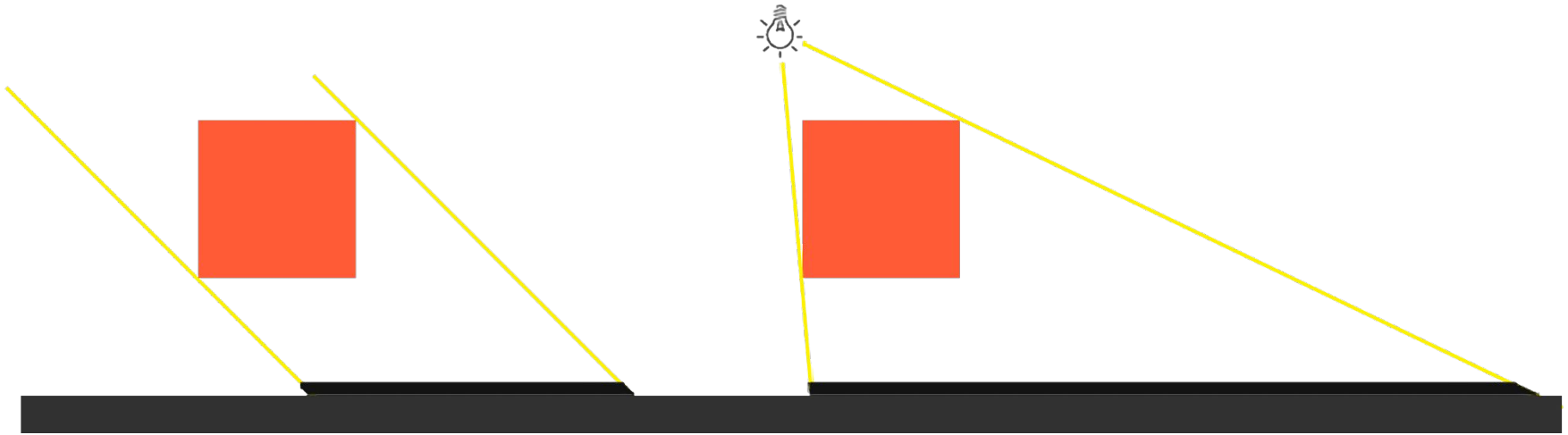
Shadow Mapping



Shadow Mapping



Shadow Mapping

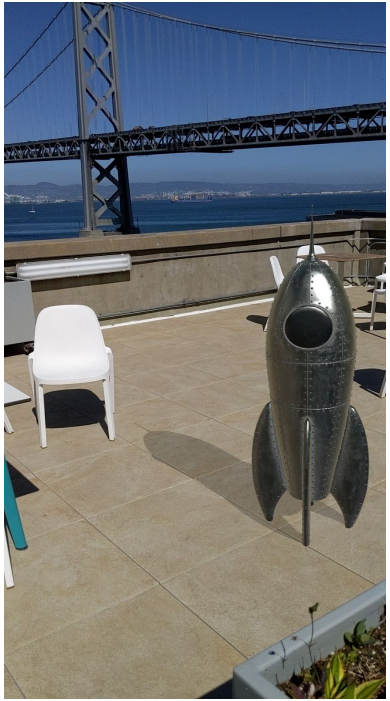
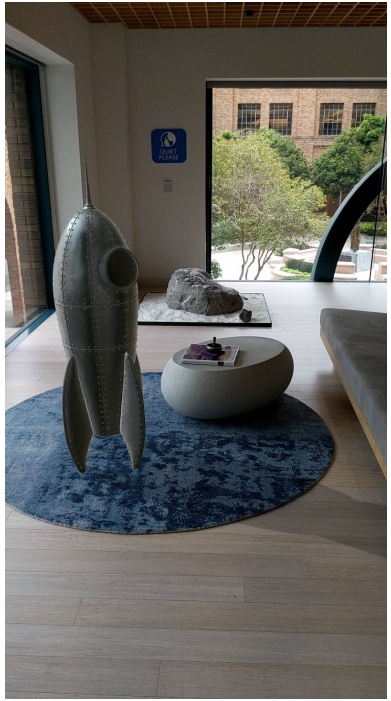


orthographic projection
(directional light)

perspective projection
(point light)

Shadow Mapping

Relighting

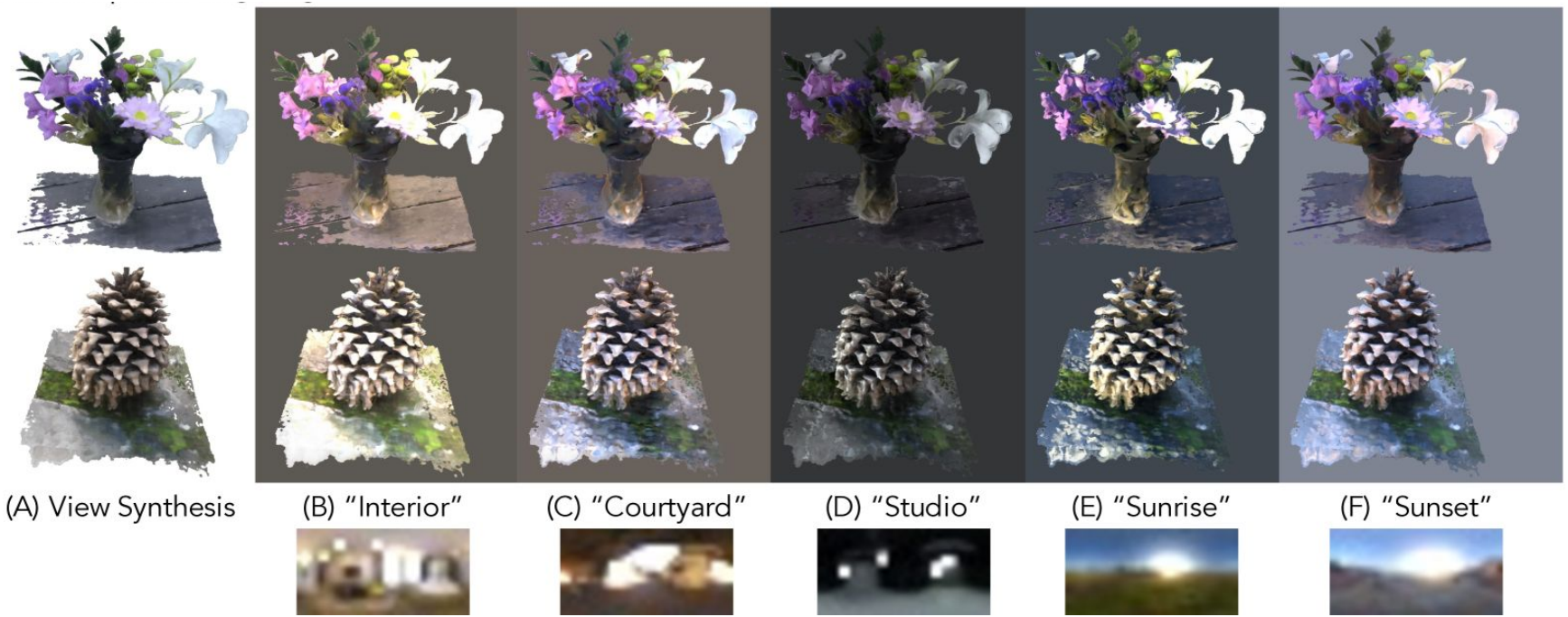




ARCore relighting

Relighting

Philip, Julien, et al. "Multi-view relighting using a geometry-aware network." *ACM Trans. Graph.* 38.4 (2019): 78-1.

Relighting



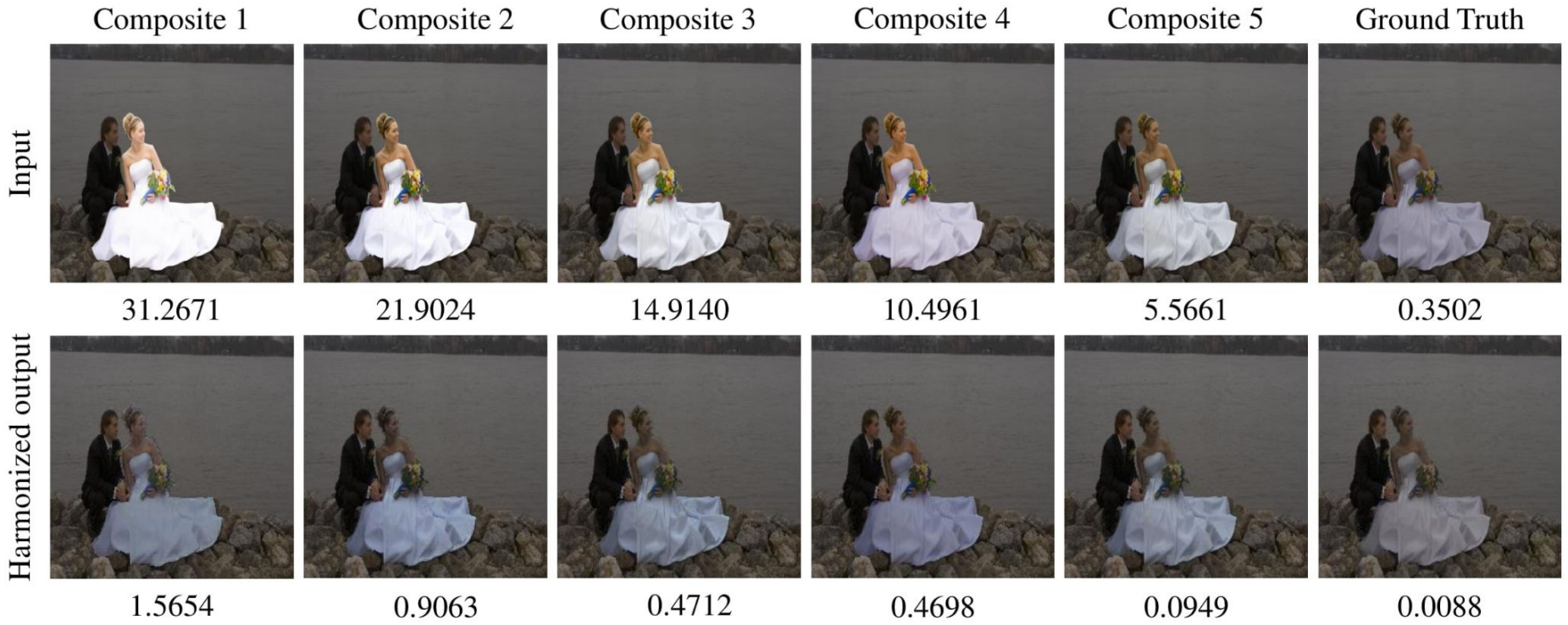
Zhang, Xiuming, et al. "Nerfactor: Neural factorization of shape and reflectance under an unknown illumination." ACM Transactions on Graphics (TOG) 40.6 (2021): 1-18.

Relighting

Input Image

Pandey, Rohit, et al. "Total relighting: learning to relight portraits for background replacement." ACM Transactions on Graphics (TOG) 40.4 (2021): 1-21.

Image Harmonisation



Cong, Wenyan, et al. "Bargainnet: Background-guided domain translation for image harmonization." *2021 IEEE International Conference on Multimedia and Expo (ICME)*. IEEE, 2021.

Image Harmonisation

(a) Input (b) IIH [21] (c) CDT [11]

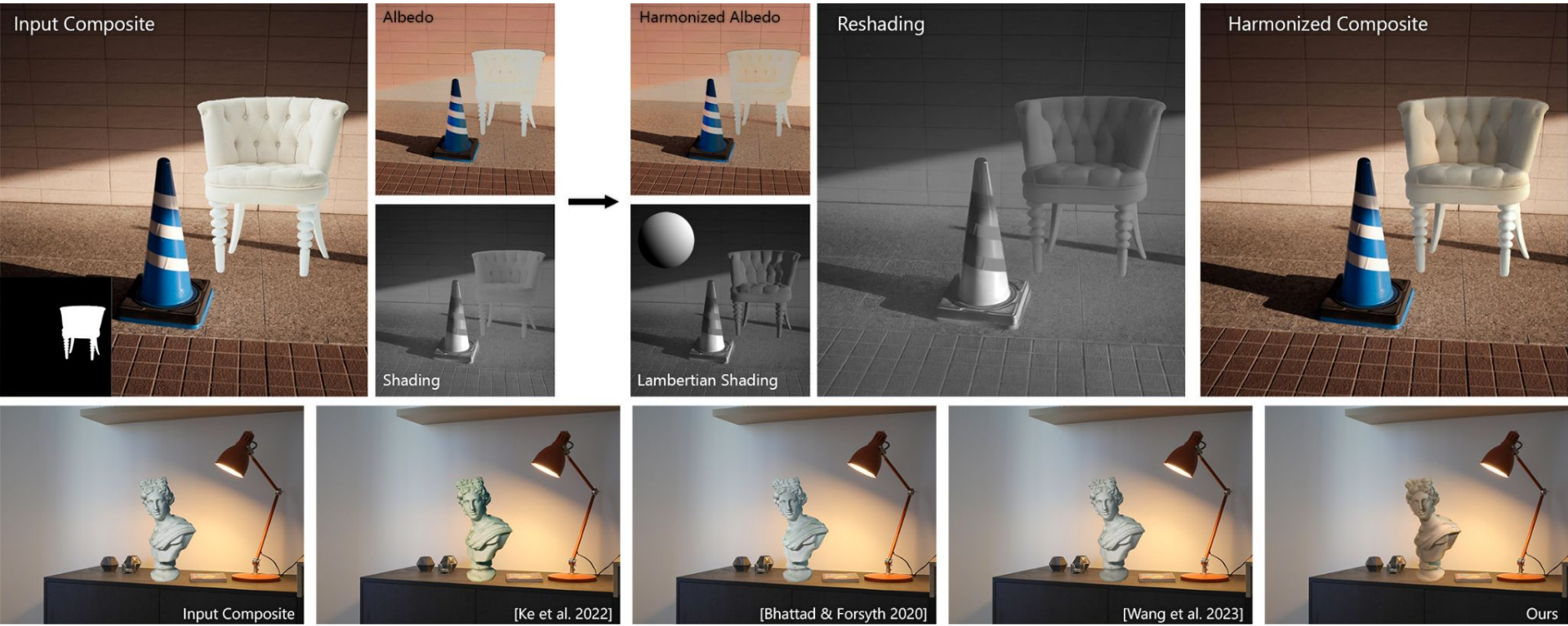
(d) WBH [29] (e) Ours (f) Ground Truth

(g) Input (h) IIH [21] (i) CDT [11]

(j) WBH [29] (k) Ours (l) Ground Truth

Xu, K., Hancke, G.P. and Lau, R.W., 2023. Learning image harmonization in the linear color space. In *Proceedings of the IEEE/CVF International Conference on Computer Vision* (pp. 12570-12579).

Image Harmonisation



Chris Careaga, S. Mahdi H. Miangoleh, and Yağız Aksoy. 2023. Intrinsic Harmonization for Illumination-Aware Image Compositing. In SIGGRAPH Asia 2023 Conference Papers (SA '23). Association for Computing Machinery, New York, NY, USA, Article 100, 1–10. https://doi.org/10.1145/3610548.3618178

Castle in the Sky:
Dynamic Sky Replacement and Harmonization in Videos

Zhengxia Zou
University of Michigan, Ann Arbor
October 2020