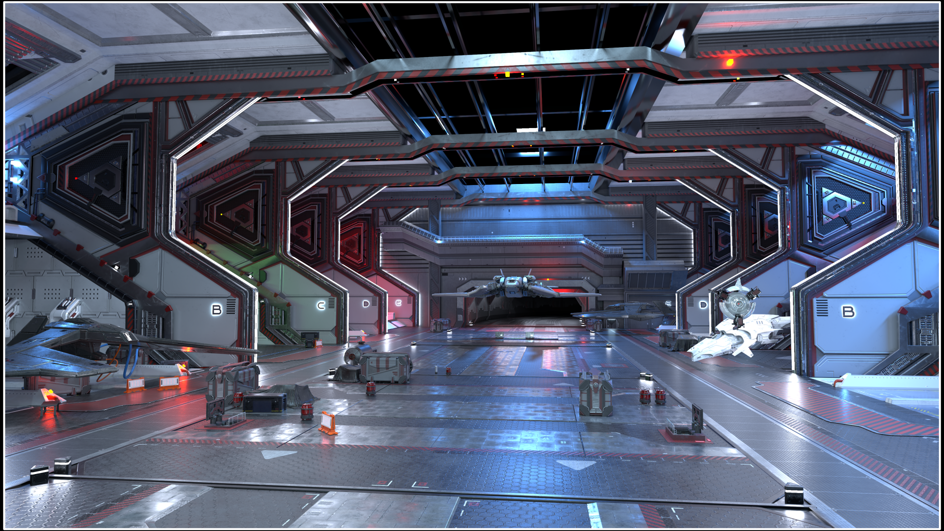
Hierarchical Light Sampling with Accurate Spherical Gaussian Lighting

Yusuke Tokuyoshi
Sho Ikeda
Paritosh Kulkarni
Takahiro Harada

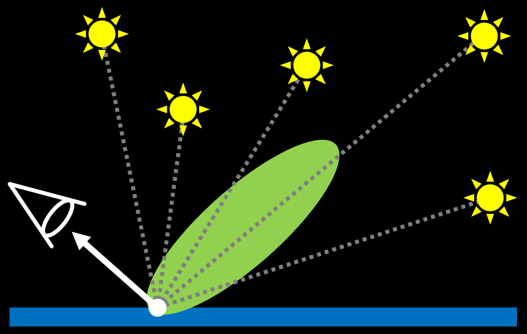
ARR
Advanced Rendering Research Group



Bistro [Amazon Lumberyard 2017]

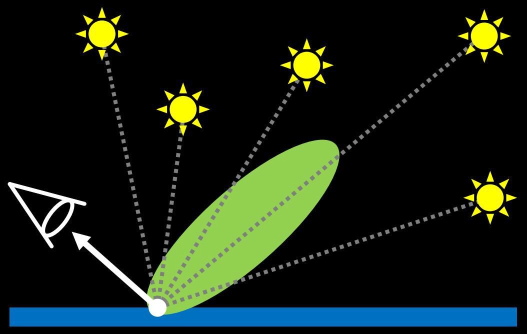
Opera House Kit [ArtcoreStudios 2022]

Challenge: Product Importance Sampling for Many Lights



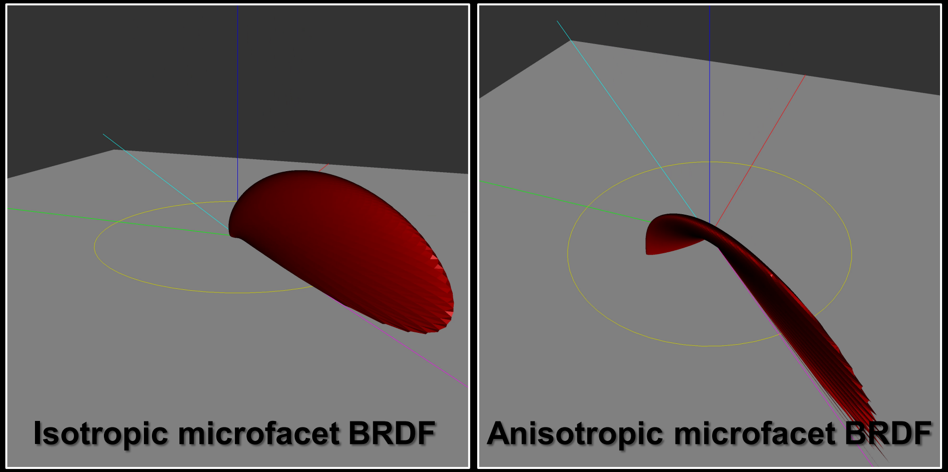
- Sampling according to a BRDF lobe × light sources

Challenge: Product Importance Sampling for Many Lights



- Sampling according to a BRDF lobe × light sources

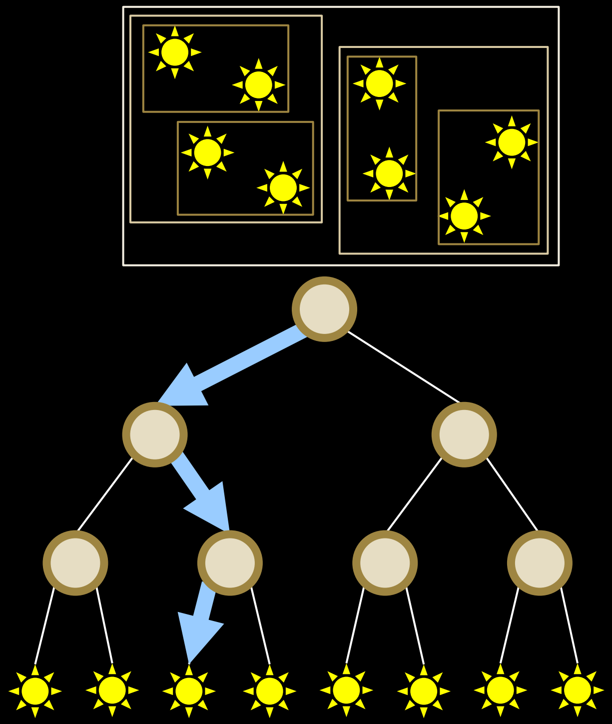
- Difficult for glossy microfacet BRDFs ☹
  - Anisotropic reflection at grazing angles
    - Even if the distribution of microfacet normals (NDF) is isotropic
  - Anisotropic NDF



The Disney BRDF Explorer (https://github.com/wdas/brdf)

Hierarchical Light Sampling [Conty and Kulla 2018]

- Sampling using a light tree (i.e., a hierarchy of light clusters)
- Traverse the tree by randomly selecting a child node according to the importance of the node



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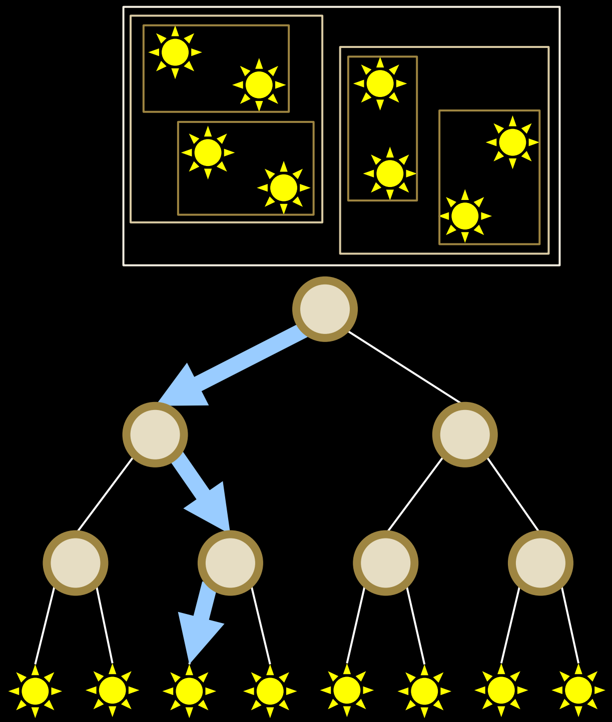

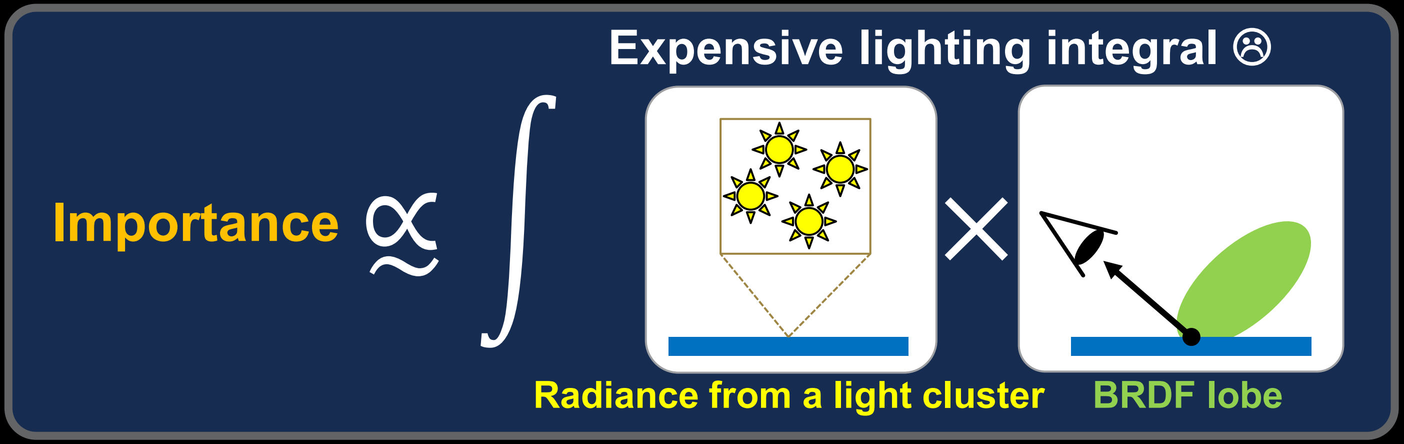

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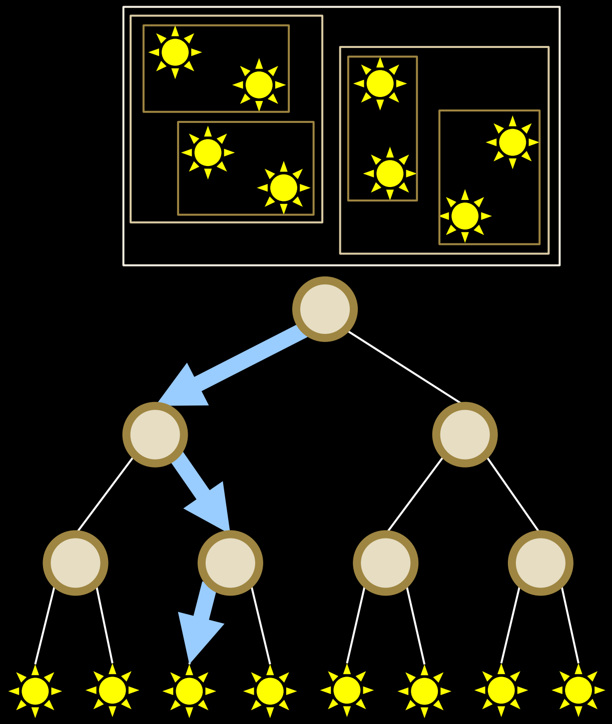

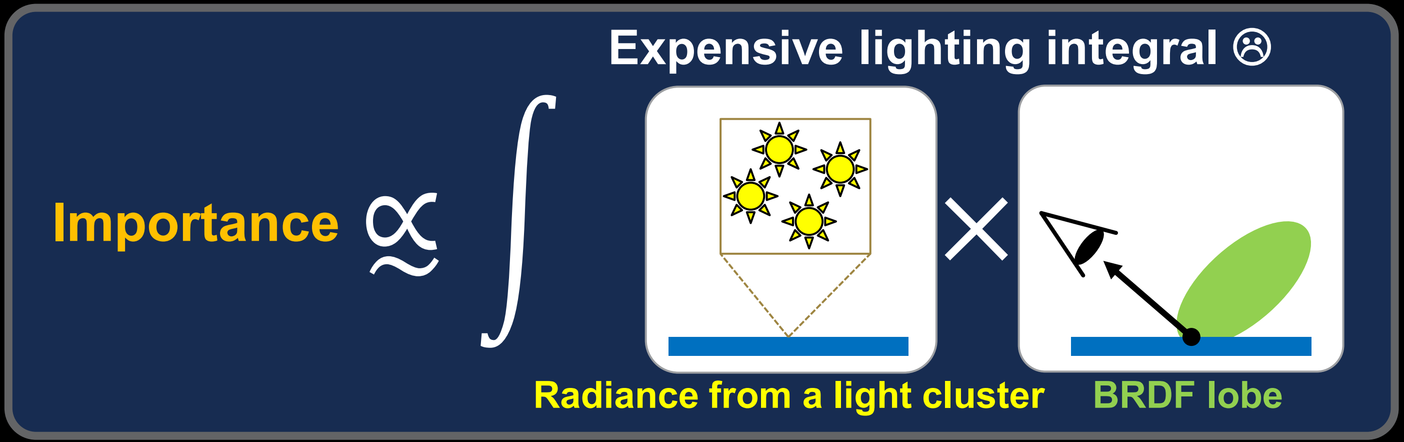

Previous approximations:

- Ignore BRDFs and use upper bounds [Conty and Kulla 2018; Yuksel 2021]
- Ignore the anisotropy of reflections [Liu et al. 2019]
- Heuristics to reduce over-estimation [Lin and Yuksel 2020; Conty et al. 2024]

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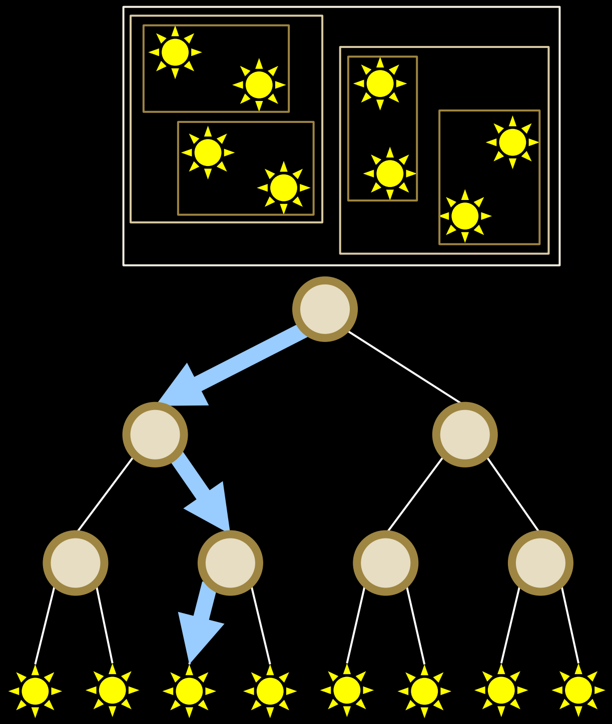
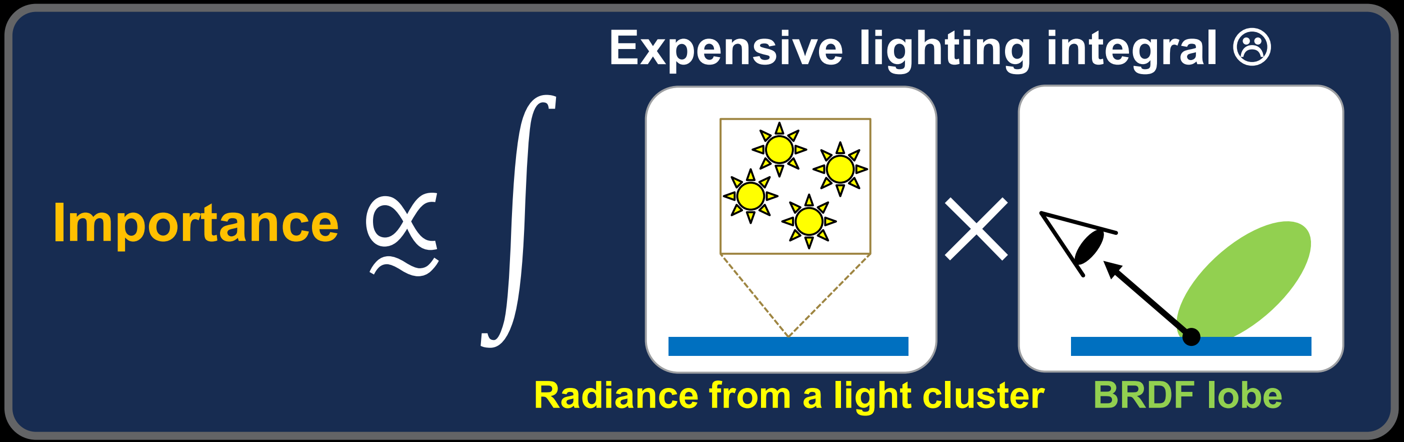


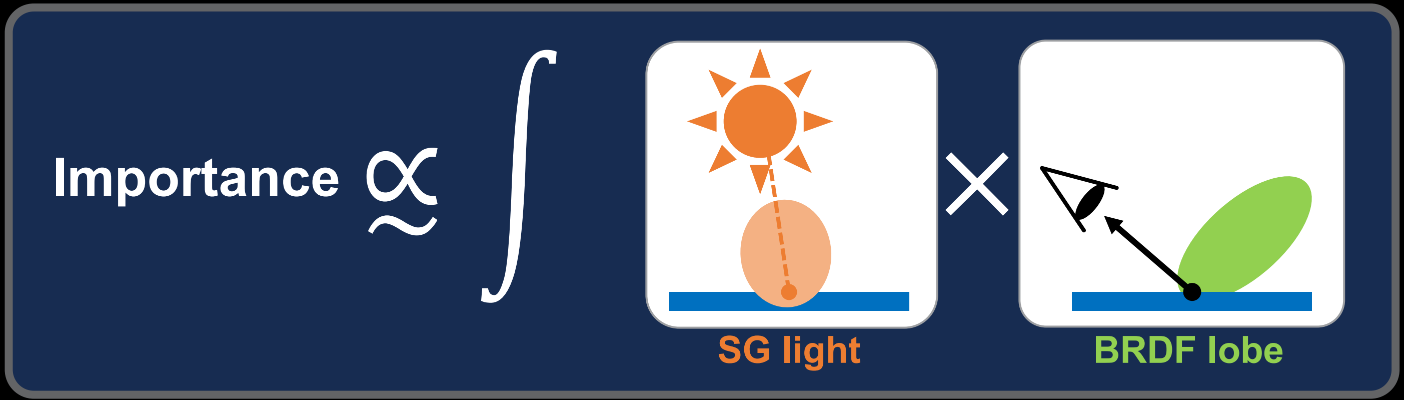


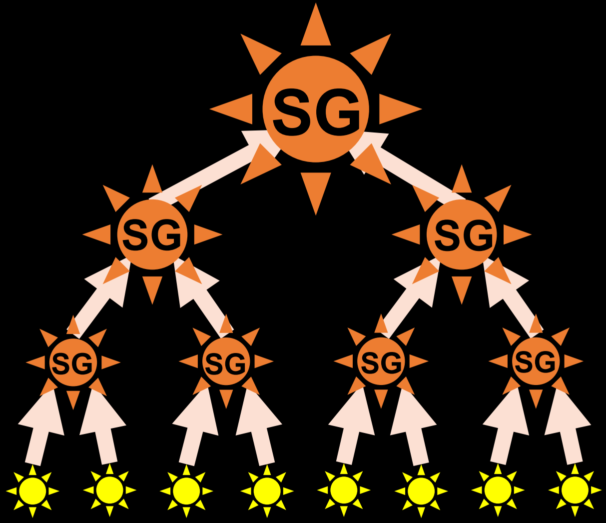
Improve the approximation

Importance Based on Spherical Gaussian (SG) Lighting

- Build an SG light tree
  - Approximate a light cluster into an isotropic SG light (Gaussian×vMF) for each node [Tokuyoshi 2015]
  - Average the Gaussian and vMF distributions of lights in bottom-up
  - More compact than the traditional light BVH [Conty and Kulla 2018]

- Incoming radiance from a light cluster → single-lobe SG
- Closed-form SG lighting?





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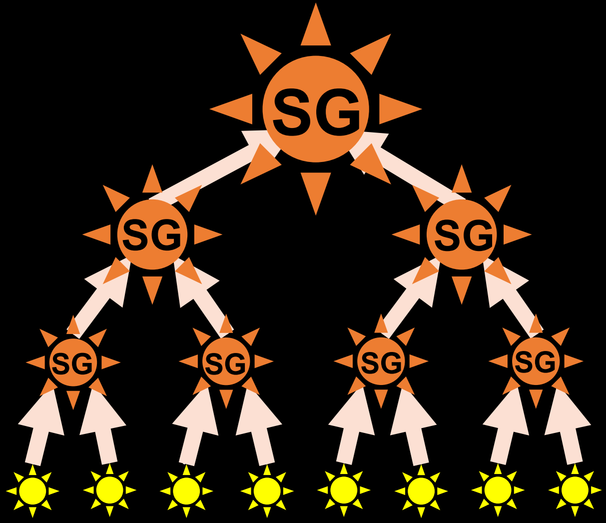

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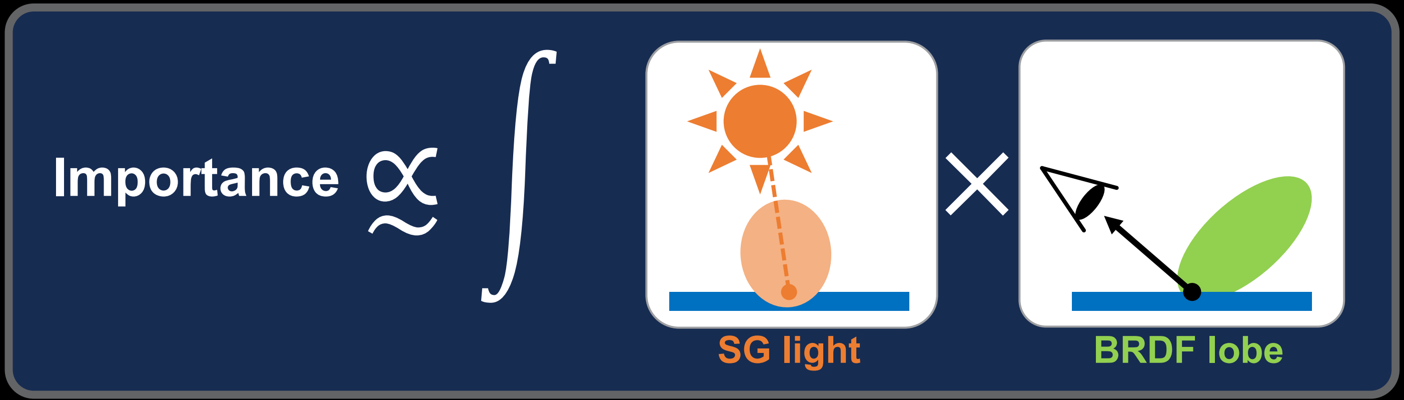


Existing SG lighting further approximated the BRDF lobe with (anisotropic) SGs [Wang et al. 2009; Xu et al. 2013]

Visualization of Existing SG Lighting Approximation

Anisotropic SG lighting
[Xu et al. 2013]

Reference

Visualization of Existing SG Lighting Approximation

☹

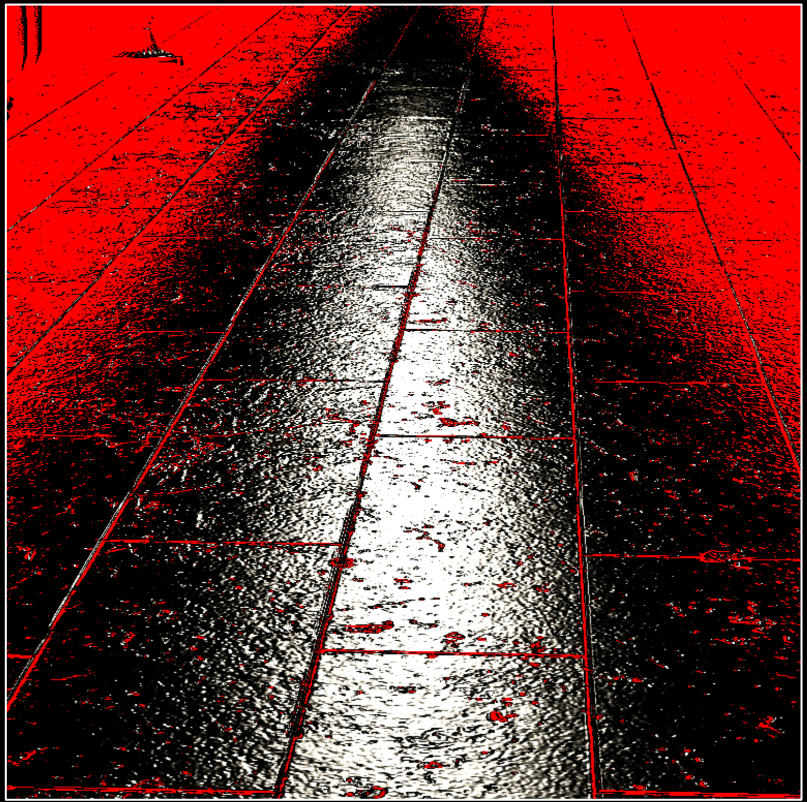
Approximated by zero

↓

Cannot sample lights

↓

Biased sampling



Anisotropic SG lighting
[Xu et al. 2013]

Reference

Anisotropic SG lighting
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New SG Lighting Approximation

Anisotropic SG lighting
[Xu et al. 2013]

Our SG lighting

Reference

New SG Lighting Approximation

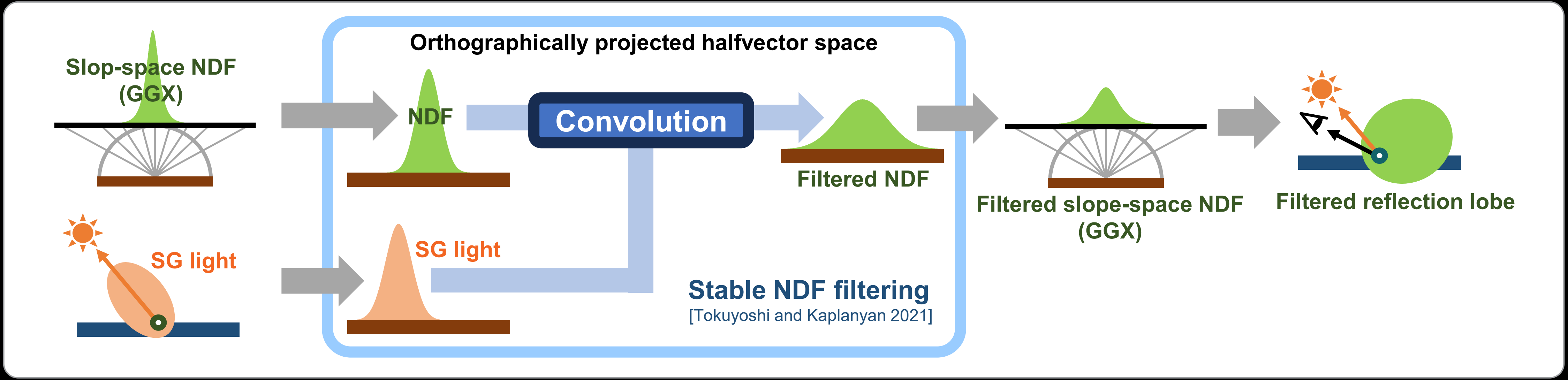
Does not approximate BRDF lobes with (A)SGs

Anisotropic SG lighting
[Xu et al. 2013]

Our SG lighting

Reference

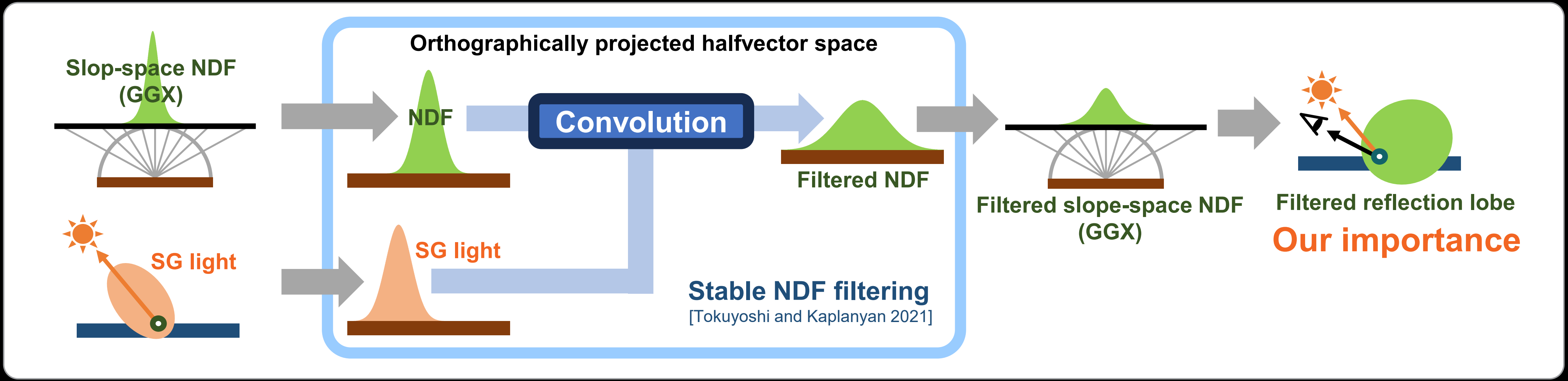
Glossy SG Lighting with Bivariate NDF Filtering
[Kaplaynan et al. 2016]



- Convolve the NDF with an SG light in halfvector space

Glossy SG Lighting with Bivariate NDF Filtering

[Kaplaynan et al. 2016]



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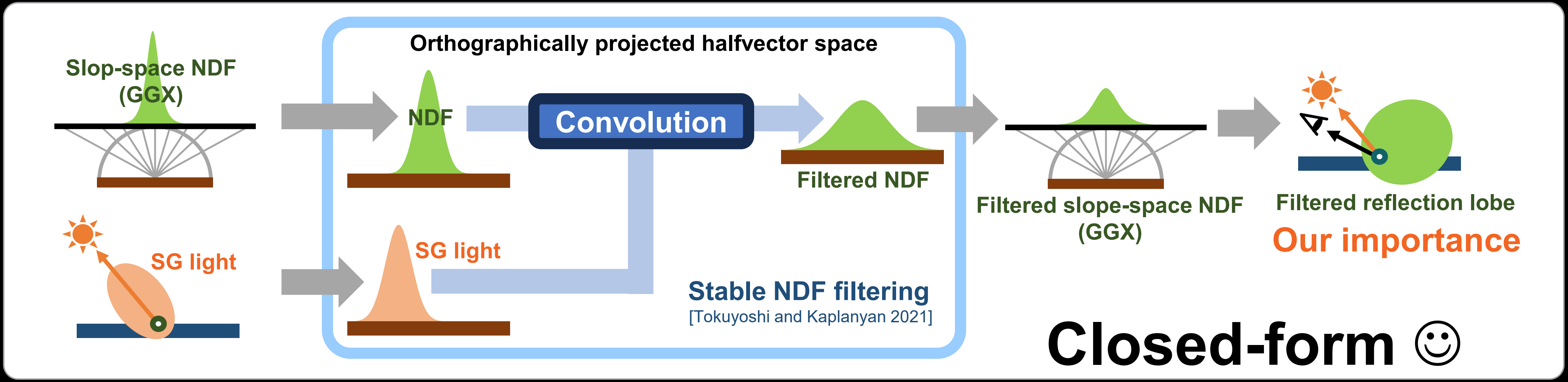

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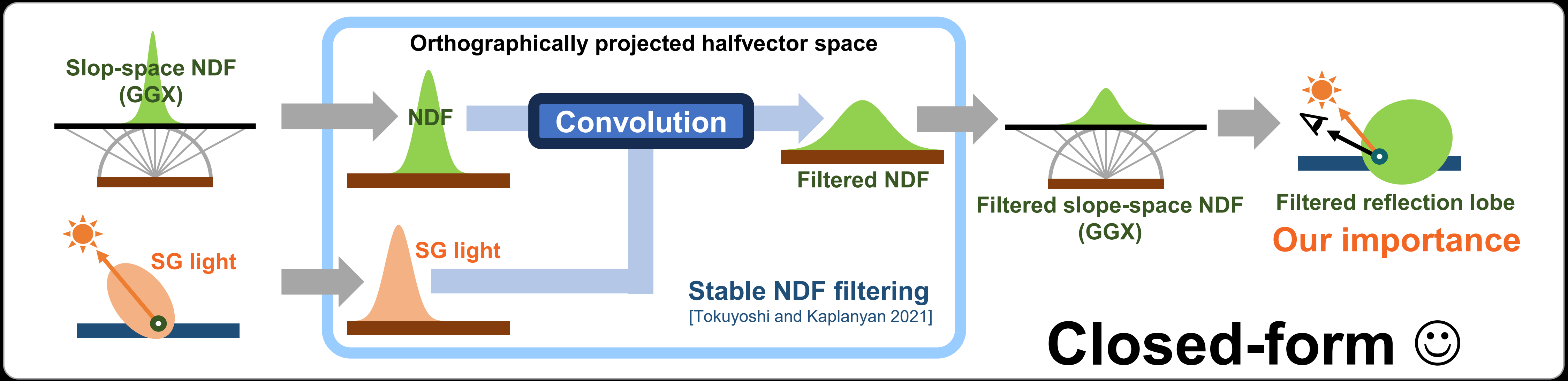
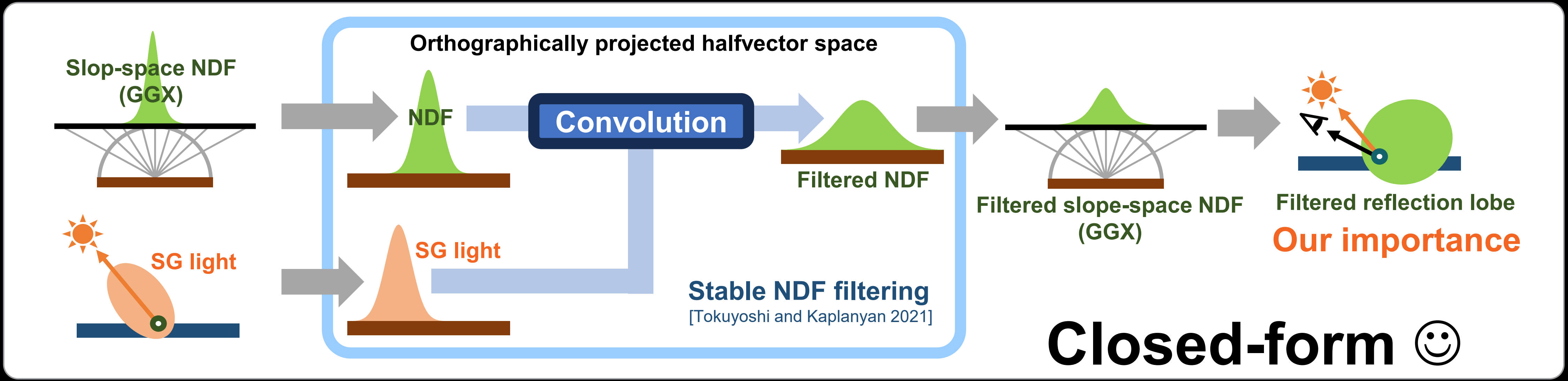


- Convolve the NDF with an SG light in halfvector space ⟹ Increase the roughness parameter (bivariate)

Glossy SG Lighting with Bivariate NDF Filtering

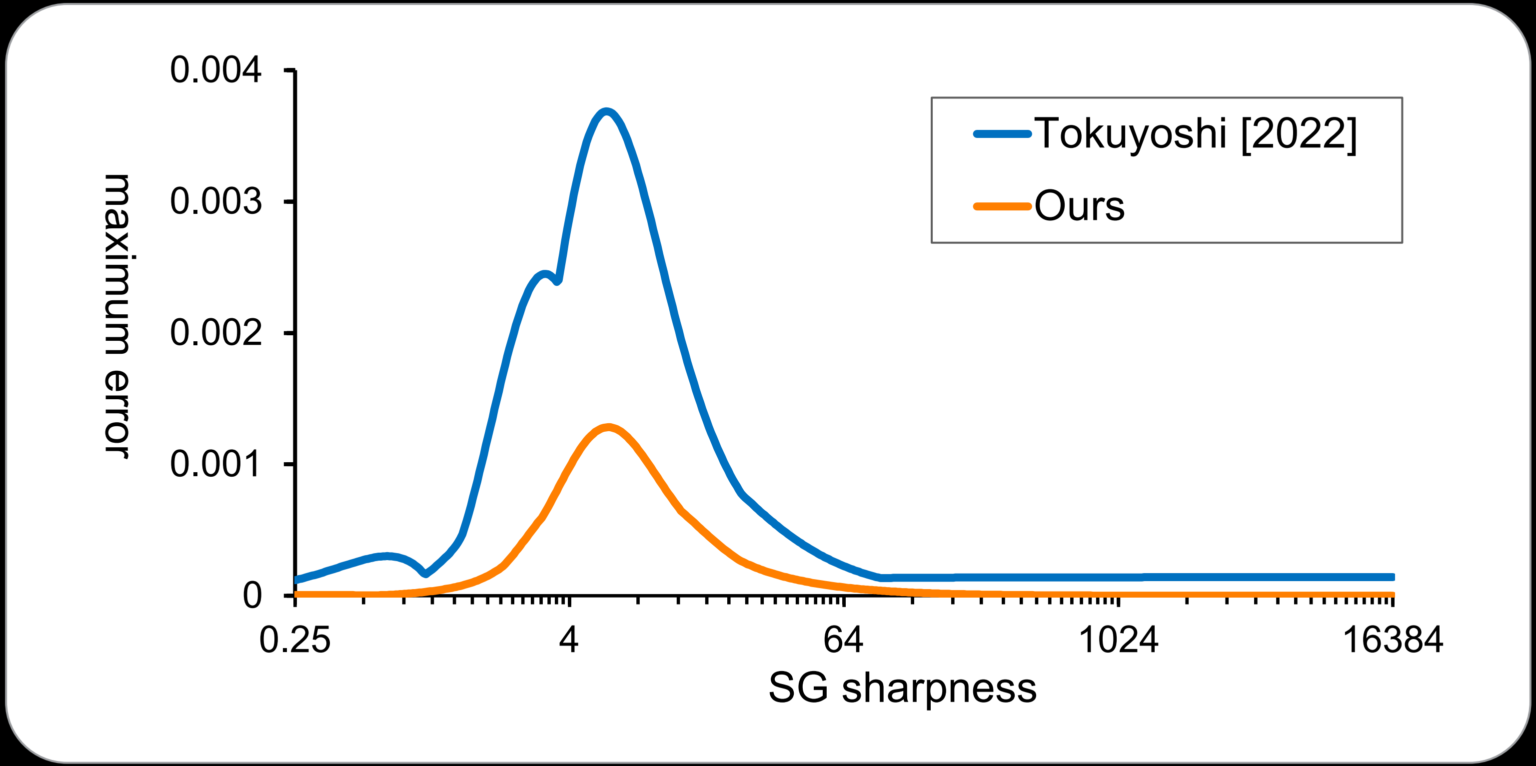
[Kaplaynan et al. 2016]



- Convolve the NDF with an SG light in halfvector space → Increase the roughness parameter (bivariate)
- Preserve the NDF model ☺
  - Accurate for NDFs with long tails (e.g., GGX)
  - Accurate for sharp SG lights (e.g., lower levels of the light tree)

Diffuse SG Lighting (omitted in this presentation)

- Simpler and more accurate than previous diffuse SG lighting [Meder and Brüderlin 2018; Tokuyoshi 2022]
- Please see our paper for details



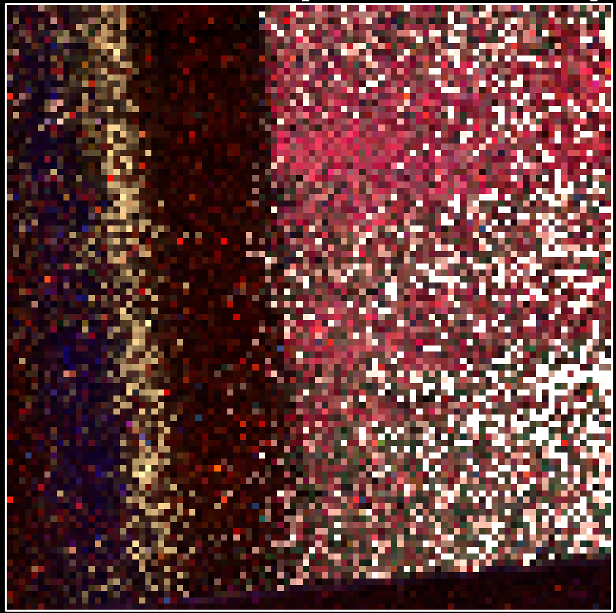
Experimental Results

Equal-time Comparison

(one light sample per tree traversal query)

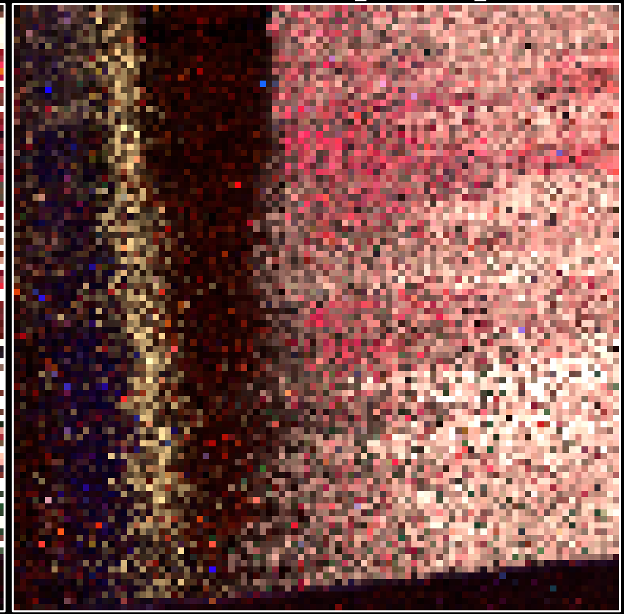
Path tracing with MIS

Conty and Kulla [2018]
+ distance heuristic [Lin and Yuksel 2020]



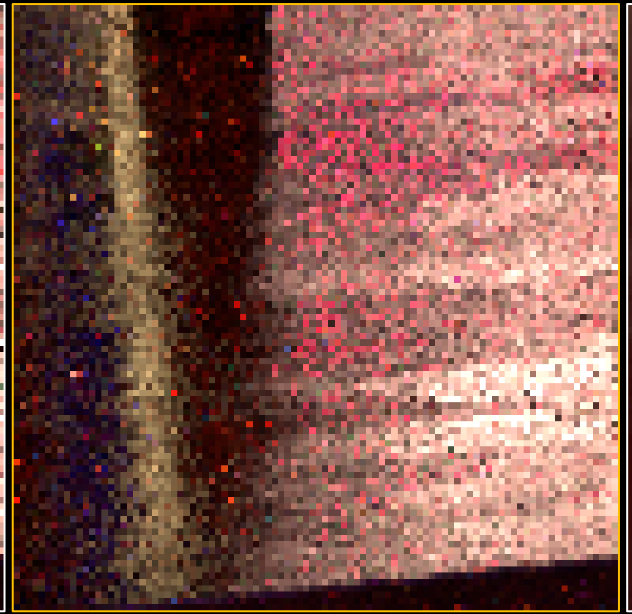
RMSPE: 30.7%
MAPE: 49.3%

Liu et al. [2019]



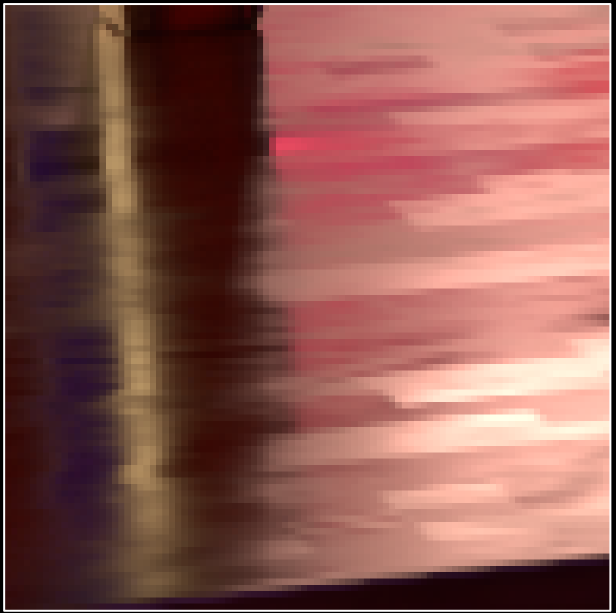
RMSPE: 39.0%
MAPE: 53.9%

Ours



RMSPE: 27.2%
MAPE: 42.3%

Reference



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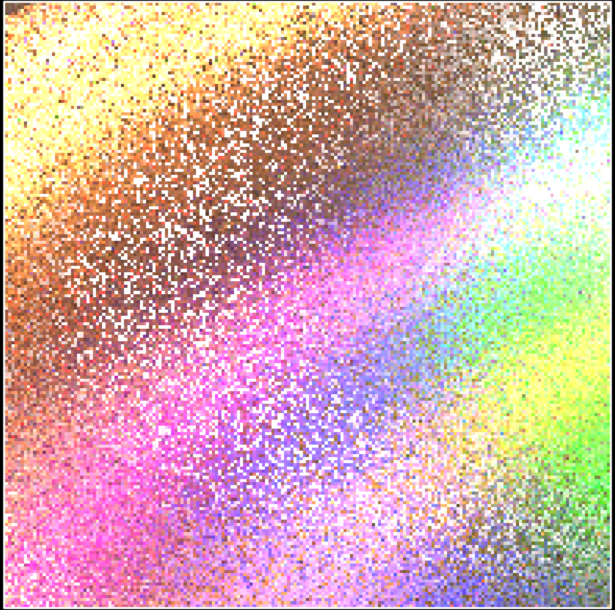
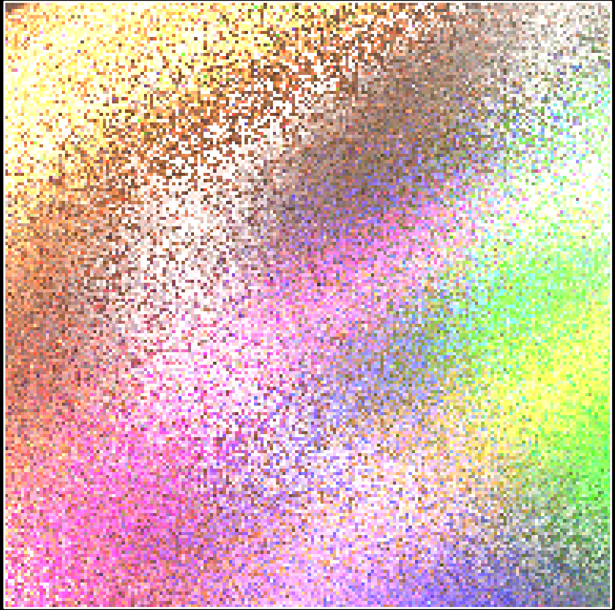


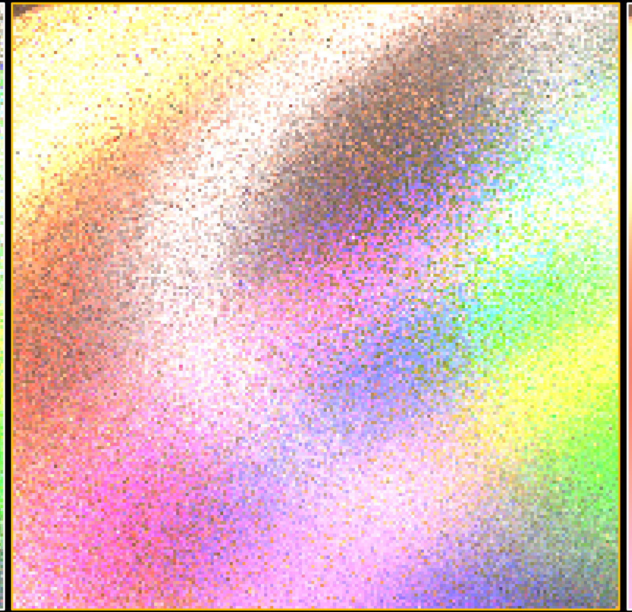
RMSPE: 32.2%
MAPE: 26.6%

Liu et al. [2019]



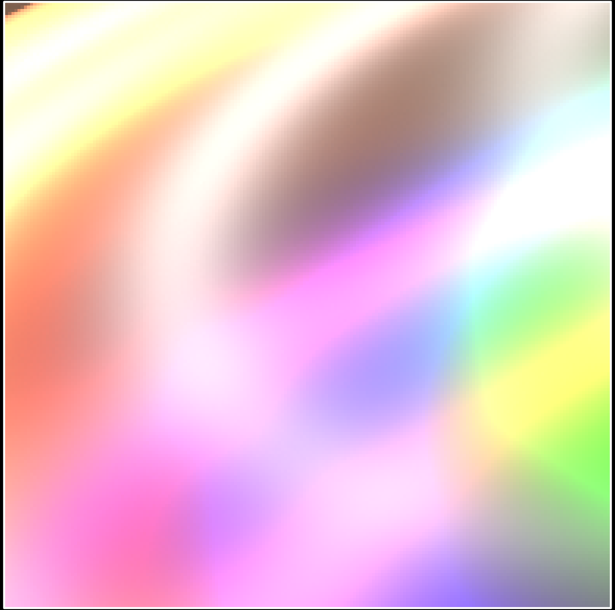
RMSPE: 33.2%
MAPE: 26.5%

Ours



RMSPE: 22.6%
MAPE: 20.4%

Reference



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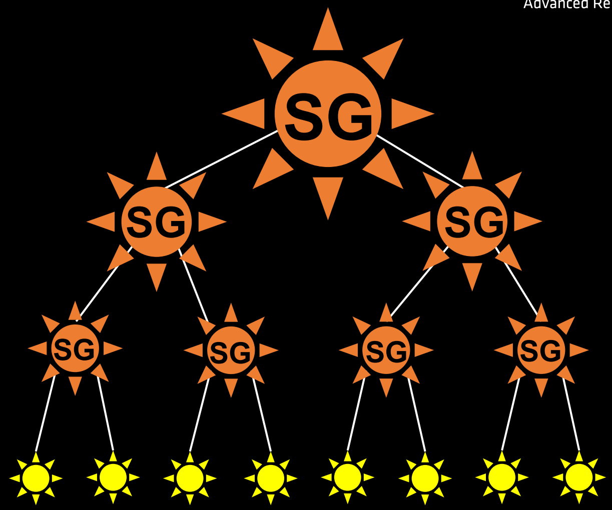
Limitations

- No shadow ray visibilities for the importance
  - Cannot reduce shadow noise
- Single-lobe isotropic SG light for each light cluster
  - Ignore multi-lobe and anisotropic distributions of lights
- Computational overhead for accurate SG lighting
- SG lighting cost $\propto$ number of BRDF lobes

Conclusions

- Unbiased hierarchical light sampling using an SG light tree
- Improve the SG lighting approximation for the node importance
  - Glossy SG lighting with NDF filtering
  - Simpler and more accurate diffuse SG lighting



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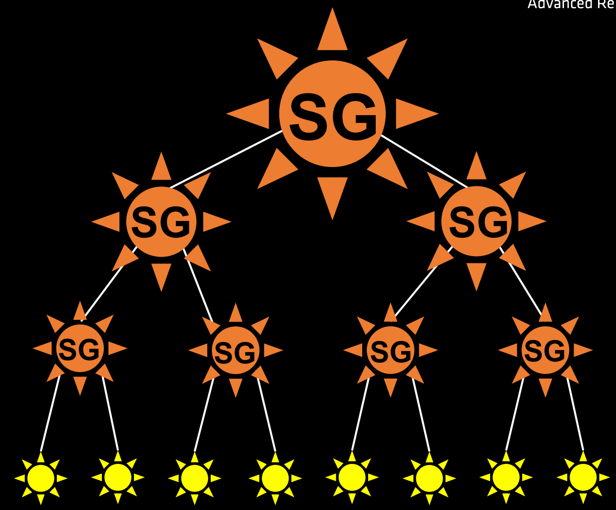
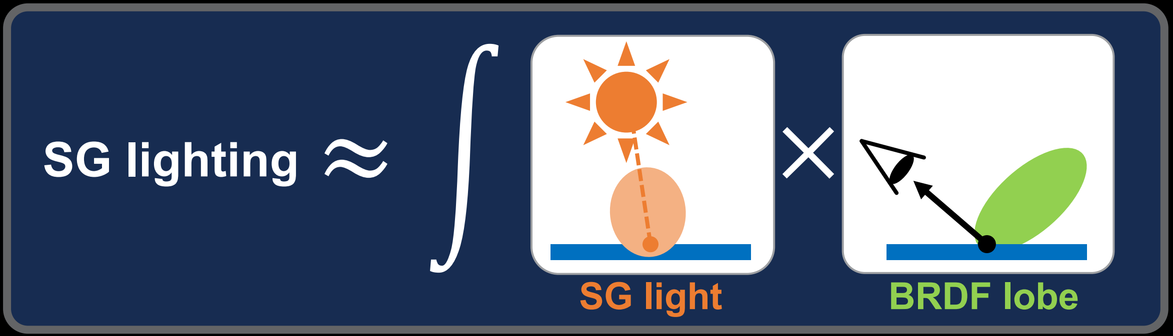


Other applications of our SG lighting

- Dynamic indirect illumination [Tokuyoshi 2015]
- Real-time rendering using the mixture of SGs
  - Light probes, lightmaps, and neural networks [Wang et al. 2009; Neubelt and Pettineo 2015; Currius et al. 2020]
- Relighting and material editing [Zhang et al. 2021]



Dynamic indirect illumination using virtual SG lights
(https://github.com/yusuketokuyoshi/VSGL)

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